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VESUVIUS

EDUCATION, SECURITY AND PROSPERITY

EDITED BY

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PREFACE

Vesuvius is today surrounded by a densely populated area. Within a radius of 10 km of the crater live about one million people and within this distance and 50 km live another two million people, with the city of Naples being situated between Vesuvius on the east and the Phlegraean Fields on the west. In the last 20 000 years, this volcano has produced many plinian and smaller scale eruptions, and is most famous for its eruption in 79 A.D. when it buried the Greco-Roman towns of Pompeii and Herculaneum. Its 1631 subplinian eruption was even more devastating for the surrounding territory and for the first time made an important imprint on the Europeans during the Age of Reason or Enlightenment in the seventeenth and eighteenth centuries. Following this eruption, Vesuvius remained active until 1944 with its many strombolian and lava flow eruptions. Since 1944, the presence of smoke has disappeared and the surrounding territory began to be veiled in asphalt and concrete, with the smoke remaining a postcard memory and the eruptions a distant foreboding.

Vesuvius sleeps today and only some faint fumaroles within the crater and low-level seismic activity below its cone suggest that this mountain of fire is preparing for another of its colossal eruptions that could affect hundreds of thousands, if not millions, of people. Computer simulations predict that there is a high probability of a subplinian or plinian eruption occurring in the twenty-first century. For five centuries or more before the eruptions of 79 A.D. and 1631, the volcano remained quiescent and the people became complacent as the memory of past eruptions was gradually forgotten. A similar situation can occur again. Indeed, according to *Osservatorio Vesuviano* in Naples and its parent institution *Istituto Nazionale di Geofisica e Vulcanologia* in Rome '*Tutto è sotto controllo*' ('everything is under control'), thanks, so they claim, to the instruments that monitor the volcano and an evacuation plan that will allow everybody to escape on time during an emergency. This is, of course, an illusion due to the difficulty of separating tectonic from volcanic events, rapid rise of magma when the premonitory signals become clear that the volcano is erupting, and gross unreliability of the evacuation plan which to date has produced little peace of mind to many Vesuvians and no social and cultural progress that would emancipate hundreds of thousands of people from their difficult predicament. Meanwhile, the population around the volcano is becoming more complacent and many are convinced that Vesuvius will not erupt again. While it would be erroneous to promote a policy of eminent danger when this danger does not exist, it is equally erroneous to promote a policy of inaction, especially since we know that it is only a matter of time before Vesuvius wakes up.

A decade ago an interdisciplinary project called VESUVIUS 2000 was proposed for the Vesuvius area. Unlike evacuation plans which tend to manage emergencies, this initiative aims at preparing the territory around Vesuvius to confront volcanic emergencies with minimum socio-economic and cultural consequences. What Vesuvians need is not so much a plan that tells them where to run in the event of an eruption, but the creation of an environment that offers security from future eruptions. VESUVIUS 2000 aims at achieving this objective while, at the same time, reducing the current state of social decay that is associated with limited economic opportunities. The danger from the volcano can be taken to advantage for producing a whole new secure and prosperous habitat for the people surrounding Vesuvius. The current evacuation plan has produced an unprecedented damage to the Vesuvius area, and, as long as it is being used as an instrument that only benefits special groups, there will be no prosperity for Vesuvians and these people will have to depend on their St. San Gennaro for protection. Since 1995, many Vesuvians have been educated on different risk management plans for the territory, but neither Italy nor the European Union has taken the Vesuvius problem seriously. Since Vesuvius is 'under control' why bother to produce a safer and more prosperous habitat for Vesuvians?

A forum on VESUVIUS 2000, held on 2 and 3 September 2004 in Villa Campolieto in Ercolano, near the ruins of Herculaneum, provided an impetus to complete this book. The forum was attended by over one hundred local and foreign scientists, educators, students, and some authorities and lay people from the Vesuvius area. Its principal organizers, besides myself and members of my organization GVES, were Giuseppe Luongo, Giuliano Panza, and Bernadette de Vanssay from the Universities of Naples, Trieste, and Paris V, respectively. The first day of the forum involved technical sessions and the second one excursions to the ruins of Pompeii and Villa Augustus on the opposite side of the Monte Somma relief. The presentations at the forum were multidisciplinary and dealt with the structure of the volcanic system, modeling of eruption processes, education, socio-economic conditions, and civil protection. The excursions to Pompeii and Villa Augustus clearly demonstrated our fragility and weakness when confronting nature and our complacency with danger.

This book should be useful to professionals and nonprofessionals alike, and, especially, to the populations of the Vesuvius area and other places around the world that face similar problems. It should also prove useful to those who want to familiarize themselves with the geographical, social, and cultural settings of the area, as well as to those who wish to know about the current understanding of the substructure of the volcanic system, the objectives of global volcanic simulation, and difficulties involved in managing risk in densely populated areas. The book should also be useful to educators, who teach primary, intermediate, and secondary school children and students about their environment, and volcanoes in particular.

Because of the multidisciplinary issues considered here, students, professionals, lay public, and civil protection managers should find in this volume sufficient information for further study, elaboration of topics, or adaption to their particular situations. The objectives of VESUVIUS 2000 need to be diffused to an audience beyond the Vesuvius area, for critical evaluation and comparison with analogous initiatives. We cannot embark on a serious path of risk mitigation in a densely populated area unless we fully understand the history, culture, and socio-economic conditions of the area and are willing to scrutinize every detail of our intended actions and fully expose our projects to constructive criticism. A mitigation and risk management plan which is hidden from the public, and its architects refuse to discuss it publicly and away from professional audience, does not serve any useful purpose, especially for those living in the close proximity of Vesuvius.

The book is divided into seven chapters, with each chapter providing a summary in both English and Italian. Following this preface, the book provides an extended summary of VESUVIUS 2000 in Italian. The Appendix of Chapter 2 is in Italian and provides a global perspective of the territory as seen by a group of intermediate students of the Vesuvius area. The Appendix of Chapter 3 is the Italian version of this chapter. The color versions of black and white figures of in Chapter 2 are collected at the end of the book, and the extensive Notes in Chapters 1 and 2 elaborate on the historical, cultural, and scientific aspects of the area and beyond.

Chapter 1 presents the difficulties associated with the management of volcanic risk in the Vesuvius area and the principal objectives of VESUVIUS 2000 which aim at transforming the area into a secure and prosperous region. The topics in this chapter deal with Vesuvius consciousness, security culture barriers, habits of mind that prevent the Vesuvians from judging different risk reduction strategies, the grand challenge associated with the protection of people and territory from the volcano, and VESUVIUS 2000 objectives and methodologies. VESUVIUS 2000 is divided into three interrelated topics: Physical environment, which deals with the development of Global Volcanic Simulator and its use for assessing the effects of different eruption scenarios; population, which addresses the social, economic, and educational issues of the people; and territory, which deals with the area infrastructures, urban planning, and civil protection.

Education of children and adults so that they become Vesuvius-conscious citizens is discussed in Chapter 2. Different age groups of students imagine things differently, and it is the aim of education to take advantage of those tools which produce the greatest developments in children. This chapter thus addresses the cognitive tools available to us and how these tools can be used to educate the primary, intermediate, and secondary school children about Vesuvius. We, therefore, discuss educational ideas, kinds of understanding, educational methods, and teaching methodologies. Educating adults about Vesuvius is also important, especially in decreasing their technological illiteracy, because this is preventing many from seeing how the modern technology can liberate them from their difficult predicament. As examples, we discuss several educational efforts in the Vesuvius area, including those from schools, nonprofit and professional organizations, lay public, and others.

The social and economic reality of the Vesuvius area is addressed in Chapter 3. Eighteen communities of more than 500 000 people border the crater of the volcano and, during the last decade, some 30 000 people have left the area for better opportunities and lower risk elsewhere. The educational level of most people living near the volcano is low and, officially, only one-fifth of the population works. Their main economic activities are services, scattered agriculture, and some manufacturing. This kind of environment breeds crime and offers few bright prospects for future generations.

Chapter 4 presents geophysical precursors of Vesuvius from historical and archeological sources. The eruption of Vesuvius in 79 A.D. was preceded by a large magnitude earthquake in 62 A.D. that caused an extensive damage. This and several other events thereafter suggest that the towns surrounding the volcano experienced significant problems before this famous eruption. The eruption of 1631 was also preceded by seismic activity for several hours, and perhaps for a longer time. The last significant earthquake occurred in 1999 and the recent seismicity has been maintained below the magnitude 4 on the Richter scale.

The characteristics of ballistic debris emitted from Vesuvius during the eruption of 79 A.D. are discussed in Chapter 5. This debris, with block sizes of up to 1 m, is common in the deposits of this eruption and reached distances in excess of 10 km from the crater. Modeling of the ballistic shower is, however, in its infancy and not reliable enough to be used today as a tool for the hazard assessment associated with this kind of material being ejected from the volcano.

Our current understanding of the substructure of Vesuvius and that of the nearby Phlegraean Fields is presented in Chapter 6. This understanding comes from the natural seismicity of the volcano and seismic tomography experiments that have been conducted in the 1990s. At that time, I was one of the promoters of such experiments for collecting data that could be used for the validation of Global Volcanic Simulator. Since then, many such studies have been made and their results suggest that both the Vesuvian and Phlegraean areas have low seismic wave velocity layers at a depth of about 10 km and that, therefore, there is no evidence of magma in the superficial regions of the volcano. According to these works, the volcanic conduit is currently sealed and magma resides in a diffused crustal magma reservoir which is fed by a regional one within the uppermost mantle.

Global Volcanic Simulator is the key tool for both ascertaining the effects of different eruption scenarios on the territory surrounding the volcano and producing a new habitat for Vesuvians where they can live safely from future eruptions. In Chapter 7, we discuss physical modeling, numerical, and computer implementation issues related to the development of such a simulator. We have already developed several useful models for simulating magma chamber dynamics and magma ascent in volcanic conduits, and are currently developing a nonequilibrium multiphase and multicomponent atmospheric dispersion model and its associated computer code. This model accounts for two-way turbulence coupling between the gaseous and particulate phases, condensation and evaporation of volatiles, aggregation and fragmentation of pyroclasts, and chemical reactions among the components of different phases. Our objective is to resolve the effects of pyroclastic flows on small and large structures located on the territory surrounding the volcano, determine the fallout characteristics of tephra and ballistic blocks, and ascertain the consequences of plinian plumes transporting the volcanic debris high into the stratosphere during and after an eruption. A practical global simulator must be able to simulate different eruption scenarios and determine their effects on the people and infrastructures, with and without engineering measures aimed at protecting the area surrounding the volcano.

During the last decade, we have only made a modest progress in achieving the objectives of VESUVIUS 2000, because of a politicized evacuation plan that distances independent initiatives and stifles collaboration on this volcano. We have made, however, a significant effort in promoting education and collaboration, and managed to involve many schoolteachers and their students on different topics associated with Vesuvius. Regretfully, the people's representatives in Italy are using the flawed evacuation plan as an instrument for discharging their own responsibility, while the institutions of higher learning and research centers are not sufficiently responsive to help design a safe and prosperous habitat for Vesuvians. We need to get rid of negative habits of mind and force ourselves beyond our personal interests and traditions, and thus attempt to construct a higher level of civilization. VESUVIUS 2000 proposes a technologically-grounded approach to territorial risk management which is dramatically different from other plans. As a consequence, it needs time to bear fruit to the people whose ancestors are the founders of Western Civilization.

Flavio Dobran
January 2006

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The development of a volcanic simulator requires vision, extraordinary experience, and dedication, and I am fortunate to have Juan I. Ramos working with me on this project. My associates of the Vesuvius area, Ida Mascolo, Gelsomina Sorrentino, Tullio Pucci, Annamaria Imperatrice, Arturo Montrone, Anna Ibello, Antonio Longobardi, and Gennaro di Donna, best understand its environment and its people. Without them, it would have been difficult to work on the territory. This book is dedicated to them and others like them who are making a truly civil progress in the Vesuvius area.

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Flavio Dobran

Vesuvius
F. Dobran (Editor)

Chapter 1

VESUVIUS 2000
Toward Security and Prosperity Under the Shadow of Vesuvius

F. Dobran

Hell of the living ... is that what is already here ... There are two ways to escape suffering it. The first is easy for many: Accept the inferno and become such a part of it that you can no longer see it. The second is risky and demands constant vigilance and apprehension: Seek and learn to recognize who and what, in the midst of the inferno, are not inferno, then make them endure, give them space.[1]

L'inferno dei viventi ... è quello che è già qui ... Due modi ci sono per non soffrirne. Il primo riesce facile a molti: accettare l'inferno e diventarne parte fino al punto di non vederlo più. Il secondo è rischioso ed esige attenzione e apprendimento continui: cercare e saper riconoscere chi e cosa, in mezzo all'inferno, non è inferno, e farlo durare, e dargli spazio.[1]

—Italo Calvino (1986)

ABSTRACT

VESUVIUS 2000 is an interdisciplinary project aimed at producing guidelines for mitigating the effects of future eruptions of Vesuvius without evacuating hundreds of thousands of people on a short notice and in a probable state of panic. Instead of waiting passively for a future eruption, VESUVIUS 2000 requires that engineers, architects, urban planners, economists, environmentalists, educators, and the public collaborate in producing a new environment where the modern technology is used to respond to the need of the people of being protected from the volcano, allowed to safeguard their culture and livelihoods, and permitted to prosper to the maximum of their potential. The new Vesuvian habitat should be built on such qualities as knowledge, ways of thinking and acting, and capabilities of a technologically literate society, because these qualities stimulate innovation, promote capabilities, and recognize that the society shapes technology as technology shapes society. Such an environment cannot be produced with negative habits of mind which pollute imagination, discourage pursuits of worthy enterprises, and stifle collaboration among the experts and with the public. The Vesuvius area is notorious for such habits and its people need to recognize and deal with them, before the volcano reclaims its territory.

Global Volcanic Simulator is the key tool for producing this new habitat, because it can ascertain safe distances from the volcano where most of the people under the shadow of Vesuvius should live and be protected from different types of eruptions. Through physico-mathematical models the simulator models all relevant volcanic processes, prior to and during an eruption, and thus serves as a tool for quantifying the effects of eruption products on the people and their surrounding. Such a simulator is under development and its preliminary results have already demonstrated its potential utility.

The achievement of VESUVIUS 2000 objectives is a messy undertaking, because of personal, political, economic, and other factors operating on the territory and beyond. A key tool for confronting such problems is education on all levels of the society, and if seriously implemented enough people should be able to overcome the incommensurability barrier that does not allow them to see how the volcano can be used as an asset rather than a liability for solving the very problem that it creates. As non-technologists, the Vesuvius evacuation plan architects have not only managed to politicize an unreliable policy for the territory, but also crippled a serious research and collaboration which could have produced today a serious plan and huge resources for the transformation of territory into a new age of security and prosperity. Evacuation plans do not produce civilization, but VESUVIUS 2000 does, because it accounts for the potential of human development.

RIASSUNTO

VESUVIUS 2000 mira alla protezione della popolazione e del territorio da future eruzioni del Vesuvio, senza che, a seguito di un breve preavviso, sia necessaria l'evacuazione di centinaia di migliaia di persone, molte delle quali probabilmente in preda al panico. Invece che aspettare passivamente una futura eruzione, VESUVIUS 2000 richiede che ingegneri, architetti, urbanisti, economisti, ambientalisti, educatori, e la stessa popolazione, collaborino insieme per produrre un nuovo ambiente, dove, dando massimo vigore alle potenzialità di ogni singolo individuo, la tecnologia moderna venga utilizzata dai cittadini per proteggersi dal vulcano e salvaguardare il territorio. Il nuovo ambiente, che necessita alla popolazione dell'area vesuviana, dovrebbe essere basato sulla conoscenza e sulle modalità di pensiero e d'azione che caratterizzano una società tecnologicamente istruita. Solo tali qualità stimolano innovazione e promuovono capacità, riconoscendo che la società e la tecnologia si formano insieme. Tale ambiente non può scaturire dal pensiero negativo che inficia l'immaginazione, scoraggia il perseguimento degli obiettivi quali lo sviluppo di opere utili, e soffoca la collaborazione tra gli esperti e la popolazione. Nell'area vesuviana queste abitudini sono diffuse, mentre i cittadini dovrebbero riconoscere i problemi ed affrontarli, prima che il vulcano si riappropri del loro territorio.

Il Simulatore Vulcanico Globale è lo strumento necessario per produrre questo nuovo ambiente, perché attraverso di esso si è in grado di definire le distanze sicure dal vulcano dove la maggior parte delle persone che abita all'ombra del Vesuvio dovrebbe vivere in sicurezza dalle diverse fenomenologie eruttive. Attraverso algoritmi fisico–matematici, il Simulatore modella i processi vulcanici prima e durante un'eruzione, determinando gli effetti prodotti dall'evento vulcanico sul territorio e sulle persone. Il prototipo di tale strumento è in fase di ulteriore sviluppo e i primi risultati hanno già dimostrato la sua potenziale utilità.

Il conseguimento degli obiettivi di VESUVIUS 2000 è un'ardua impresa, a causa di fattori personali, politici, economici e di altri elementi che operano sul territorio e al di là di questo. Uno strumento chiave per contrastare tali problemi è l'educazione in tutti gli strati sociali. L'educazione, se ben utilizzata, dovrebbe essere capace di superare le barriere culturali che vedono nel vulcano un carico di responsabilità derivanti dai problemi che crea, e non come una risorsa benefica. La mancata applicazione della tecnologia da parte degli architetti e dei sostenitori del piano di evacuazione dal Vesuvio, non solo ha fornito una politica inadeguata al territorio, ma ha anche danneggiato una seria ricerca e una collaborazione che, oggi, avrebbe potuto produrre un valido piano, con enormi risorse per la trasformazione di un territorio, portandolo in una nuova era all'insegna della sicurezza e della prosperità. I piani di evacuazione non producono la civilizzazione: VESUVIUS 2000 lo fa perché tiene conto delle potenzialità dello sviluppo umano.

Un'eruzione di grande energia del Vesuvio può causare la distruzione del territorio in alcuni minuti a seguito del collasso di una colonna eruttiva. Decine di migliaia di vite umane possono perire, e innumerevoli abitazioni, infrastrutture e patrimoni culturali possono andare perduti. Oggi abbiamo mezzi tecnologici e strutture amministrative capaci di lavorare per ridurre significativamente l'impatto di una eruzione vulcanica del Vesuvio e, quindi, i mezzi per evitare un disastro umano e socio-economico che diverrebbe un serio problema non solo per la nazione, ma anche per l'Unione Europea. Chiaramente, i responsabili nelle istituzioni locali, nazionali ed europee non possono permettere che tale catastrofe accada.

VESUVIUS 2000 non arreca danni né alla comunità scientifica, né alla collettività. Esso tiene conto delle incertezze derivanti dalla previsione delle eruzioni, salvaguarda gli elementi positivi delle strutture sociali, previene l'azione di speculatori che approfittano dell'emergenza, e ha lo scopo di rendere alta la qualità della vita attraverso un efficiente utilizzo della tecnologia moderna. VESUVIUS 2000 richiede di superare le difficoltà dovute alle barriere culturali, scientifiche e sociali, consapevole che è un'illusione aspettarsi soluzioni rapide.

Abitudini radicate subiscono lenti processi di trasformazione e soltanto le nuove generazioni, che crescono con nuove idee, possono essere capaci di trasformare gli obiettivi di VESUVIUS 2000 in un nuovo paradigma per i Vesuviani. Un'attività vulcanica del Vesuvio innescherebbe un'accelerazione di questo processo, ma oggi la popolazione è afflitta da troppe cattive abitudini che vanno sradicate dalla società. Fin quando esistono la corsa al potere, l'ignoranza del rischio vulcanico, il conformismo, il codice del silenzio e il clientelismo, profondamente radicati in tutti i livelli della società (locale, provinciale, regionale e nazionale), le barriere mentali sono talmente grandi che non fanno vedere il pericolo che rappresenta il Vesuvio e le straordinarie opportunità di riorganizzazione del territorio, capaci di realizzare un ambiente molto più sicuro e prospero per i Vesuviani. Gli amministratori locali, nazionali e dell'Unione Europea si comportano come se non capissero quanto il Vesuvio abbia aiutato a costruire la civiltà occidentale, e perché è necessario salvaguardare quest'area e i suoi tesori. Al vulcano occorrono pochi minuti per distruggere centinaia di anni di lavoro umano e seppellire l'unicità di queste esperienze. Se ciò non si è capito alle soglie del terzo millennio, non dovremmo sorprenderci delle serie conseguenze dovute all'immobilismo.

Ogni secondo, centinaia di chilogrammi di magma si accumulano sotto il Monte Vesuvio e la popolazione sui suoi pendii potrebbe già essere considerata condannata. Potrebbe non esserci più tempo per costruire ambienti prosperi, né la possibilità di scappare verso terre promesse. Come negli ideali di Platone, nei quali la diretta conoscenza del reale, del vero, del buono e del bello non è mai raggiungibile, ma lo sono soltanto i benefici promessi, lo stesso destino potrebbe attendere VESUVIUS 2000. Ma finché le scuole dell'area vesuviana continueranno ad insegnare gli ideali di Platone, sono fiducioso che sia possibile formare una consapevolezza dell'urgente bisogno di affrontare la difficile situazione delle genti vesuviane. Rendersi conto di questo è un importante inizio e potrebbe essere sufficiente per rivendicare la nozione di civiltà di Voltaire.

1.1. HOSTAGES OF VESUVIUS

In this place with 3 million souls honeycombed in a jungle of asphalt and concrete the open sea stretches beyond the Pillars of Hercules,[2] golden and mesmerizing sunsets and enchanting islands hide the secrets of the sirens, and smoldering chasms from time to time open their fiery jaws and unleash their anger upon the children of this worldly paradise. Being wedged between the beautiful and the terrible produces a unique quality of this land where its peoples from time immemorial have refused to leave it, because here stands Mt. Vesuvius as a symbol of fertility of the land and continuity of life. While the tourist guides trot out the standard stuff how Vesuvius killed thousands in the Roman towns of Pompeii and Herculaneum in 79 A.D., and how the volcano has been sleeping peacefully since 1944,[3] they tend to avoid mentioning that this mountain of fire is now preparing for another colossal eruption, capable of killing tens of thousands in a matter of minutes. When the plug of this mountain gives way, a cloud of molten rock, ash, and gas will be blasted high into the sky; there it will be held aloft by the heat of the roaring volcano and for hours transform day into night, until it collapses and swoops along the ground at upwards of 100 miles per hour. At that speed, the 500 degree Celsius cloud will reach the town of Torre del Greco with a population of about 100 000 in 200 s and arrive to the sea in less than 5 min. The nearby Ercolano (modern Herculaneum) to the southwest and Torre Annunziata to the southeast will be engulfed in around the same time, and the Neapolitans will again implore San Gennaro for another of its miracles to save the city from their most spectacular backdrop.[4]

Faced with this appalling prospect, a multidisciplinary group of scientists from several European countries requested in 1995 from the European Union a support of a project called VESUVIUS 2000,[5] with its principle objective being to determine safe areas around the volcano where people can live in security and prosperity. Based on the recommendation of geologists the Italian government supported, instead, an evacuation plan[6] according to which 600 000 people surrounding the volcano can all be evacuated in several weeks before the eruption and resettled all over Italy. Not surprisingly, many became deeply skeptical whether Vesuvius will give a reliable warning of several weeks before it explodes. This is because our experiences with similar volcanoes teach us that such a warning occurs only 1 or 2 days before magma begins to rise rapidly toward the surface and that in this time frame it is not possible to evacuate hundreds of thousands people. The decision to evacuate is normally based on the recommendations from scientists who monitor the volcano with instruments and who fear issuing an evacuation alarm without objective data. After the eruption of Mt. St. Helens in 1980 the scientists declared that the 'predictions must be accurate: Repeated inaccurate predictions encourage popular distrust and may be more harmful than no predictions at all'.[7] One must, therefore, legitimately ask: What are the chances of evacuating hundreds of thousands of people from the immediate danger zone of Vesuvius if the eruption cannot be predicted more than several days in advance? The eruption of Pinatubo in 1991 was predicted in this time frame and about 50 000 people were barely evacuated on time, while the Central American volcano Montserrat erupted in 1997 without warnings and killed 19 people.[8] Evacuating hundreds of thousands of people from the Vesuvius area in 1 or 2 days, and in a probable state of panic and absence of adequate infrastructures, is hopelessly optimistic.

Only those who cannot see beyond the simplest strategy of running away from danger, and who are technically and culturally shortsighted, believe in the premises of Vesuvius Evacuation Plan, while those who do point out to too many of its deficiencies: Scientific because eruptions cannot be predicted reliably weeks or months in advance, social because the public has not been educated about the pros and cons of the plan, cultural since a massive displacement of population away from the area and to distant Italian provinces would destroy the local culture and open the way to speculators, and engineering and managerial because of the non-practicality of constructing and maintaining massive evacuation infrastructures in an area that is densely populated and lacking social and ecological soundness. Even the administrators of the regional government (Regione Campania) have recently abandoned the unreliable claims of the evacuation plan and opted for some of the objectives of VESUVIUS 2000[9] in order to reduce the skepticism of the public which over the past decade has become more and more aware of the inherent fallacies of the evacuation plan. As the people become acquainted with the premises of VESUVIUS 2000 they rebel against abandoning their homes and livelihoods.

VESUVIUS 2000 requires that the people around the volcano become conscious of their environment and that they participate in the solution of their difficult predicament by working toward the establishment of a secure and prosperous environment for themselves and their offspring. To achieve this goal requires educating the public on the consequences of inactions and merits of different strategies aimed at risk reduction, or overcoming many socially and culturally inhibitive habits of mind and mental barriers on all levels of the society. Only through adequate, prudent, and incisive modalities can the risk from Vesuvius dissolve gradually and decisively a socially decaying and environmentally degrading urban life that is veiled in asphalt and concrete, and hiding a time bomb which in a matter of minutes can wipe out hundreds of years of human experiences.

1.2. THE VESUVIUS AREA

The Vesuvius area[10] (Fig. 1.1) was first populated in the pre-historic time, but it is only with the colonization of Greeks in the eighth century B.C. that it began thriving commercially and in the later half of the twentieth century that it developed into one of the most populated and abused areas in the world. Under Greeks and then Romans the area enjoyed a relative autonomy because of its special recognition as a part of the confederation. The eruption of Vesuvius in 79 A.D. buried much of the territory under several meters of pyroclastic material and it took several centuries before the area began thriving again. With the fall of the Roman Empire in the fifth century and with it the slave method of production, the Vesuvius area peasants passed under the domination of feudal landowners where they had more incentives to produce. The feudal regime signified, however, another limited development of the area, and for many centuries the Byzantine, Norman, Angevin, Aragonese, and Spanish feudal barons controlled the territory and maintained the population at subsidence levels. With the passage of time and proximity of the area to the sea, the coastal cities of Torre del Greco, Resina (Ercolano), and Portici began developing independent income from fishing and coral manufacturing, and in 1699 bought themselves out from feudal barons and declared the territory a Free University (*Libera Università*). The new proprietors were now merchants, professionals, and military officers who contracted the land to the peasants.

On the eve of *coup d'état* by Napoleon in 1799 and French entrance into Naples, the Neapolitan Jacobins declared the city a republic. But the republican ideals could only reach a minority of the population, as the majority of people remained under monarchic and Catholic influence and were largely ignorant of the ideals of the Enlightenment which produced the Age of Revolutions in Western Europe. With the fall of Napoleon and return of Bourbons to power in 1815, the Vesuvius area came once more under the domination of a monarchic regime and prospered considerably. The Bourbons were fully aware of the consequences of eruptions and

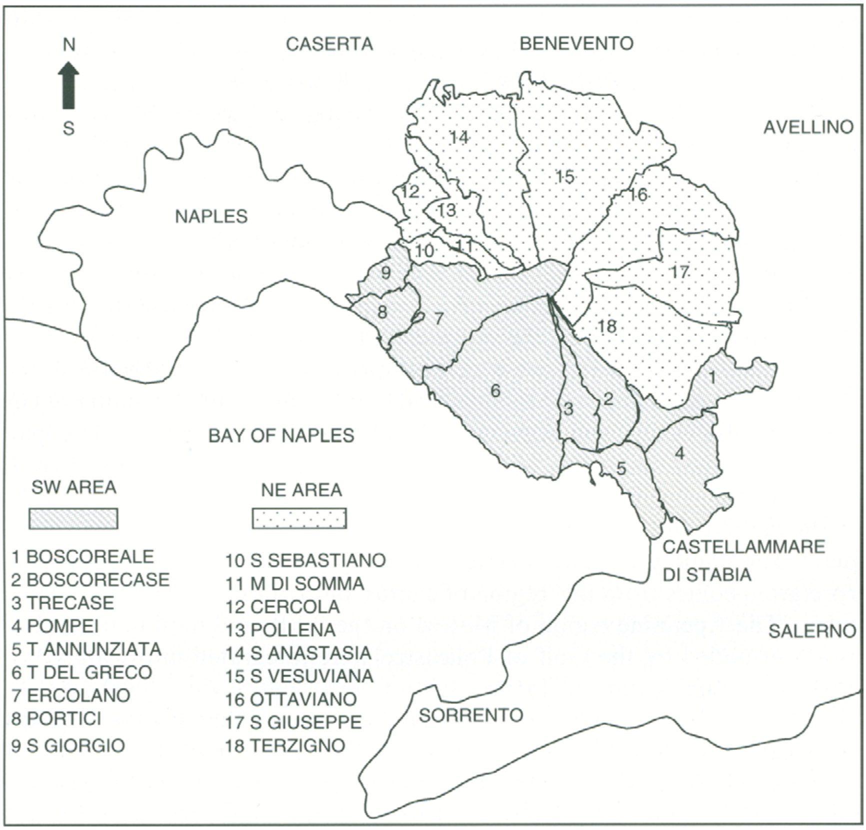

Fig. 1.1. The Vesuvius area includes 18 municipalities which surround the volcano. They are all situated within 10 km radius of the crater.

inundations, and maintained forests and an efficient system of channels to regulate floods and mudflows after heavy rains and eruptions. They cleared water and mudflow beds each year before the rainy season, both on the slopes of Vesuvius and neighboring mountains. In the twentieth century these structures were transformed into housing complexes and roads. The forests have been cleared to accommodate the demographic pressure of Naples, and the volcanic soil has become susceptible to mudflows and the towns exposed to new dangers.

In 1860 Garibaldi defeated the Kingdom of the Two Sicilies and annexed the territory to the newly born Italian State. With the Liberals in power, the industry and agriculture developed in the north while the south (*Mezzogiorno*) was practically excluded. The new Italian ruling class practiced the politics of patronage to buy votes from southern landowners that had no interest in relinquishing the control of their Latifundias and bypassing a real army of intermediaries who profited from the illiterate and ignorant peasants. When during the second half of the twentieth century Naples could not absorb the demographic pressure many Neapolitans settled into the neighboring S. Georgio a Cremano and Portici and created their own Little Paris (*piccolo Parigi*) away from Naples' Via Toledo, Via Chiaia, and Mergellina. The municipal and hazardous waste has also found its way into the Vesuvius area. First the local organized crime (*camora*) digs the tuff and pozzuolana and sells it to the construction market, and when the caves stop producing fill them with tons of refuse, often toxic and imported from the north. The rubbish and toxic products are then covered with earth and the 'new land' sold for constructing more abusive buildings. It has been estimated that just from this business alone the Neapolitan *camora* earns some 10 billion euros a year.[11] This and other construction practices have been very profitable, and neither many businessmen nor politicians wish to become involved in other, less profitable, affairs which would protect the public from the eruptions of Vesuvius.

Italy is divided into 20 regions which comprise a territory of about 300 000 km^2. Its total population is about 60 million, with Lombardia and Campania having the largest number of people and highest population densities of about 400 people/km^2. Campania occupies about 5% of the national territory and is bounded by Lazio, Abruzzo, Molise, Puglia, and Basilicata. It has about 6 million people, with Naples being the capital and the third largest city in the country of little over 1 million people.[12] The name Campania derives etymologically from Capua, but its vulgar interpretation comes from the 'region of camps' or an area around the river plain of Volturno. The Apennine region of Matese on the north and mountainous areas on the south bounded by the Gulf of Policastro were integrated into Campania only after the Italy's unification in 1860s.

About one-third of Campania is covered by mountains and the largest of its five provinces (Avellino, Benevento, Caserta, Naples, Salerno) is Naples. From 1951 to 1989, Campania's population grew about 30%, while that of the province of Naples by about 50% and City of Naples by 16%. After 1981 the population of Campania remained, however, relatively stable. Based on the resent census, over half of the people live in the province of Naples. The Vesuvius area is comprised of 18 municipalities[13] with a current population of about 550 000 (Fig. 1.1). The most significant population increase took place after World War II, between 1951 and 1981, when some towns like Portici, Somma Vesuviana, and San Giorgio a Cremano doubled and tripled in the number of people. The average population increase of the area during this period is about 200%. Some towns like Pollena Trocchia, Somma Vesuviana, and Terzigno have recently exhibited some rise in inhabitants, while the towns near the cost like Portici and Torre Annunziata lost a modest number of people, principally because of poor employment opportunities, danger from living too close to the volcano, and decrease of fertility rate. Large population densities of Portici and San Giorgio a Cremano of about 15 000 people/km^2 also reflect some of the smallest areas of these towns on the territory (about 4 km^2). On the other hand, Torre del Greco is the largest town in the area with about 100 000 people and 3000 people/km^2. There are about 600 000 people living within the 7 km radius of the volcano, along the path of eruption products of Vesuvius.

Over 40% of active population is in commerce and about 30% in construction and manufacturing. Agricultural, public service, educational, and other employment sectors comprise about 8% each. There are many small landowners on the territory who are still using traditional methods of cultivation on a very rich volcanic soil that is also often abused from the use of chemicals. Compared to a century ago, the population living around Vesuvius has in effect been transformed from an agriculturally based to commerce-, construction-, manufacturing-, and services-based society where there are still too many people involved in illegitimate businesses (*camora*). About one-third of the people have primary, one-fourth intermediate, and one-fifth secondary school diploma, and as many as 5% are illiterate and 17% illiterate without diplomas. About 3% of the people have college education. Although the national illiteracy level fell dramatically from 40% in 1914 to the current level of only few percent in the Vesuvius area, this level is still too high in comparison with the Northern European countries where it is less than 1%. These data do not reflect the education of population pertaining to the volcanic risk and neither are these data available from any official census bureaus or surveys.

In 1995 my colleagues and I began collecting such data as part of the VESUVIUS 2000 project.[14] We processed about 3000 questionnaires from children and adults between the ages of 8 and 85 years. When asked the question 'What is Vesuvius?', the majority of adults correctly responded that it is an active volcano. When asked the question 'What is inside Vesuvius?' people responded imprecisely that it is lava instead of magma. The majority of adults climbed only rarely the volcano, but most know that the last eruption occurred in 1944. The majority also responded correctly that the last eruption destroyed San Sebastiano al Vesuvio and many have relatives with experiences of the last eruption. A significant number of adults erred, however, in responding that Ercolano and Pompeii were destroyed during this time. When the volcano begins showing signs of activity people will be afraid of gas, earthquakes, and, what is very significant, other people. When asked whether an eruption can occur in hours, days, weeks, years, or suddenly, most adults demonstrate poor knowledge about the behavior of Vesuvius before it erupts. Our survey also shows that the population will not know how to behave during an eruption, since the public does not know whether to leave immediately, wait for instructions, or look for family members. People prefer to leave in the direction opposite to the direction of eruption clouds. About 50% of the adults prefer to leave the area by using their own transportation systems, while the remaining wish to leave on foot or utilize public transportation means.

An important consequence of these results is that whatever type of eruption occurs, Naples may be affected the hardest, either from people, if the eruption is directed toward the east, or from the eruption, if this is directed toward the west. People fear that the transportation systems will block city streets and prevent exodus. Most adults are convinced that Civil Protection (*Protezione Civile*), and then schools, town halls, and prefecture, should be responsible for keeping the public informed about the risk, although they do not concur that these institutions are keeping them currently sufficiently informed. In fact, about 80% of the population is uninformed but wishes to be informed preventively by television or through public meetings. Our survey also shows that the people of the Vesuvius area have little confidence in authorities to protect them and do not wish to leave the territory because of the volcano, but prefer instead that a better future be created where they live.

The survey responses from school children of the Vesuvius area are similar to those of the adults. Most primary school children have never been on top of Vesuvius, whereas the older children have rarely made such trips. Most children also erroneously believe that Ercolano and Pompeii were damaged by the last eruption, which implies a superficial volcanic risk education in Vesuvius area schools. Whereas the primary school children do not know in which direction to leave in the event of an eruption, those from intermediate and secondary schools prefer to escape to Naples or in the direction opposite to the eruption clouds. The children are also much less skeptical than the adults regarding the ability of police to maintain order during an eruption and of being sufficiently informed about the hazard. As adults, they also prefer to live on the territory where a better future should be provided for them.

Our survey of school children and adults from the Vesuvius area suggests that the volcanic risk-reduction guidelines for this territory should be developed with great care in order to: (1) respect the population's wishes to remain in the area or vicinity during and after eruptions, (2) account for friends and family members before leaving their homes, (3) have effective police and reliable transportation systems for maintaining order and reducing traffic jams, (4) inform the public about the risk, (5) involve the public from the beginning in the development of risk-reduction guidelines and urban plans, and (6) create a much better environment for the people where they live. This is a demanding and complex list which requires an extensive reorganization of the territory and creation of economic incentives, rather than waiting for an emergency and then trying to evacuate the people far away from the territory as promoted by Vesuvius Evacuation Plan. Large majority of school children and adults believe in education and prevention and are willing to contribute toward the creation of a better place for their future. The results from our survey are consistent with the objectives of VESUVIUS 2000 and contradict those of the evacuation plan. This is because this plan does not call upon for the creation of an effective Vesuvius consciousness, reorganization of the territory to confront future eruptions with minimum socio-economic and cultural damage, preservation of culture and growth of citizens, or for the creation of a modern sustainable environment.

1.3. VESUVIUS CONSCIOUSNESS

The Vesuvians can be characterized by a scarce or even distorted consciousness. This is diffused not only among the young, but also among the adults. Vesuvius and people on its slopes sleep and by sleeping they forget. And even those who remember forget to tell others why something occurred that transformed the memory into an obscure foreboding. The eruption of Vesuvius in 1631 brought the attention of Europe to a magical place where the scientific and philosophic mystery of creation opened a horizon for the first time visible to the human eye and changed the perspective of the landscape and territory for collective and artistic imagination. From this time on, Naples was not anymore reproduced with the sea in the background, but 'from the sea' with Vesuvius in the background. This scenic picture has been changing only in colors and looks, and integrating its actors, the Vesuvians, who from always have interpreted the difficult and dramatic intervening between the man and volcano in the search for a possible cohabitation. From the gleam of the colors of *guaches* Vesuvius began forming the architectonic conception of the villas during the 1700s, with volcano on one side and sea on the other. A long process of transformation that began with the technology of the machine age and railroad in 1850s sharply cut accesses to the sea from the villas and thus modified the territory and banished Vesuvius into the background, always more remote and less readable, all the way to an 'illustrated postcard' since 'Vesuvius smoked'.[15]

The eruption of 1944 was the last visible signal of life of the volcano for the Vesuvius area population. After the eruption, its famous 'smoke' continued for a certain time to mark the presence of volcano even if in a form always less 'reassuring', because that smoke was not hurting anybody and appeared or was interpreted like a sign of return toward a possible peaceful coexistence. But today, where is Vesuvius? A series of events, and above all beginning with 1950s and 1960s when Italy ushered into the consumption age, when the technology permeated and defined modern culture, have profoundly transformed the territory and with it the consciousness of Vesuvians. Massive building speculation and absurd urbanization without regard for the environment has during these years, and especially in the towns near the sea, uplifted a sort of a 'curtain' of cement with the volcano hardly visible and, what is worse, not anymore fruitful. The once sustainable environment produced from the fertile soil of volcanic material has been transformed into a human-built world of degrading social and cultural services, and brought man and nature one step closer onto the collision course.

This collision must be avoided through a new Vesuvius consciousness that cannot be founded on fear, nor identified as an 'emergency culture' as promoted by architects of the evacuation plan, because, by definition, an emergency is that which menaces the culture, history, life, traditions, and aspirations of peoples. It is necessary to establish with the volcano an educational, cultural, and environmental relationship that deteriorated in the course of time until it has been fully distorted at the present time. The notion of danger and risk must be completely renovated with contents and significance, for a volcanic activity occurring in an area where there is nothing to protect has a risk of zero, since the risk does not only consist of volcanic activity but also of the wrong choices of men. If one cannot intervene on the internal dynamics of the volcano, one can certainly intervene on the external one, because with respect to this dynamics we are to some extent its actors. All of this depends, however, on what role the Vesuvians want to play: That of protagonists of their future or that of a mass of appearances moving to the commands of the directors.[16]

Vesuvius offers formidable opportunities to integrate science, engineering, art, literature, urban-planning, economics, sociology, psychology, and politics into a socially sustainable community that emphasizes civic engagement, social justice, environmental soundness, and economic diversity. These are no quick fixes or ad hoc solutions, for to achieve their goals requires working toward a true overturn of Vesuvian value: From a threatened background to a relational background, from fear to respect, from a degrading to a prosperous future. The educators have the responsibility to produce Vesuvius-conscious citizens of tomorrow, while the engineers must tackle the grand challenge in designing future urban centers with their patterns of supply and use of energy, materials, products, information, and services. This holistic view of interactions between natural and human systems can be no more and no less than the enlightened state of which all mankind is capable: That what Voltaire[17] called 'civilization'. For Voltaire, this must be a pursuit of human spirit (*l'esprit humain*) where the 'reasons and human industry will continue to make further progress', where 'great men [are] all of those who have excelled in creating what is useful or agreeable', where 'great men come first and heroes last', because 'great men have prepared pure and lasting pleasures for men yet to be born'. Like *Encyclopèdie* of *philosophes*, tackling the Vesuvius problem cannot involve a point of view, but the whole of knowledge. And like *Encyclopèdie* that could not be burned by priests as ordered by Pope Clement XII, so too the defective educational policies and flawed territorial development plans cannot be forced upon the Vesuvians for this would negate them the possibility of being conscious citizens. Unfortunately, too many Vesuvians are pessimistic about their future and like Calvino's Khan see little hope of getting out of their ever closing-in inferno.

1.4. SECURITY CULTURE BARRIERS

According to an Italian Civil Protection law of 1987 the mayor of each town is directly responsible for the security of citizens. Each town is required to prepare an emergency plan, establish an area to house its citizens (2.5 hectares for each 500 people) in the event of earthquakes or other calamities, provide the area with the necessary sanitation and infrastructures, and inform the Civil Protection of the needed number of temporary shelters. The population of each town must also be informed about the risk and know how to confront it. Each citizen should know what to do and where to report in the event of an emergency. The Italian Republic has this and many other good laws, but they are poorly enforced. Even a simple civil case can drag itself for years in the courts and the leaders of institutions are too often not compelled to act responsibly. When a tragedy strikes people blame each other, survivals are compensated, and the tragedy soon forgotten. This is what happened after the 1998 Campanian mudslides that killed over a hundred people. The regional government was responsible for implementing prevention measures on the territory, but complained that it never received the necessary resources from Rome. When the tragedy occurred the regional administrator was given a higher title (Commissary for the Emergency) but few resources to carry out the post-disaster reconstruction. The Regional Council missed a golden opportunity to obtain large concessions from Rome and was subsequently voted out of power and replaced by no better administrators. This and many other stories like this have made the territory what it is today: A socio-economic and political quagmire where much is based on appearances and too little on substance.

Too many leaders of political and cultural institutions go through the daily life by building alliances and nurturing and spreading 'cultures' that are detrimental to the public. And as long as the volcano is tranquil, who cares? Vesuvius does not 'smoke' and 'everything is under control', continually assure the public both *Protezione Civile* and *Osservatorio Vesuviano*, without specifying what is under control. The spread of this kind of information with an obvious goal to prevent creating Vesuvius-conscious citizens can only be acceptable to those who strive to conserve power or an egalitarian view that the public needs to follow the experts without questions. This type of 'culture' is especially rooted in those institutions which should be the first to get rid of this disease. Many Italian research centers and universities should have been very active in debating publicly both VESUVIUS 2000 and Vesuvius Evacuation Plan, but ignored this debate altogether and have remained passive toward the entire problem. The faculty and students of University of Naples Federico II have also remained passive, in spite of several attempts to provoke critical discussions.[18] The former director of *Osservatorio Vesuviano* is still promoting the evacuation plan to those who do not have the knowledge or courage to confront her, while its present director is showing no signs of collaborating with those who remain critical of this plan.[19]

In *Mezzogiorno* the population rarely moves to prevent disasters, but tends to wait for calamities and state reconstruction aids that too often wind up in the hands of organized crime. This is what occurred after the Campanian earthquakes of 1980 where it is estimated that two-thirds of the aid was dispersed in this manner.[20] During numerous seminars on the territory I am often asked: When will Vesuvius erupt? And when I answer that it is not possible to determine the precise date and that a massive evacuation is not reliable the people agree, but not to the extent that they are willing to take actions that would force their representatives to consider the Vesuvius problem an election issue. As a matter of fact, I have never heard any politician addressing this problem during elections and most, if not all of them, shy away from the problem. Most Vesuvians are not yet mature enough to demand from their representatives concrete actions on the territory.

Conformity (*conformismo*) is another widely diffused 'culture' of the Vesuvius area, with its origins dating back to Liberal Italy. I have met countless schoolteachers and public administrators who belong to the conformismo and often wondered whether they are really brainwashed conformists or acting as such for the purpose of obtaining concessions and promotions from the system. It is extremely difficult to work with these individuals, for they promise to collaborate but do not and in many instances act as informers and clients that protect status quo. Conformists are afraid and appear educated, and correctly behave at the table, but when constrained to act demonstrate that below their golden face masks lie heads full of straw. Getting ahead in Italy and in the patronage society of *Mezzogiorno*, in particular, is, however, very much easier through conformity of political affiliations than by utilizing one's professional skills.

The patronage (*clientelesimo*) 'culture' of *Mezzogiorno* is greatly responsible for difficult economic problems of the south and prevents the accomplishment of many worthy projects. It is very difficult to do anything on the territory unless one employs intermediaries or clients that must gain from one's need. Responding to calls for proposals for obtaining contracts does not work, for these proposals are seldom if ever considered unless promoted by the clients. These clients are building contractors, lawyers, and doctors who are council members in local municipal governments and who provide wining or client votes to their parties. But even with their help it is very difficult to obtain any support for serious projects on Vesuvius. The volcano is tranquil and why bother perturbing the status quo. Why bother supporting serious educational and research projects when receiving kickbacks from building speculations and illegal dumps of municipal solid waste and hazardous materials are much more profitable? For these 'gentlemen' even speaking about Vesuvius is 'risky' and making any decision in this regard is considered outside of their jurisdiction. After all, aren't *Protezione Civile* and *Osservatorio Vesuviano* doing something about it? Why should a provincial or regional office set up with the task of promoting education get involved with educating people that may become 'dangerous'? Why should the Italian private and public sectors, with some of the worst records of scientific expenditures among the Western European states,[21] invest in Vesuvians when they comprise only 1% of Italian population?

Many statements from the staff of *Osservatorio Vesuviano* are often used by the local administrators and news media in an irresponsible manner.[22] And since a politicized group of scientists is controlling this and other institutions responsible for monitoring Italian volcanoes,[23] there is no guarantee that its resources are properly used or that it responsibly protects the people around the volcanoes. This group's competence is attested by the spread of its 'emergency culture' in the Vesuvius area, and a reason that some area administrators are catering to this group is that they apparently need a protection in the event of an eruption. This arrangement of convenience does not cherish the values and responsibilities of the public service. Its members do not understand basic engineering concepts of systems, constraints, and tradeoffs; they do not understand how technology shapes human history and people shape technology; they do not understand that technology reflects the values and culture of society; nor do they know how to seek solutions to complex problems that require the support of interdisciplinary projects such as VESUVIUS 2000. Chasing people away from Vesuvius is apparently the only strategy that is understood by these barons of Middle Ages, a strategy that Vesuvians have perfected without any help from the outsiders. Making progress under these conditions is difficult and the Vesuvians have little chance of being rescued in the foreseeable future from their difficult predicament.

The Italian mass media, and television in particular, have shown little capacity to debate the Vesuvius problem. *La Stampa* from Turin and *Il Giornale del Sud*, *Roma*, *Metropolis*, *Napoli Più*, and *Il Giornale di Napoli* from Naples have published critical reviews on different risk-mitigation projects for the territory, while the Neapolitan newspaper *Il Mattino* and RAI television stations have been very cautious in reporting anything that would criticize the evacuation plan of Prime Minister Romano Prodi. The television stations owned by *Il Cavaliere* (Silvio Berlusconi) have also been uncommonly quiet as if the Vesuvius problem does not exist or should only be addressed by his opposition. The international scientific journals and newspapers such as *Nature*, *The Times*, *The European*, *Newsweek*, *Stars and Stripes*, and *Sunday Telegraph*, and the radio and television stations *British Broadcasting Company*, *American Broadcasting Corporation*, *Societè Radio Canada*, *Granada Television Station*, *Discovery Channel*, and *The New York Times Television* have demonstrated considerable investigative capacity.[24] While reporting from international mass media has been more serious, the local mass media have been more restrained in their 'domestic affair', as if Vesuvius is too close to home and not as mysterious as the tales of epic poems, while for foreigners in faraway lands Vesuvius is such a mysterious place where the man and nature helped to build the Western Civilization.

There are thus many security culture barriers in the Vesuvius area and not all of them have perverted intentions. We have seen that even the most informed and leading members of general public are not very anxious to take actions that could bring about a greater Vesuvius consciousness. The scientists who are monitoring the volcano with instruments are also contributing to the risk, because the local and national politicians are providing them with resources to look after their own interests. In this mutually benefiting contract, the politicians are freed from social and political responsibilities in the case of an eruption while the scientists gain by receiving lucrative contracts and privileged positions within the state institutions. By acting in this manner both parties apparently believe that the risk of loosing their privileges are minimized. They believe that this arrangement of convenience will allow them to keep the precarious situation under control; that they will be able to cope with socio-economic and political consequences, and find excuses in the event of a catastrophe. The general public evaluates the risk and possibilities for averting it differently, however, because of different interests and little ability to evaluate the tools used by scientists and politicians.

1.5. HABITS OF MIND, INCOMMENSURABILITY, AND PARADIGMS

1.5.1. Habits of mind

The Vesuvius area issues are therefore complex, for the conflicts about power and responsibility and who governs whom and for what ends the public policies are being used involve conflicts beyond the risk. The majority of these conflicts on the territory are associated with politics, and with who is going to be given and denied power, and for what ends. Under these circumstances the technical issues surrounding the reliability of different territorial projects tend to loose their relevance and many efforts to communicate expert guidance about technical details prove futile. This explains why, in spite of the logical criticisms that Vesuvius Evacuation Plan is flawed, its architects have remained relatively immune to the critics. 'In a society where great social issues are reduced to who has and has not power, where income and power are not justified by market economics, and where governing the territory is enforced by an egalitarian elite that favors the allocation of resources seen from the perspective of those peculiarly qualified to comprehend what is worthwhile for everybody else, its activities are intrinsically perverse and many leaders of its institutions are intrinsically evil'.[25] Such a society can breed both the right wing and left wing egalitarians exhibiting conspiratorial tendency, with the brainwashing media playing a central role in the conspiracy. This normally produces conflicts on the territory because of the loss of trust by the public in institutions that seek to assure it that the danger is under control. The experts from those institutions who are responsible for the well-being of the people can be wrong, of course, and yet the people ordinarily accept the experts' premises without questioning their validity. Experts have entrenched judgments that usually associate risk quantitatively, while lay judgments are open to much larger number of factors, such as catastrophic potential, understanding, uncertainty, personal controllability, effects on children and elderly, effects on future generation, trust in institutions, mass media attention, equity, benefits, reversibility of effects, personal stake, natural or human origin, etc.[26] Ideology, trust by the public, and rivalries between experts all have something to do with the difficulty of addressing the problem and they are not mutually incompatible. And an individual can be drawn to either one, depending on 'unconscious cueing of habits of mind'.

Habits of mind are associated with entrenched responses that occur without conscious attention, and even if noticed are difficult to change. They are driven by the patterns in the brain: The neural embodiment of patterns that command muscles to specific actions.[27] Sometimes these patterns can be mentally visualized and the motion rehearsed and corrected before taking actions. As we learn more we are normally able to control better this process and then act 'rationally'. Things we know could be partitioned into instincts, habits, and judgments. Habits are built from instincts, while judgment induces an ability to consider more than one alternative. No one is born programmed to specific behavior, no matter whether Asiatic or Western European. Learning a language, for example, involves knowing how to produce elaborate muscular operations that allow the utterance of specific sounds, and once such a habit is entrenched (learned) it is very difficult to eradicate it. Acquiring habits requires practicing, and once acquired we easily fail to notice when they are activated.

Although habits of mind cannot be easily observed their consequences are things that can be seen. An individual or group can be made to respond to various contexts and thus his or its habits of mind discovered. As we have seen, both the local, national, and European Union administrators, as well as many scientists and other professionals, do not readily respond to direct solicitations for actions in the Vesuvius area, but prefer instead to remain behind the controversies. This habit of mind is just one of the detrimental 'cultures' which is widely spread in the modern society and can produce a belief or habit that a massive escape from Vesuvius is really possible even on a short notice of 1 or 2 days. This could become a habit of mind and prevent the public from considering and taking alternative actions.

Everyone prefers to take minimal efforts to change, and in a society polluted with negative habits of mind (we called them 'cultures') it is very difficult to change them.

1.5.2. Incommensurability

An individual is an expert because he possesses peculiar habits of his profession, and in many situations his personal habits serve him well. On occasions, however, one becomes aware that something has gone wrong and that a new habit has to be adopted. This may involve realizing, for example, that some information or premises behind Vesuvius Evacuation Plan are flawed, that the standard tools of volcanologists who drafted this plan are inadequate when dealing with volcanic risk in densely populated areas, that some readjustment or radical change is needed. To some this anomalous evidence may be minor or an annoyance, while to others very serious or incommensurable that requires challenging the entrenched habits of mind. In principle, the entrenched habits can be challenged if there is evidence and argument that yield intuitions that conflict with those prompted by the habits. But a habit that is difficult to notice by an individual will also be difficult to challenge. This is especially relevant for a community which shares habits, for these become invisible to the members of the community. It is difficult to notice habits that everyone takes for granted and we should therefore not marvel why it is so difficult to produce a Vesuvius-conscious public in the presence of so many negative attitudes and mentalities.

Habits of mind are intimately tied to communication. The more we communicate within a restricted group the more we tend to adopt or develop habits of the group or community. These communities could be social, cultural, scientific, organized crime, political, and so on. Within each community incompatible habits of mind block communication, evoke resentment, and produce frustration of those who attempt to change the community's habits of mind.[28] When a new discovery arises from the changes of habits of mind of the discoverer this can easily prompt incredulity, confusion, and even revulsion if the community has not yet tuned its habits of mind to those of the discoverer. If the new experience of the discoverer can be readily shared with others, the experience becomes contagious and unproblematic. Most often, however, conflicts arise because individuals with the same information as the discoverer are blind to the discovery. The discoverer can become frustrated and the society may alienate him. This is especially true for radical discoveries because their consequences are striking. An individual with radical ideas usually wants to persuade others to see things his way, but his method of seeing things is ordinarily incommensurable with seeing the same by the others.[29]

A scientist does not ordinarily produce anything from which to live directly and is dependent on the existence of state institutions or private sponsors to support his science. And when the social considerations (religion, politics, economy) enter into scientific initiatives it is not unusual that they are deliberately hindered, as we have already encountered the situation with VESUVIUS 2000. This initiative has strong scientific, socio-economic, and cultural aspects because it aims at producing an organized and safe territory, but both the Italian and European Union administrators appear to be afraid of 'increasing their risk' by supporting such a revolutionary project. Entrenched habits of mind often prevent the realization of very useful social projects.

1.5.3. Paradigms

Shared habits of mind, shared beliefs, or paradigms are essential constituents which tie together a community and can change when there is a paradigm shift[29] or a special change in habits of mind within the community. Paradigms are ordinarily found in textbooks because they are widely accepted as the norms of communities. The notion of 'paradigm shift' should be understood as having a sharp boundary between the normal and revolutionary shifts, for even a 'normal' discovery can upset some established or previously held habits of mind. The vast majority of discoveries are, however, 'trivial' and they are simply acknowledged as 'Jones found such and such'. In situations when the discoveries are not trivial the Kuhnian incommensurability becomes well-defined, as we will see shortly when we look into some of the scientific revolutions of the past.

A new idea always involves a conflict with some existing habits of mind. To be persuasive the idea must 'look right' and 'be believable'; its positive tenets must override its negative characteristics. To be persuasive the results from an idea must look right and its reasons look convincing. If both the results and reasons are wrong the idea is wrong. But an idea may provide results that look right but its reasons are not convincing, or its results are wrong but its reasons are convincing. In these situations a state of paradox is reached. If the reasons look convincing or not but the results are uncertain the idea becomes doubtful, whereas when both the results and reasons are uncertain the idea becomes uncertain. A belief/disbelief in the idea is generated when the reasons for its validity are uncertain and its results look right/wrong, respectively. This rather complicated belief matrix of cognitive states available also defines knowledge (results look right and reasons look convincing) and contrary knowledge (results look wrong and reasons are not convincing), and can be used to examine different risk-mitigation strategies.

To many a massive escape (evacuation) from Vesuvius 'looks right' because they are unaware of the better alternative VESUVIUS 2000. According to the belief matrix, a project is either right, believable, paradoxical, doubtful, uncertain, not believable, or wrong, depending whether one believes that its premises and consequences are convincing. Since these premises and consequences depend on complex social and scientific issues which most people cannot evaluate, Vesuvius Evacuation Plan and VESUVIUS 2000 are interpreted depending on the individual's habits of mind or degree of risk education. If the same people were familiar with the latter project they would judge the idea of massive escape differently, because there would be other cueing patterns that would contribute to the decision-making processes. The validity of a massive escape strategy from Vesuvius thus depends not only on the capacity of its promoters to legitimize it by indoctrinating the population, but also on the capacity of VESUVIUS 2000 supporters to use their strategy to challenge the validity of massive escape.

In some extreme situations a new idea may be seen absurd or even perverse. Yet at some later time it is accepted and the same people who once rejected it are puzzled why such an idea was seen as making no sense initially. In our situation the case in point is the recent initiative of Regione Campania[9] which is closer in spirit (but not in seriousness) of achieving some goals of VESUVIUS 2000 than following the strategy of evacuation plan. The same individuals who have been promoting the evacuation plan appear to be now convinced that it is wrong! This is a strong case of incommensurability or a case of the Kuhnian barrier.[29] A barrier is a habit of mind that is both highly robust and critical for the emergence of a new idea. In the case of Ptolemaic to Copernican transition there are two candidates for the barrier: One is that the Earth wonders through space and another the nested-spheres structure of the world.[30]

Although Copernicus established himself almost immediately as the modern Ptolemy, it took about 50 years before anything substantial was done with the new view; until the new generation was brought up with the idea, in spite of Columbus' voyage in 1492 which predates Copernicus' publication of the heliocentric system in 1543. Like the biblical 40 years in the desert it took people to free enough of older habits of mind for the contagion to reach a new social norm. Similar situation also occurred four centuries later in the case of Darwinian theory of evolution. In 1859 Darwin made the claims that new species evolve from the existing species, and that natural selection can account for this process. The first barrier was easily overcome because the notion that species can be transformed appeared repeatedly for over 2000 years. But the natural selection barrier that drives the evolution was difficult to accept, as still is for many even today.[31]

A century later the plate tectonics provided the explanation of the 'mystery of mysteries'. During the first half of the twentieth century Wegener's theory of continental drift[32] was rejected by the experts because he could not provide the mechanism for the movement of continents, even though the alternative and accepted habits of mind of 'land bridges' between the continents provided no better explanation. New evidence for drifting continents began appearing from oceanographers after World War II, but it was not until mid-1960s when new compelling magnetic anomalies in oceans were found that vindicated the predictions of drifting continents theory. After this there came a very rapid collapse of opposition, because a much wider community than the geologists could follow the arguments that the 'result looked good' and 'reasons looked convincing'.

Radical discoveries such as these are marked with strong confrontations with the entrenched habits of mind (the system) and caused Max Planck to declare: 'An important scientific innovation rarely makes its way by gradually winning over and converting its opponents. What does happen is that its opponents gradually die out and that the growing generation is familiarized with the idea from the beginning'.[33]

As we pointed out on several occasions, Vesuvius Evacuation Plan is flawed from the scientific, engineering, environmental, social, and cultural perspectives, and yet it tends to be accepted by many volcanologists, local, national and European Union leaders, as well as by many people in the Vesuvius area. This is not because all of these people are stupid or even bigoted, but because they are blind to the argument of the critics of this plan. This blindness is defined by Kuhn[29] as incommensurability and to resolve its puzzle requires the creation of a greater Vesuvius consciousness, or what we have been discussing above, carefully tending to the habits of mind of the people exposed to the danger from the volcano. The force of habits of mind can be startling. We have seen that neither the Copernican, Darwinian, nor Wegenerian (just to name a few) discoveries were readily accepted by the educated or lay public. If one believes that good arguments are necessarily convincing, one assumes that one's perceptions are always reliable insights about the true nature of the world. There is nothing guaranteeing that this is so and when we are confronted with novel, blurred, unfamiliar, or difficult situations our intuition can be vulnerable to illusion. Expert and lay cognitions are different, because each draws from different repertoires of available patterns that are grown from different experiences. It is easier to cue a default or known pattern than a rival one that we still need to insert into our repertoire of patterns. Habits of mind can produce cognitive illusion judgments and can give rise to good and bad consequences. But since we are not born with these judgments, we can also eradicate them.

The 'acceptance' of Vesuvius Evacuation Plan is, in my view, a situation of severe case of blindness or incommensurability on the part of many and to a large extent is being maintained by an inadequate challenge from the alternative VESUVIUS 2000. To respond to the challenge requires seeing the challenge or alternative, seeing a cognitively effective rival intuition to challenge an intuition, because the mere logic by itself of pointing out the deficiencies of a massive escape from Vesuvius has not proven to be very efficient. Negative habits of mind of Vesuvians contribute significantly to the difficulty in producing a paradigm shift: From viewing Vesuvius as a menace to seeing it as an asset.

1.6. RISK, RISK MATRIX, AND RISK COMMUNICATION

1.6.1. Risk

On several occasions we have used the word 'risk' without precisely defining the concept. We noticed that experts and lay public use the word differently and that we can talk about risk to people from eruptions, risk education, political risk, environmental risk, etc. When asking 'What is risk?' one can ask three questions[34]: What can happen?, How likely is that to happen?, If it does happen, what are the consequences? In objective terms, risk is a 'measure' and as such involves all possible scenarios, S_i, likelihood of each scenario, L_i, and consequences of the ith scenario X_i; i.e.

$$R = \{S_i, L_i, X_i\}_c$$

where 'c' stands for complete to emphasize that we need to know all possible (or at least the most important) scenarios. The consequences are damages to people, property, environment, wild life, etc., and in general can be expressed by probability curves[35] $P_i(X_i)$. The likelihood can be expressed in terms of probability of frequency $P_i(f_i)$ when a repetitive situation exists, but we are uncertain about what that frequency is. The risk scenarios S_i can take various forms, depending on our definition or knowledge of the initiating event. One can have one or more end states from one or more initiating events by following the appropriate decisions along the 'scenario tree'. We could find all initiation events and draw the outgoing tree from each, or we could identify the end states of interest and draw the incoming trees to each.[36] The end result of risk analysis is to determine risk maps that delineate the levels or contours of different risk categories, because different people have different risk perceptions or interests.

In the determination of risk categories one should also include protection of the territory from different eruption events or scenarios (lava flows, ash fall, mudflows, pyroclastic flows). Since it is not possible to displace all Vesuvians from the slopes of the volcano, some engineering protection measures will be necessary for those who remain. These can include reinforced roofs and walls of houses to withstand ash and pyroclastic flow loadings, channels to divert *lahars* and pyroclastic flows away from populated areas, reinforced structures to protect some ancient ruins of Pompeii and Herculaneum, basic services infrastructures, and so on. If a new habitat is to be built for Vesuvians, this habitat must be better and safer than it is today and should be built only after an extensive risk analysis or feasibility study as intended by VESUVIUS 2000. A key tool in this analysis is Global Volcanic Simulator, or a physico–mathematical–computer model of the entire volcanic complex. The simulator serves to determine the likelihood of different eruption scenarios and their consequences on the territory, with and without protection measures to defend some people and properties from the volcano.

1.6.2. Risk matrix

Besides the experts' interpretation of objective or probabilistic risk there is also a visceral or subjective risk that expresses a certain discomfort or vigilance that is not readily quantifiable. A lay person is normally concerned with many dimensions of risk, while an expert is more focused on such things as fatalities. But there is no risk if there is nothing to gain from taking some risk. And to prevent or reduce the risk we must incur the cost of taking precautions. Our natural or Darwinian tendency is to economize or adapt to the situations at hand, a tendency which is somehow entrenched in our habits of mind as species. This tendency to economize as species can be expressed in terms of opportunities that are available to accept risk and the danger that is averted by taking precautions. Instead of utilizing cognitive illusions of 'results look right/wrong' and 'reasons look convincing/not convincing' discussed earlier, it is easier to utilize a simpler 'risk matrix' where one dimension expresses danger and the other opportunity.[37]

In the risk matrix shown in Fig. 1.2 the costs of precautions are indicated on the horizontal axis (yes and no opportunities), whereas the danger of doing without these precautions on the vertical axis. Often, the costs of avoiding one risk include the costs of accepting some other risk. An individual may not be sensitive to all risks

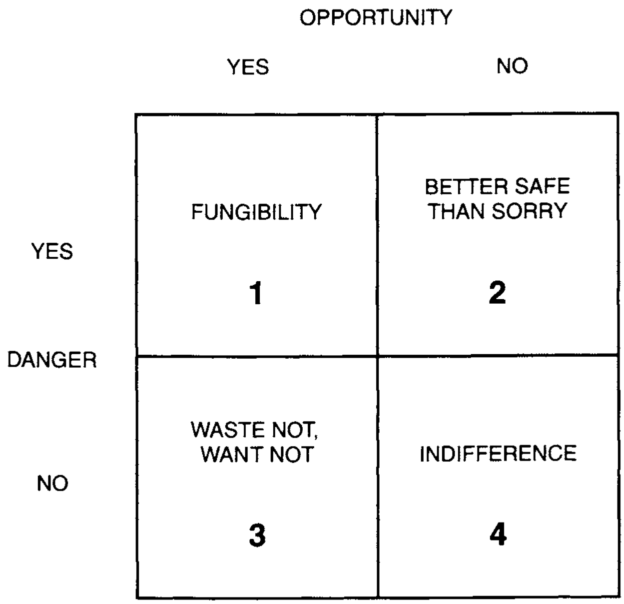

Fig. 1.2. Risk matrix showing the relationship between the danger and costs of precautions or opportunities to avert the danger. Low danger and lack of opportunities produce indifference. High danger and availability of opportunities produce a state of action on the part of those who are exposed to the risk.

and costs in a situation, but when this occurs some sort of global risk averaging must take place in order to minimize risky decisions. In cell 1 of the figure an individual is aware of the danger and there is an opportunity or incentive of taking precautions against the risk. In this situation of fungibility a risk is considered seriously and there is a strong chance that the individual will do something about it (protest, collaborate, invest). On the other extreme in cell 4 the danger and opportunity are perceived as being low and an individual behaves indifferently. When in other cells one is either convinced about the danger but not of the opportunity (cell 2), or convinced about the opportunity but not of the danger (cell 3). A person ordinarily moves from cell 4 to cell 2 and if there is no opportunity slips backs to indifference of cell 4. This is the average behavior of Vesuvians, because even after some of them are educated about the potential danger from Vesuvius they are not provided with opportunities that address this danger. Few individuals remain in cell 2 and even fewer in cell 3. Most of the people in the Vesuvius area act therefore indifferently, and even if a minority is concerned about future eruptions by being in cell 2 it adapts to the social choices of the majority. The territorial administrators apparently prefer to keep it that way to eliminate risky political choices that would be associated with a risk-conscious population. The governing elite thus see the risk matrix differently: They perceive that governing is more effective when keeping the people less informed about the danger and the possibilities how to avert it.

An evacuation plan tends to move the population only into cell 2 where there is the perception of danger but few opportunities to address it until an eruption becomes eminent or after it is practically over. But when this occurs it will be too late for many to take advantage of opportunities (post-eruption reconstruction aid). Providing a risk opportunity only after a disaster does not contribute toward a social progress, and Vesuvius Evacuation Plan does not produce the necessary condition of fungibility that is required for a serious risk reduction. VESUVIUS 2000 has the goal of bringing the population into cell 1 and keep it there.

1.6.3. Risk communication

Any actions in the Vesuvius area aimed at risk reduction can be perceived as either producing intended or unintended consequences, and to a large extent depend on whether these actions create or strip opportunities. The administrators of the territory apparently decided that any change of status quo will hurt them politically or economically, while the lay people are under an illusion, or became fatalists because of poor risk education, that the volcano will remain tranquil for a long time and will be able to escape when the time comes. And when such a message of false security arrives from an expert or experts, the public tends to accept too often the experts' judgments without questions.[38] To reduce the risk from future eruptions requires a shift in the current fatalism paradigm. And because of the complexity of social and environmental issues with little understood dynamic, the simplest suggestion to follow to reduce the risk should be that of the great Greek physician and father of medicine, Hippocrates of Cos.[39]

Hippocrates suggested to the physicians to 'do no harm' to their patients. This precautionary principle is appropriate when dealing with complex systems, such as with a human body or those that include interacting social, cultural, and environmental issues. The 'do no harm' principle is already built into the risk matrix for it 'seeks to build a measure ... of fungibility deeply into the *process* of risk assessment and risk management in a way that appeals to everyday intuitions about fairness'.[40] If we are going to take the trouble to do something for Vesuvians, that something ought to produce more positive than negative consequences. Although this risk management proposal is modest, its consequences are far-reaching, as we will illustrate with Vesuvius Evacuation Plan. First of all, this plan produces harm to the volcanologists because it promotes bad science (eruption prediction at least 3 weeks in advance when there is no science to substantiate this premise). It also produces harm to the engineering and management professions because it promotes the evacuation of hundreds of thousands of people in a week in the absence of adequate infrastructures (evacuation of masses on short notice is impossible when the territory shakes and railways and roads become inoperable). The plan is also harmful to the public because it was not involved in producing it (it is antidemocratic) and its consequences are the destruction of culture and speculation of territory (a massive evacuation from the Vesuvius area will leave the territory wide open to looting and influx of new people who will take the possessions of those who left). Worse of all, this plan projects an illusion that 'everything is under control' when it is not and thus harms the trust between its promoters (*Protezione Civile, Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano*) and the public. By being harmful in so many different ways it is incredible that such a plan was proposed in the first place and that it is still being supported in some circles. But as we noted above, even harmful projects for some can serve their purpose for others. VESUVIUS 2000 is a far better solution than the simple-minded and harmful massive evacuation plan for it strives to produce a new socially and environmentally acceptable habitat for Vesuvians.

1.7. FUTURE HABITAT FOR VESUVIANS

1.7.1. The choices

Vesuvius is today surrounded by a sea of humanity and at night its presence is given away by the blackness that is surrounded by densely distributed dots of light. These dots of human dwellings surround the Bay of Naples and extend over the Campanian Plain as far as the eyes can see. What was once a sustainable land producing the basic services of food, water, and shelter for its inhabitants is today strained by insecurity and limited prosperity. Naples, with its own demographic and service pressures, represents the best source of opportunities and banishes many into suburbs to be confronted with the risk from eruptions and an environment that has been polluted from illegal waste and hazardous material dumps. The space surrounding the volcano is filling up fast and there may be no more land where to relocate the Vesuvians or time to bring the territory under control. Inequities in the form of health and security undermine the sustainability or the ability to meet the needs of people without compromising the ability of future generations to meet theirs.[41] The carrying capacity of humans around Vesuvius depends, therefore, on the demographic and economic arrangements, political institutions, use of available technology to produce consumer products and social services, peoples' willingness to tolerate a certain physical environment, moral values, etc. In other words, it is culture-dependent and the choices that are made today for the territory could place a heavy burden on future generations. The United Nations Development Program says that the quality life has to do with 'creating an environment in which people can develop their full potential and lead productive, creative lives in accord with their needs and interests'.[42] The goods alone cannot deliver this life once the basic needs and adequate social services to the people are provided.

1.7.2. The grand challenge

A safe and prosperous environment for Vesuvians cannot be created without modern technology or in the absence of craftsmen, inventors, designers, engineers, scientists, machines, and knowledge gained during the last several thousand years. The technology offers creative means to control the human-built world,[43] just as for the Greeks Prometheus symbolized creativity in stealing fire from the Gods. Leonardo da Vinci is remembered as an architect-engineer of canals and automated machines, while Goethe's Faust finds earthly fulfillment by creating new land for humans from drained wetlands. And even in Genesis, humans were engaged in creating outside of Garden of Eden a living and working place. Humans have been transforming the uncultivated physical environments into cultivated and human-built ones, and in the process have been reshaping nature and in many instances causing undesirable consequences of environmental degradation and loss of quality of life.

What does this mean for Vesuvians? It means that the engineers, architects, urban planners, economists, environmentalists, educators, and the public must collaborate as they design and build a secure and prosperous habitat for Vesuvians – a habitat where the technology is used to respond to public's need of being protected from the volcano and being allowed to pursue high quality of life. This is a messy undertaking, because of the problems laden with political, economic, social, and esthetic values. An approach that is limited to technology only (building escape routes from Vesuvius, for instance) can amount to no more than a 'technological fix' that satisfies exigencies of special interest groups and their cronies. But an ecotechnological habitat will be value laden, for it will not only serve as a towering symbol of man's creative ingenuity, but also a model for others to follow in their quest to live in harmony with nature. Italy is a superb example of such models and that the Vesuvians are being denied their proper place in history is a crime, in no small measure perpetrated by inept architects of the evacuation plan and their cronies in scientific and non-scientific establishments.

In Italy the democratic instruments are at hand enabling citizens, engineers, scientists, sociologists, economists, and other professionals to help shape the world of Vesuvians. The national, provincial, and local governments, as well as numerous local interest groups, have a unique opportunity of taking the advantage of high risk from eruptions and transforming this risk into public benefits. The volcanologists' style of confronting the volcanic risk from their perspective only and politicizing their personal interests[44] slows down other professions from carrying out their job. The public needs to know this and learn how engineering, urban-planning, and managerial processes can be used in creating a whole new metropolis with modern services and in harmony with the environment. The educators, on the other hand, need to produce a whole new generation of individuals who know what questions to ask and what kind of technology can be used to produce a harmonious cohabitation under the shadow of the volcano.

The new environment that needs to be produced for Vesuvians should include community participation; provide jobs, housing, and health; project a sense of belonging and pride; be self-adapting and efficient in providing and managing services; minimize geographic and resource footprints; have the public feel secure from different eruption scenarios; and above all be manageable. The materials, energy, and information are some of the essential engineering parameters which interact with biological (humans, plants, animals), machine (reliability, precision, automation), and social organization components of a city, and an approach that minimizes the use of materials and energy may be most acceptable. The engineering challenges of producing a safe and prosperous habitat for Vesuvians should not only limit the external effects on the city (eruptions), but also minimize the effects of the city (its wastes and noxious emissions) on its surroundings. In tackling the grand challenge the engineers must address how the stringent environmental and safety requirements limit technical options in certain economic sectors and increase options in other sectors, what are the alternative methods of waste disposal and levels of recycling, can waste heat be captured, what levels of power and communication will provide reliable service, how to protect some parts of the territory from the destructive power of Vesuvius, etc. A city that emphasizes civic engagement, social justice, environmental soundness, economic diversity, and that is governable and manageable is a grand challenge for designers and investors alike.[45] Such a challenge is necessity if we want to maintain the continuity of life and preserve over 2000 years of human activity in the Vesuvius area. VESUVIUS 2000 addresses such a challenge.

1.8. VESUVIUS 2000

1.8.1. Overview

Future catastrophes in the Vesuvius area can be prevented only if a secure environment can be created for people living around the volcano. This cannot be produced by evacuation plans which by definition are designed only for managing emergencies, but by information campaigns aimed at educating the public about the risk and provision of economic incentives aimed at producing a safe, prosperous, and ecologically viable environment. In a socially sustainable environment[46] people are aware of the danger and are willing to tolerate a minimal risk because they are convinced that the hazard will not hurt them. A risk-conscious population is not told what to do or how to march under the command of a director, but knows which actions it must take in the event of an emergency. In the ideal situation the territory at risk should autoregulate itself and there should be a great deal of trust between the public and its administrators. All of these characteristics are lacking in the Vesuvius area and an escape-from-Vesuvius strategy cannot create them because this was not designed for this purpose. A strategy that only provides an illusion of safety and its proponents keep sending messages that ‘everything is under control’, while the public and independent professionals are being kept in the dark what exactly is under control, was not designed to produce security for the population but to control it for the purpose of extracting political and economic benefits from it.

VESUVIUS 2000 works in the opposite direction. Its basic premise is that a secure cohabitation of people with the volcano is possible and that this arrangement can produce socio-economic, scientific, and cultural benefits, without producing adverse effects on the environment. As such, VESUVIUS 2000 does not aim at a massive escape from the volcano in the event of an emergency, but at preparing the people and territory to confront the emergency with minimum cultural and socio-economic losses. Due to many detrimental habits of mind in the Vesuvius area, this preparation should commence years or even decades in advance of a volcanic emergency.

The hazards from future eruptions of Vesuvius cannot be eliminated, but their effects on the territory, or the level of risk, can be controlled by reorganizing the environment where people live and work. Different areas around the volcano are exposed to different earthquake, volcanic (lava, pyroclasts, mudflows), and hydrogeologic hazards, all of which must prominently enter into quantitative risk assessment (QRA). QRA must take into account the whole body of evidence items (volcano, people, dwellings) and process them through Bayes theorem[36] for the purpose of determining 'evidence-based' QRA and subsequently utilize this information to produce the necessary decisions. Different actors on the territory should become aware why it is necessary to work together to produce optimal decisions and why these decisions cannot be based on unreliable predictions of eruptions, deportation of population, and destruction of its culture. One needs to carefully tend to the habits of mind of Vesuvians to safeguard their positive habits and eliminate, or at least reduce, their negative ones. Without such care it is impossible to produce a change of the current paradigm of resignation on the part of many. VESUVIUS 2000 aims to address these and other issues and its purpose is to bring the population into cell 1 of the risk matrix (Fig. 1.2). In this state the people are fully aware not only of the danger, but also of the opportunities to avert the danger. Many people are aware of the first because the volcano has been active until recently, but they are not aware of the second, or they do not see how to take advantage of the first to produce conditions for the second. This is what VESUVIUS 2000 is all about, but the entrenched habits of too many people living around the volcano prevent them from seeing how to overcome this incommensurability paradox. It is amazing how this paradox reaches the highest levels of experts and leaders of national and European Union governments.

1.8.2. Principal objectives

VESUVIUS 2000 intends to produce guidelines for transforming high-risk areas around Vesuvius into safe and prosperous communities. This can be accomplished through interdisciplinary projects involving engineers, environmentalists, geologists, computer scientists, historians, urban planners, sociologists, economists, educators, civil protection volunteers, and the public. Such a multidisciplinary group of experts and lay public must work together synergistically, whereby the research and development results from separate groups are integrated into concrete recommendations or guidelines for use by local communities and institutions, national and European Union governments, and domestic and foreign scholars and entrepreneurs (Fig. 1.3). The central objectives of VESUVIUS 2000 are:

1. Definition of the volcanic system of Vesuvius, and past eruptions in particular, for the purpose of developing accurate models of the volcano that are capable of assessing future eruption scenarios and their consequences on the surrounding territory. For this purpose, it is necessary to develop physical and mathematical models of magma supply and pressure buildup in magma

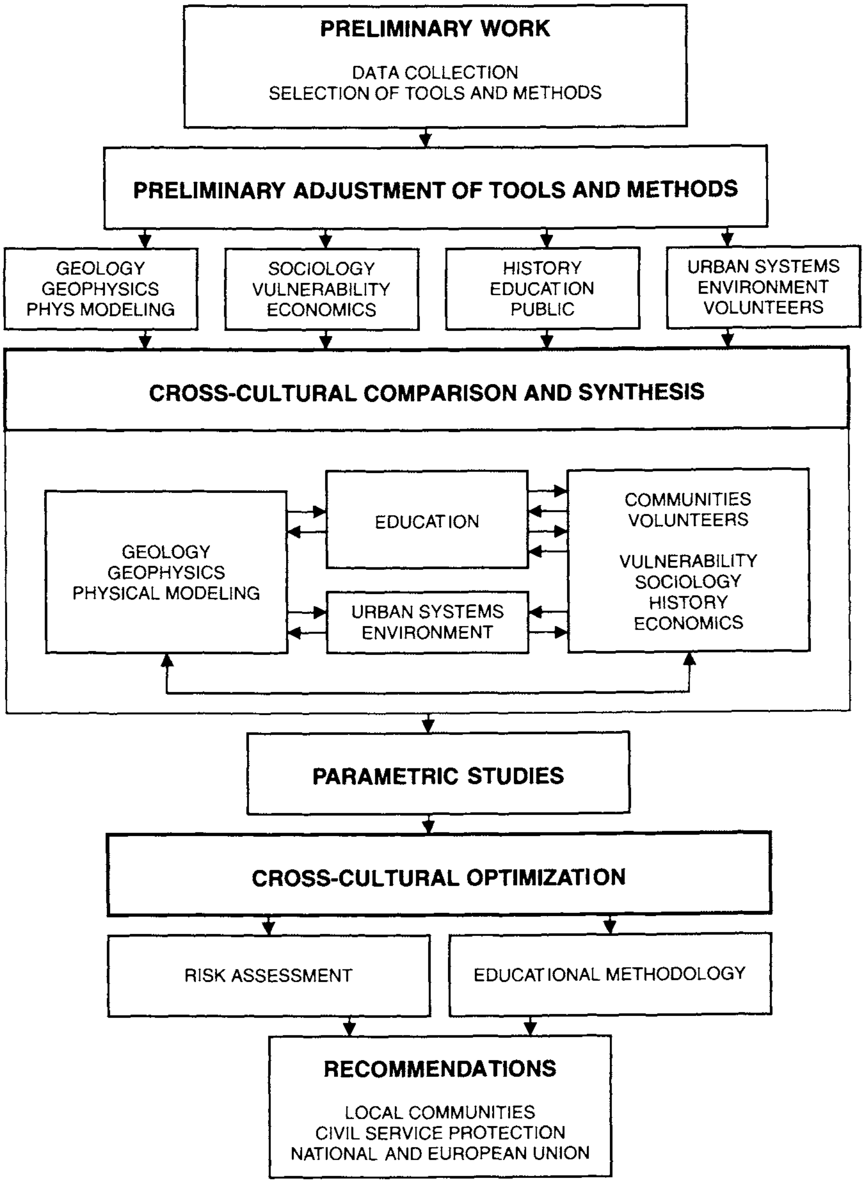

Fig. 1.3. Interdisciplinary integration of knowledge from experts and public on VESUVIUS 2000.

chamber, magma ascent along conduit(s) and its interaction with the surroundings, stability of the volcanic cone, and distribution of pyroclastic material in the atmosphere and along the slopes of the volcano. These models must be validated[47] with past eruptions before they can be employed to determine the most likely eruption scenarios.

2. Assessment of consequences or vulnerability of population, dwellings, and key industrial, cultural, telecommunication, and infrastructure systems in the Vesuvius area and vicinity for the purpose of establishing cost, benefit, and damage probabilities. This assessment includes medical consequences on the public from the interaction with volcanic products and hazardous materials produced from anthropogenic activities (municipal solid and hazardous waste landfills, chemical products factories, ammunition storage facilities). An assessment of socio-economic and other consequences is necessary before the preparation of urban plans which are aimed at building a safe and prosperous habitat for people around the volcano. One should not provide economic incentives for relocating people or promote development before carrying out an exhaustive feasibility study of the consequences of such actions.[9,16]

3. Development of an educational methodology that promotes Vesuvius consciousness and autoregulation of the territory, for the purpose of establishing new habits of mind that are conducive for the creation of security culture. Without such an education it is not possible to produce socially conscious citizens of tomorrow who must collaborate in building an ecotechnological environment that is characteristic of high standard of living.

The ultimate objective of VESUVIUS 2000 is not only to produce a QRA, or expected human, material, socio-economic, environmental, and cultural losses in the Vesuvius area from future eruptions of the volcano, but also to produce guidelines which minimize these losses and provide for autoregulation of the territory. The public and the experts need to be brought together so that the former can contribute to the development of these guidelines. An effective interdisciplinary collaboration is vital for determining equitable distribution of resources and to protect the territory from future eruptions. Toward this end it is necessary to produce:

a. Sociological impact statements that identify possible behavior of the population as a result of personal and family danger, and fear of property loss, prior, during, and after the eruptions.
b. Economic and territorial settlement impact statements that identify the value on the territory and possible population migrations before and following different eruption scenarios and urban-planning interventions.
c. Environmental impact statements that identify the effects of erupted material on the local and regional environments, and an interaction of this material with hazardous materials of the territory.
d. Educational methodologies for producing and maintaining a volcanic risk-conscious population.
e. Volcanic risk-mitigation guidelines for use by the public and local and national administrators, educators, urban planners, engineers, and civil protection volunteers.
f. Reports and educational material dealing with the multidisciplinary issues of the territory and procedures involved in systems integration and optimization.

Making the public conscious about its environment and involving it from the beginning on various aspects of the project can produce new opportunities and with them a higher quality of life.[48]

VESUVIUS 2000 is divided into three major interrelated interdisciplinary areas: Physical environment, population, and territory. The physical environment involves issues directed at quantifying the likelihoods of different eruption scenarios in the Vesuvius area and assessing their consequences on the local and global environments. The population involves issues directed at the consequences of these scenarios on people and property, including a reduction of people's adverse habits of mind and creation of new ones that 'see' the volcano as a useful asset for producing safety and prosperity on the territory. The territory involves issues associated with Vesuvius area communities, civil protection volunteers, environment, infrastructures, and national and European Union leaders.

1.8.3. Physical environment

1.8.3.1. Global volcanic simulator

Eruption scenarios are determined from the knowledge of past behavior of the volcano and by using a tool that can extrapolate this behavior into the future. This tool is Global Volcanic Simulator, or a physico–mathematical–computer model of the entire volcanic complex. The simulator incorporates physical and chemical models of all conceivable magmatic processes within the volcano and in the atmosphere above it. This includes the geological and geophysical data pertaining to the origin and composition of volcanic deposits, magma and lava flows, aquifers or underground reservoirs of water, strength, elasticity and plasticity of magmas, lavas, surrounding rocks and soils, etc. These data are utilized to produce constitutive equations or mathematical models of material behavior at the microscale and macroscale levels at different pressures and temperatures. The constitutive equations are then used in basic physical laws of conservation of mass, momentum, energy, and entropy to produce an overall physico–mathematical model suitable for solution on efficient computers that may require taking advantage of their special design or architecture[49] (single and multiple processors). The simulator is then used to produce the likelihoods of different eruption scenarios and determine their consequences on the territory surrounding Vesuvius. The development of Global Volcanic Simulator of Vesuvius does not only depend on future scientific breakthroughs in several fields of science, but also in bringing together responsible agencies and professionals with different cultural backgrounds.[28]

Global Volcanic Simulator requires initial and boundary conditions of material properties to determine the temporal and spatial evolution of volcanic system.[50] It is important to note that if these conditions are incomplete or poorly defined, the predictions of simulations can be unreliable. The initial conditions determine the initial state of the volcanic system and include thermal, fluid, and chemical properties of magma, gas, and pyroclasts, and structural mechanics properties of rocks and soils that make up the volcanic edifice. The boundary conditions specify the interaction of the volcanic system with its surroundings. If a simulation is initiated from a closed-conduit state of the volcano, this simulation should then be able to predict subsequent eruptions, or future times associated with conduit openings, dispersions of volcanic products above the volcano, and interactions of discharged material with the infrastructures on the slopes of Vesuvius. Since the volcanic system is very complicated and its internal state difficult to define during an eruption, it is preferable to initiate a simulation when the volcanic conduit is closed. A volcano which is externally inactive may remain in this state for centuries and tends to 'forget' its initial properties. This is not, however, true for the boundary conditions, because these normally control the future evolution of the system.

Initial conditions for simulations should be, therefore, obtained after a large-scale eruption with the volcanic conduit closed. After the plinian eruption in 79 A.D. this closure apparently occurred around 203[51] and requires further studies. Based on the deposits of erupted materials and chronicles the subplinian eruptions of Vesuvius in 472 and 1631 are known reasonably well[52] and provide good cases for validating the simulator's predictive capabilities. But in order for the simulator to be validated with these eruptions it needs to simulate magma supply, differentiation, and crystallization in magma chamber for centuries.[53] The closure of conduits following a large-scale eruption can last for several centuries, as attested by the subplinian eruption of 1631 whose small-scale strombolian and lava flow activities persisted at least until 1944.[3] Long-term forecasting of these small-scale activities is unreliable and not necessary for achieving the objectives of VESUVIUS 2000.

1.8.3.2. Definition of volcanic system

A large-scale plinian eruption of Vesuvius can discharge between 2 and 6 km^3 of material in about 20 h of sustained activity and has a cycle of several thousand years. Intermediate-scale subplinian eruptions occur between two plinian cycles and discharge about 10 times less material than the plinian eruptions. Each of these has a cycle of several centuries and its main phase also lasts for about 20 h.[3] The small-scale strombolian and effusive events close the cycles of these eruptions and occur every few years or decades in succession until the volcanic conduit(s) closes. A common feature of Vesuvius' eruptions is that they were intermittently interrupted by partial column collapses which produce pyroclastic surges and flows, and terminate with the interaction of magma with water from underground aquifers. Recent plinian and subplinian eruptions are characterized by the emission of highly differentiated trachytic and phonolitic magmas. The location of magma below Mount Vesuvius is currently in dispute, with estimates that range from 3 to 10 km below the volcanic cone, in spite of the large number of volcanological, petrological, and geophysical studies which have been inundating the scientific literature.[54]

Vesuvius can lie dormant for long periods of time and the quantification of time scales over which magma storage and differentiation take place is of vital importance. Current understanding of the subsurface of volcanoes is poor and only some rough constraints are available on the time required for magma storage and differentiation between eruptions.[55] Although a great deal of information on the deposits of recent plinian and subplinian eruptions of Vesuvius is available,[3] more precise data are required on the spatial and temporal evolution of deposits, sedimentological structures, granulometry, clast types and morphology, and field and laboratory studies of magma–water interaction. A significant effort should be directed at identifying the spatial and temporal relationships associated with fallout, pyroclastic flow, lithics provenance and distribution, and hydromagmatic components in the eruptive sequences. An accurate identification of the volcanological character of each depositional layer of recent eruptions of Vesuvius is essential for validating magma chamber, magma ascent, and pyroclastic dispersion models.

Magma–water interaction processes at Vesuvius are poorly understood. As magma ascends along one or more conduits or fractures toward the surface, it can come in contact with groundwater and cause violent explosions because of the conversion of water into steam. The more effective the mixing between magma and water is the more intense this interaction becomes. This process can produce bulging of volcanic edifice, landslides, and decapitation of the volcanic cone.[56] The possibility of avalanches and landslides from Gran Cone (of Vesuvius) is, therefore, very real and should be assessed through geotechnical studies with the objective of producing geological, geomorphological, lithotechnical, slope, landslide, and soundings maps.

A closely related study pertaining to the structure of Somma–Vesuvius should be directed at establishing relationships between the activity of Somma volcano (regional tectonism, origin of the caldera) and structure of Gran Cone in order to ascertain weakness areas along which sector collapses are possible. For this purpose, use can be made of Landsat and aerial photo analyses to study the geomorphology, field surveys of fault fractures and dykes to analyze structures, analyses of drill-hole and geophysical data to ascertain deep structures, and evaluation of the volume of the caldera and comparison with plinian eruption volumes. The results of this study should permit an assessment of the influence of regional tectonism on the volcanic activity, evaluation of lateral sector collapses of Somma–Vesuvius, and definition of a rheological model for the volcano. This study needs to be further complemented by physical modeling of the stability of volcanic cone to determine likely scenarios leading to eruptions. Such scenarios could have been responsible for destroying the sea-ward part of Monte Somma caldera.

1.8.3.3. Systems integration

The volcanic system of Vesuvius can be divided into different parts or domains, each of which can be characterized by unique properties or characteristic physical phenomena. These parts may consist of magma chamber or reservoir, conduit(s), soil and rock surrounding conduits and magma chamber, and atmosphere domains (Fig. 1.4). The magma reservoir domain consists of an open system for mass, momentum, and energy transfer between the chamber and its surroundings. Some possible magma chamber processes include multicomponent crystallization, exsolution, melting, and solidification. The conduit domain can be characterized by propagating fractures in which magma exsolves dissolved gases, fragments into pyroclasts, and interacts with conduit walls and surrounding groundwater. The soil and rock domain encloses magma chamber and conduit domains, and can be characterized by elastic, plastic, and non-homogeneous material behavior, depending on temperature, pressure, and chemical compositions of materials within this

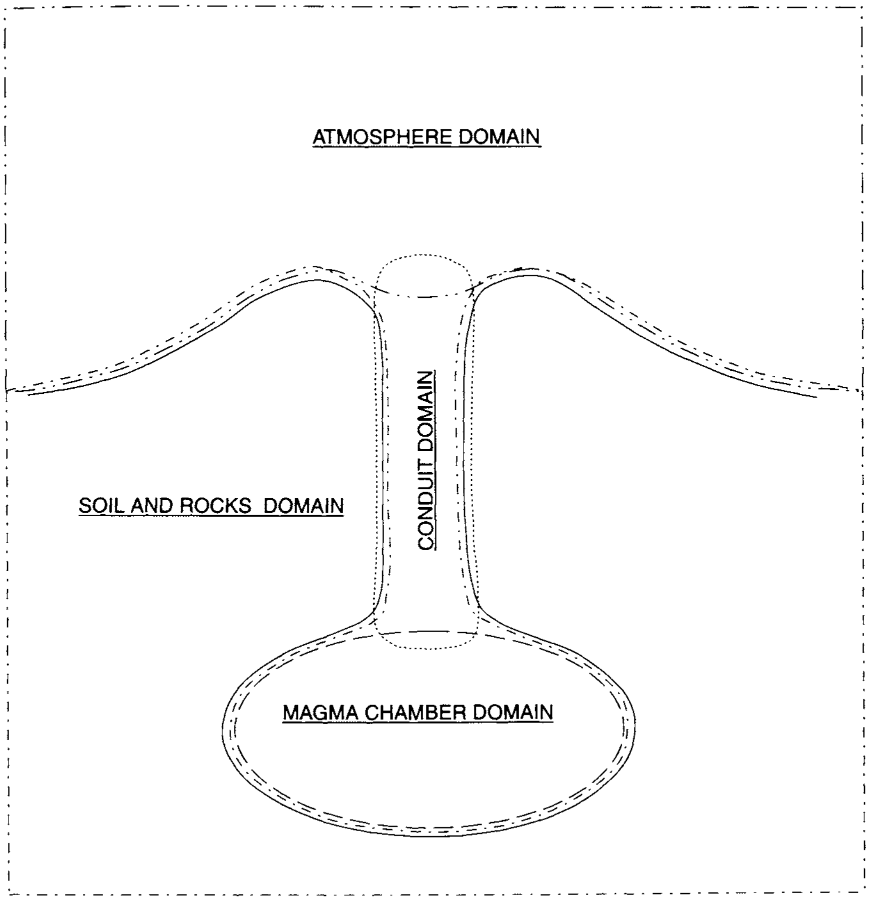

Fig. 1.4. Decomposition of a volcanic system into its characteristic subparts. These are comprised of magma chamber, conduit(s), soil and rocks, and atmosphere domains. Each domain is characterized by its unique processes which are defined by their temporal and spatial scales. Coupling of subdomains is achieved at subdomain boundaries through which mass and energy are exchanged.

domain. The atmosphere domain involves a region where the volcanic products mix with the gases in the atmosphere and interact with people, dwellings, and infrastructures on the slopes of Vesuvius. Physical and chemical processes in each of these domains have different temporal and spatial scales and thus require appropriate physical modeling considerations and numerical techniques for solving the resulting set of mathematical equations.[49] An effective simulation of these processes over several thousand years of activity depends on the effective combination of different domains into an overall model (Global Volcanic Simulator) suitable for solution on high-speed computers.

The most important use of Global Volcanic Simulator of Vesuvius is for the quantification of eruption scenarios and determination of their consequences on the territory surrounding the volcano. This information is then used in the QRA for producing safe habitat(s) for Vesuvians. The simulator can also be employed to protect those people and structures that cannot be relocated from immediate danger areas.[57] Global Volcanic Simulator can also be used to produce movies of eruption scenarios for teaching the public, school children, policy-makers, city planners, insurance companies, and others about the potential effects of eruptions and how to protect certain areas of the territory from these eruptions.[58]

1.8.4. Population

More than half a million Vesuvians are highly vulnerable and many of them could perish during a future eruption. A significant effort needs to be directed at these people with the objective of changing their negative habits. This population is largely uneducated about the potential danger from the volcano and how to avert it.[14] During the preparation of VESUVIUS 2000 objectives in 1994 and 1995 we were fully confronted with this problem and the lack of collaboration from many scientists and public officials.[59] Such widespread negative attitudes, behaviors, and mentalities act in detriment to the public, and scientific and cultural progress, in particular. Volcanic risk mitigation in the Vesuvius area requires, therefore, confrontations with these realities, or with very complex personal, political, and socio-economic interests that are impeding serious work on reducing the risk. It is, therefore, necessary to approach this problem with an open mind, and above all from an interdisciplinary perspective, with the central objective being to develop new habits of mind that are conducive to collaboration and responsibility on the part of those who receive public funds.

1.8.4.1. Sociology

Many volcanic risk-mitigation strategies rely on an implicit cartesian theory which assumes that if the population is given a sufficient information it will choose optimal adoption measures.[60] Case studies of individuals and groups and my experiences in the Vesuvius area demonstrate, however, that people do not follow the given instructions but tend to adopt decisions on the basis of what they know, believe, hear, or hope. Most of the people follow a 'bounded rationality' which is deeply rooted in the entrenched habits of mind. In the Vesuvius area the volcanic risk information needs to be translated into how each one should react in the event of an emergency. The administrators of the Vesuvius area are not trained either to assess or interpret much of the information that they receive, and a failure to correctly interpret the recommendations from experts or following the anxiety of people can result in the misinterpretation of a serious event or issuance of a false alarm. Both of these consequences cost enormously and may produce grave human consequences. It is of little use to keep transmitting messages to those who cannot or are not willing (because of personal, economic, cultural, or political interests) to listen, collaborate, or translate information into the behavioral advice for the public.

From a psycho-sociological point of view, one should aim at modifying the mental collective view of 'being trapped' (that people in the vicinity of dangerous volcanoes display) into a clear understanding of how best to prepare for an emergency.

An emergency can produce frustrated and divided public because of the loss of livelihood and physical environment. Sociological studies should include:

1. Defining the information needs of the public, emergency agencies, and civil protection authorities.
2. Educating the public and local authorities of possible volcanic events and their consequences on the territory.
3. Analyzing various management processes for coping with different eruption scenarios in order to assess possible problems and obstacles to an adopted response.
4. Investigating perceptions, intended behaviors, population preferences, etc. in the event of an eruption.
5. Analyzing relationships between the public, environment, and land use occupation in order to plan for an equitable, safe, and prosperous environment for Vesuvians.
6. Establishing inventories of disaster processes in order to avoid worsening of post-disaster situations due to social conflict and disruption of social functions. Working on post-disaster processes with mayors of small communities should provide the necessary sensibilization for adopting organizational preventive arrangements.

1.8.4.2. Vulnerability

The vulnerability of a territory depends not only on its physical parameters, but also on the knowledge of local communities and behavior of local decision-makers. Accordingly, any actions directed at reducing this vulnerability should confront how to transform acquisitions from experts into diffuse knowledge of communities and how to induce local decision-makers and apply recommendations from the experts. The usual procedure would be to establish information and sensibilization campaigns which are not always efficient, since the recommendations from experts may be in conflict with the consolidated interests of the community. In the Vesuvius area, where eruptions have been occurring with certain regularity, the behavior of various actors may be better translated into actions that reduce vulnerability if the risk conscience is reinforced through a recovery of the local risk culture.[61] The demographic pressure in the Vesuvius area is enormous, the population density is one of the highest in the world, the efficiency of the government on the territory is weak, the credibility of public administrators is, in general, very scarce, and the volcano is quiescent. This implies that by utilizing the traditional methods of sensibilization may not contribute significantly to the building of Vesuvius consciousness.

An effective consciousness of the volcano could be produced through the decision-makers who utilize the territory to satisfy their own personal exigencies. A study aimed at reducing the vulnerability in the Vesuvius area through a recovery of the local risk culture should, therefore, include:

1. Furnishing local communities some instruments of consciousness and evaluation in order to reinforce this consciousness.
2. Involving local communities from the beginning in various phases of feasibility study project in such a manner that the actors become involved as co-authors

of volcanic risk-reduction guidelines for the eventual transformation into concrete interventions on the territory.

3. Producing, testing, and spreading methodologies aimed at reducing the vulnerability of the area by means of active involvements of local communities in a recovery of the local risk culture. This requires:
   a. Identifying key actors and their needs on the territory.
   b. Establishing encounters between local community leaders and experts for the purpose of analyzing the actual level of risk consciousness.
   c. Planning common actions aimed at increasing volcanic risk education in schools and among the adult public.
   d. Extracting historical information on the traditional protection from the volcano.

When actors use the territory only for their own interests, this acts in detriment to the general interests of the public. The political decision-makers should transfer the recommendations of experts into the instruments of government of the territory, but they have only a very brief useful life and it is an illusion to expect that they will accept with enthusiasm the limited recommendations of experts. Urban planners usually fail to assume that the politicians do not impose sacrifices on their electorate as objective data and tend to protect the territory and multiply restrictions. Experiences have shown that the territories which did not respect urban plans only fueled abusive urbanization, and that the restrictions and limitations of such plans produced additional vulnerability. The history of the Vesuvius area teaches that before the massive urbanization following World War II the volcanic risk was well-known and that this knowledge was employed to utilize the territory efficiently for building construction, manufacturing, agriculture, and recreation.[62]

In order to reduce the vulnerability of population it is necessary to involve the local decision-makers in the transformation of the territory and employ suitable urban plans that are capable of assuming an autoregulation of the territory. Urban-planning studies involving communities of 2000 and 7000 people have shown that the personal interests of local actors and exigencies of local communities need to be considered as objective data of the system to regulate and that these conditions induce an autoregulation. These studies need to be extended to large communities in the Vesuvius area. An effort aimed at reducing the vulnerability should, therefore, consider how to induce political decision-makers to make use of experts' results and transform these results to the lay public on the territory, and how to prepare urban plans which induce the behavior of various actors such that, pursuing their own personal interests, they determine modifications of the territory for the general benefit of the territory (cell 1 in Fig. 1.2). This effort should include participation of landowners, contractors, administrators, urban planners, professional engineers, and other groups, and be based on simulations of different eruption scenarios and their consequences, with and without modifications of the territory. A study pertaining to autoregulation should include a historical analysis in order to discover 'rules' (socio-economic, building practices, use of resources of the territory) that have guided past interactions of the community with the territory, an analysis of the existing urban-planning practices in order to define illegal construction practices and use of the environment, and an identification of those rules that are capable of favoring an autoregulation of the new habitat of Vesuvians.

1.8.4.3. Economics

A large-scale plinian eruption of Vesuvius can produce not only an unimaginable loss of life, but also an enormous economic burden for the nation that is ultimately responsible for post-eruption reconstruction. An effective risk analysis should, therefore, account for both the human and natural resources of the territory.[63]

The principal objective of a socio-economic study is to analyze the whole territorial settlement on the Campanian Plain for the purpose of providing detailed geographic data related to population dynamics, housing and real estate property, facilities, and public services. An analysis of population dynamics should include demographic studies of natural and migratory flows at the regional, municipal, and submunicipal levels, whereas a real estate property analysis should include private properties (number of rooms, crowding index, building periods, housing quality) and public buildings (offices, schools, hospitals, museums, military buildings, and historical, artistic, and archeological sites). These data should then be used to construct a synthetic index regarding the real density of each municipality and use destination of the territory which is split into rural, urban, protected, and facilities areas. A first-order analysis should provide the following information:

1. Physical conditions of facilities (roads, railways, harbor infrastructures, information and telecommunication structures) and public services (aqueducts, power systems, sewers, water purification plants, waste disposal systems).
2. Employment patterns associated with agricultural, manufacturing, industrial, and service sectors.
3. Scenarios of population dynamics, urban and industrial developments, environmental protection, recreation, and historical and archeological bonds.

Such an analysis can identify the natural and social capital in the Vesuvius area, assess socio-economic losses and impact on the territory caused by different eruption scenarios, identify and assess different hypotheses of management and intervention, and stimulate economic investments for the purpose of producing a safe and prosperous environment for Vesuvians.

These and other objectives dealing with economics can be achieved through exhaustive data evaluations pertaining to the demographic progress of the population, craftsmanship, industrial sector and productivity establishments, commerce, tourism, public infrastructures, and historical, archeological, buildings, and environmental patrimonies. Such data can be used to produce an economic map of the territory (both general and specific pertaining to the territory and local communities) that integrates different aspects of the analysis and identifies interdependent effects between multiple existing variables. This work should also be able to identify principal economic development areas which through econometric models should allow the determination of near- (up to about 50 years) and long-term economic tendencies of the Vesuvius area and vicinity. A subsequent phase of the economic analysis should involve studying the economic consequences on the territory associated with different eruption scenarios. The final phase of this analysis should be aimed at identifying the socio-economic cost of possible interventions on the territory in order to minimize economic, cultural, and social losses produced from future eruptions of Vesuvius. A viable economic analysis should produce guidelines that favor the construction of a sustainable habitat for Vesuvians.[64]

1.8.4.4. Education

Education is fundamental in producing a Vesuvius-conscious population and a security culture of tomorrow. This is one of the most important and urgent objectives of VESUVIUS 2000 and involves:

1. Establishing links between different educational groups operating on the territory for the purpose of exchanging information, eliminating duplication, and establishing collaboration.
2. Analyzing existing volcanic risk-educational methodologies in primary, intermediate, and secondary schools through seminars and group discussions.
3. Identifying effective volcanic risk-educational methodologies pertaining to different age groups of children and adults.
4. Identifying negative habits of mind (we called them 'cultures') and producing strategies aimed at overcoming barriers for adopting new habits that are conducive to the creation of a Vesuvius-conscious public.
5. Preparing educational material for school children and adults, and dissemination of this material on the territory.
6. Involving the public in co-authoring VESUVIUS 2000 volcanic risk-mitigation guidelines.
7. Training of educators and territorial administrators for diffusing correct information on the territory.
8. Establishing links between local, national, and international institutions (scientific, cultural, political).

Volcanic risk-educational activities in the schools can include teaching different age groups differently about Vesuvius and involving them in exploring the volcano through field trips, art, science, dramatizations, music, and exhibitions aimed at remembering the past eruptions. It is of fundamental importance that Vesuvius area schools work toward the creation of security-conscious citizens of tomorrow that nurture positive habits of mind. This is an effective way of breaking away from many current paradigms which are producing serious mental barriers. The secondary schools should adopt those volcanic risk-educational programs that aim at producing well-rounded individuals who can objectively evaluate the merits of different projects for the territory.[65] Lecturing to children and adults that they pertain to different colored risk area[66] and telling them that 'everything is under control' is not education and will never produce security of the people living under the shadow of Vesuvius.

1.8.5. Territory

The territory includes environment, energy and water supply, water and waste disposal, telecommunication, transportation, recreation, socio-economic and political policies of population management, civil protection volunteers, and so on. This systems study should employ a Geographical Information System for the purpose of integrating this information with eruption scenarios.

1.8.5.1. Urban and environmental systems

Urbanization is the most powerful and most visible anthropogenic force which invests the territory. The surface 'footprint' in the Vesuvius area consists predominantly of human habitats and concrete (or asphalt). These deprive supply of water, space to construct employment and service facilities, space for waste disposal, and land for cultivation of crops and enjoyment of recreational activities. Since the Vesuvian habitat of the future should be an essential source of opportunities for social and cultural advancement, it is essential that this be environmentally and socially sustainable. The urban plans that need to be developed must account for the needs of tomorrow. This is a grand challenge for engineers and urban systems planners. It is a challenge to understand the patterns of supply and use of energy, materials, products, information, and services. And it is a challenge to produce those plans that integrate an emotionally satisfying place to live with the effective use of human and natural resources, technology, and management system structures, with the public playing a central role in decision-making. All of these characteristics must interact synergistically in order to minimize future risks from eruptions and pollution from transportation systems and industry, improve livability, and endure sustainability.

These goals call for urban systems simulations involving land use utilization and transportation management that make up the Vesuvius area communities which interact with the rest of the territory and with the city of Naples, in particular. Such simulations can be based on a model of market theory that includes inputs, outputs, and utility and demand functions.[67] This model includes the use of land and transports, where the use of land and transports assumes a simultaneous relationship and the use of transports and land assumes a time-delayed relationship. Such a model belongs to the Lowry family of models and needs:

1. Adaptation and calibration for use in the Vesuvius area.
2. Simulations to assess the model's utility for reproducing present conditions on the territory.
3. Insertion and simulation of alternative socio-economic and urban systems scenarios based on different eruption scenarios.
4. Critical evaluation of different settlement scenarios using interdisciplinary data.
5. Development of game simulations for dissemination on the territory.

The future habitat of Vesuvians must be respectful of its environment even if the volcano is quiescent. The emissions of hazardous chemicals and greenhouse gases into the atmosphere, soil, and water must be limited and these limits must be enforced through the regional or national environmental protection agencies. These emissions should also enter into the QRA for the territory.

1.8.5.2. Civil protection

Civil protection volunteers are an important part of risk management, for in the event of an emergency they (through their knowledge of local population and its culture) can provide most of the aid at the beginning of a calamity. This situation occurred during the 1980 earthquakes and 1998 mudslides in Campania, because the central bureaucracy of *Protezione Civile* was inefficient in dealing with the unexpected calamities. For volunteers to be effective it is necessary to involve them in planning of emergency services and emergency needs. These needs are defined not only by an eruption, but also by the quantity and location of hazardous materials that could be uprooted by the eruption and distributed in land, water, and air systems. What use is emergency planning if it is being hidden from the public and not being available to the public and independent professionals for evaluation? The responsibility for such a planning resides with the regional government of Regione Campania whose best solution so far for Vesuvians is to chase them away with its project VESUVIA.[9]

1.8.5.3. Risk-assessment guidelines

The systems studies involving physical environment, population, and territory must be integrated through a quantitative and visceral risk-assessment methodology in order to produce the necessary volcanic risk-reduction guidelines for local communities, and national and European Union governments (Fig. 1.3). This is the end result of VESUVIUS 2000 feasibility study and the beginning of a process that should begin transforming the Vesuvius area and vicinity into a safe and prosperous community or communities. But this will not occur until the current communities around the volcano begin collaborating among themselves and with those capable of achieving the goals of the grand challenge. Most of this challenge is associated with education, engineering, urban-planning, and securing resources. We have the technology and human capital to meet this challenge, but lack a Vesuvius-conscious public which is capable to deal with its inept risk managers and their consultants.

1.9. CONCLUSION

A large-scale eruption of Vesuvius can produce a catastrophe in several minutes following the collapse of a volcanic column. Tens of thousands of people can perish and countless habitats, infrastructures, and cultural patrimonies can be wiped out. Today we have the technological means and management structures available to start working toward this encounter with Vesuvius, and significantly reduce the potential of such a human and socio-economic disaster that would become a serious problem not only for the nation but also for the European Union. Clearly, the responsible institutional leaders at the local, national, and European levels cannot allow for such a catastrophe to occur. But since no significant steps have been taken so far by these leaders to our calls for action, and since it is difficult to conclude that all of them are negligent, it is clear that the problem lies elsewhere: In the entrenched habits of mind which prevent these leaders to see how VESUVIUS 2000 attempts to combine danger and opportunities into volcanic risk awareness and minimization of adverse consequences from future eruptions. VESUVIUS 2000 does no harm, either to the scientific community or to the public. It accounts for the uncertainties inherent in eruption predictions, safeguards positive elements of social structures, prevents speculators from taking advantage of emergencies, and aims to produce a high quality of life through the efficient use of modern technology. VESUVIUS 2000 requires overcoming some difficult cultural, scientific, and social barriers, and it is an illusion to expect quick solutions.

Old habits change slowly and only new generations which grow up with new ideas may be ultimately capable of transforming VESUVIUS 2000 objectives into a new paradigm for Vesuvians. An activity of the volcano can speed up this process, but the population is polluted with too many adverse habits of mind that first need to be eradicated from the society. As long as the pursuit of power, volcanic risk ignorance, conformity, code of silence, and patronage are deeply rooted at all levels of the society (local, provincial, regional, national), the (mental) barriers are just too great in seeing that there is a great danger from Vesuvius, let alone becoming conscious that associated with this danger there are also tremendous opportunities to reorganize the territory for producing a much safer and prosperous habitat for Vesuvians. Both the local, national, and European Union administrators behave as if they do not understand how Vesuvius has helped build the Western Civilization and why it is necessary to safeguard this area and its treasures. It takes the volcano a couple of minutes to destroy hundreds of years of human labor and bury unique human experiences. And if this much is not realized at the beginning of the third millennium, then we should not be surprised by the serious consequences of inactions.

Every second hundreds of kilograms of magma accumulate below Mount Vesuvius and the population on its slopes may be already doomed. There may be no more time left to build safe and prosperous habitats nor the possibility to escape to promised lands. Like Plato's ideal that the direct knowledge of the real, the true, the good, and the beautiful is never attainable, but only the promised benefits of this ideal, the same destiny may await VESUVIUS 2000. But as long as Vesuvius area schools continue teaching Plato's ideals, I am hopeful that it is possible indeed to bring about a much greater awareness of the urgent need to confront the difficult predicament of Vesuvians. By realizing this much is an important beginning and may be just sufficient to vindicate the Voltaire's notion of civilization.

NOTES

1. In *Invisible Cities* Calvino (1986) provides an inspiration for the development of cities. In the book the empire of the Tartar emperor Kublai Khan is crumbling and to divert him the Venetian traveler Marco Polo recounts stories of the cities he has seen during his travels. He describes cities of memories, cities of dreams, thin cities and wide cities, trading cities, cities of desire, signs, and eyes, cities of names, and

hidden cities. It soon becomes clear to the emperor that each of these fantastic places is really the same place – his empire, but Khan sees no hope of getting out of the closing-in inferno around him.
2. To the ancient Greeks, the Pillars of Hercules – the name given to the twin rocks that we now know as the Straits of Gibraltar – represented the gateway from the known Mediterranean to the unknown beyond.

3. *Eruptions of Vesuvius*

Vesuvius was born inside the caldera of Monte Somma stratovolcano which is about 400 000 years old (Brocchini et al., 2001). The oldest products of Somma–Vesuvius date back some 25 000 years, during which time the volcano produced at least eight large-scale pumice-fall and pyroclastic-flow eruptions: Codola (about 25 000 years ago), Sarno (about 22 000 years ago), Basal (about 17 000 years ago), Greenish (about 15 000 years ago), Lagno Amendolare (about 11 000 years ago), Mercato-Ottaviano (about 8000 years ago), Avellino (about 3700 years ago), and Pompei (79 A.D.) (Delibrais et al., 1979; Arnò et al., 1987; Rolandi et al., 1993b, c; Nazzaro, 1997). Each of these eruptions discharged between 2 and 6 km^3 of material. Their deposits consist of ash and pumice falls from eruption clouds, pyroclastic surges and flows produced from partial or total collapses of volcanic columns, debris flows or *nuèe ardentes* produced from the rupture of volcanic edifice, and mud flows or *lahars* caused by the fall of wet ash from the condensation of water vapor in the plume. A summary of some of these and more recent eruptions stresses the seriousness of the destructive power of Vesuvius. For a summary of earthquake precursors to 79 and 1631 eruptions, see Chapter 4 (Marturano, 2006).

6000 B.C. Mercato-Ottaviano eruption

The Mercato-Ottaviano eruption occurred in the early pre-history some 8000 years ago and its products spread at least 70 km from the volcano. It is estimated that the eruption discharged about 2.5 km^3 of pyroclastic material in about 20 h, its column height rose to about 20 km, and its variable eruptive activity produced tephra (ash and pumice) falls and pyroclastic surges and flows that swept toward the north-northeast of the volcano or in the direction of Ottaviano.

1700 B.C. Avellino eruption

The Avellino eruption occurred in the Bronze Age, around 1700 B.C. Based on the eruption deposits it is estimated that the first hours of the cataclysm produced an eruptive cloud almost 40 km high. The dense ash and pumice fall buried dwellings and villages over a vast area along the direction of stratospheric winds that during the winter months blow from the southwest toward Avellino. The ash and pumice fall was felt in the mountains of Irpinia and the subsequent pyroclastic flows, surges, and *lahars* deposited thick layers of debris over an area of more than 400 km^2. These flows traveled more than 20 km from the volcano, and in Casoria, at the north of Naples, produced 5-m-thick deposits. During 20 h of activity almost 4 km^3 of volcanic debris was deposited on the surrounding countryside.

79 A.D. Pompei eruption

The catastrophic eruption of Vesuvius on 24 August 79 A.D. is vividly described by Pliny the Younger (Gaius Plinius Caecilius Secundus) in two letters to the Roman historian Cornelius Tacitus (Radice, 1963). The eruption was pre-announced by several earthquakes that were recorded in the area and date back to at least 37 A.D. (Chapter 4; Marturano, 2006). Several volcanological studies have been devoted to the deposits of this eruption, but the one of Sigurdsson et al. (1985) is of particular value because their interpretations correlate with the observations of Pliny. The Pompei eruption ejected between 3 and 4 km^3 of material which is distributed in an area of about 500 km^2 to the southeast where ash and pumice fell from the eruption cloud, and between southeast, south, and west where the impact of pyroclastic surges and flows was the greatest. People perished in Pompeii, Oplonti, and Herculaneum at different times. Pompeii was rained with ash, pumice, and lithics from one in the afternoon until approximately midnight of 24 August, during which time most of the roofs of buildings collapsed and those people who were escaping had to find their way in semi-darkness. Herculaneum, however, was not affected during this time, or experienced only a light ash fall, and most of its residents probably escaped toward Naples. But by the end of the day this changed, as the first surges and flows came down along the two valleys surrounding this town of Hercules and spilled on the marina in front of it. Here they found hundreds of people hiding in the arched chambers and engulfed them. Subsequent pyroclastic surges and flows devastated the town. Meanwhile, the first surge that hit Pompeii in the early morning hours of 25 August killed a surprising number of people (the remains of about 2000 people have been unearthed so far), probably because many returned during the tephra fall phase and before the initiation of the phreatomagmatic activity that produced very powerful surges and flows. The latter surges probably produced a great deal of anxiety in Stabia, 15 km away from the crater. But shortly after 8 a.m. on 25 August neither Stabia nor Herculaneum, nor even Miseno or the entire Bay of Naples, could have escaped the massive sixth pyroclastic surge and flow. And even Pliny, his mother, and people of Miseno 30 km away were running away from the deadly grips of this wave of doom (Radice, 1963, p. 172):

'Ashes were already falling, not as yet very thickly. I looked round: A dense black cloud was coming up behind us, spreading over the earth like a flood. ... darkness fell, not the dark of a moonless or cloudy night, but as if the lamp had been put out in a closed room. You could hear the shrieks of women, the wailing of infants, and the shouting of men ... A gleam of light returned then darkness came on once more and ashes began to fall again, this time in heavy showers ... At last the darkness thinned and dispersed into smoke or cloud; then there was genuine daylight, and the Sun actually shone out ... We were terrified to see everything changed, buried deep in ashes like snowdrifts ... the earthquakes went on ...'

Pliny does not tell us what happened afterwards, but the eruption deposits show the evidence of thick accretionary lapilli beds which can be associated with the phreatomagmatic activity and continuation of eruption for several hours. Four main phases of the eruption have been proposed (Barberi et al., 1989; Carey and Sigurdsson, 1987; Civetta et al., 1991): (1) a phreatomagmatic explosive opening phase, (2) a plinian phase which included a fallout-derived white and gray pumice, and interbedded pyroclastic surges; (3) a 'dry surge and flow' phase characterized by the collapse of volcanic column, and (4) a final 'wet surge and flow' phase of phreatomagmatic origin.

The Pompei eruption occurred during the reign of Roman emperor Titus (79–81 A.D.) who personally visited the devastated areas and was instrumental in providing aid to the survivors, as both Roman historians Suetonius (1979, p. 296) and Dio attest (Renna, 1992, pp. 56–57). But the territory devastated by the eruption returned to life only after the second and third centuries when the newly formed soil and underground water supplies began supporting life. Meanwhile, Pompeii, Herculaneum, and other towns buried by the volcano were largely forgotten until the seventeenth century as if the mighty Greco-Roman civilization never existed. Further details of Pliny's description of this eruption and the resurrection of Pompeii and Herculaneum are available in Chapter 2 (Dobran, 2006, Section 2.5.2 and Note 48).

472 Pollena eruption

When on 6 November 472, Vesuvius began 'boiling with intestinal fires that vomited its burning entrails and, while the dark gloom menaced the daylight, covered all of the land of Byzantium with ash' (Renna, 1992, p. 65) and an earthquake struck the Holy Land a day or two later, it was interpreted by many as the end of the world. The new Christian order saw the volcano as the underworld or the reign of the dead which is taking revenge on those alive. The details of 472 eruption come from the radiocarbon dating of eruption deposits (Arnò et al., 1987; Rosi et al., 1987; Mastrolorenzo et al., 2002). The eruption first produced a plinian column that deposited ash and pumice in the directions of Avellino and Benevento, or northeast in the direction of prevailing stratospheric winds of winter and spring. (The Pompei eruption occurred in August when the prevailing stratospheric winds blow from their spring–summer northwest to southeast direction, causing preferential tephra dispersal toward the southeast.) The maximum thickness of these deposits is about 2 m to the northwest of Ottaviano and less than 20 cm in Avellino, 35 km away. After the plinian phase, the volcano produced pyroclastic surges and flows that were directed along the valleys and in direction of Pollena, in particular, where the deposits are over 15 m thick. Flows from this Pollena eruption extend less than 10 km from the volcano and demonstrate an increasing magma–water interaction with time. This subplinian eruption discharged less than 0.3 km^3 of volcanic debris and was 10 times less powerful than the plinian eruption of 79 A.D. After 6 November the volcano most probably continued erupting with strombolian and effusive lava flow eruptions, since it was active in 512 (Renna, 1992, p. 65) and possibly in 536–537 (Alfano and Friedlaender, 1929). It is also possible that the cult of San Gennaro consolidated itself because of this eruption as the Neapolitan Christians were hiding in the catacombs (Nazzaro, 1997).

472 to 1631 eruptions

The eruptions of 685, 787, 1037, and 1139 are confirmed by several sources and are well documented in the archives of the time (Figliuolo and Marturano, 1997; Principe et al., 2004). The eruption of 685 occurred in March and according to chronicles produced explosions and ash fall that partly destroyed the surrounding countryside. The following eruption in 787 (October–November) produced both strombolian and lava flow activity with spectacular lava fountains. A lava flow invaded the territory to the west of the volcano and threatened and destroyed some inhabited towns. On 27 January 1037, Vesuvius produced a large cloud that spread toward the southeast. From its eccentric mouths lava flows poured for 2 weeks and reached all the way to the sea. The chronicles also recorded that the eruption lowered the summit of Vesuvius. The eruption on 29 (or 30) May 1139 was predominantly explosive and 'exceptionally large'. It began with lava fountains that lasted for 8 days and was followed with an eruption cloud that persisted for 22 days, spreading its ashes toward the southeast all the way to Calabria. Naples and Capua were also rained with ash and it appears that the strombolian activity continued beyond 1139. Giovanni Boccaccio (1313–1375), the Italian writer and poet, and author of *Decameron*, testifies that Vesuvius in his time was not emitting smoke nor fire.

Sometime after 1139 Vesuvius apparently entered into a long period of hibernation, similarly to what occurred after the subplinian eruption around 800 B.C. (Rolandi et al., 1998). It is possible that the eruptions of 685, 787, 1037, and 1139 were in effect the continuation of the subplinian eruption of 472, during which time the volcanic system was attempting to close its fractures and impede magma ascent toward the surface. Marturano and Scaramella (1997) opinion that the eruptions of 685, 1037, and 1039 were also subplinian, without providing sound justifications. Nevertheless, from the descriptions of these eruptions it does appear that the eruption of 1037 was significantly larger than those of 685, 768, and 1139, and that it may indeed qualify as a very significant event in the area. The eruption of 1139 may had been the final phase of this process which sealed the central conduit of the volcano. To reopen it would require centuries of magma supply into the volcano's magma reservoir, until enough pressure could be produced to initiate another cycle of activity. In the meantime, the volcano would give the surrounding population more than enough time to become complaisant, as the memory of catastrophic eruptions on the territory would be forgotten. This is what happened before 79 and 1631.

1631 eruption

The subplinian eruption of Vesuvius on 16 December 1631 is the most catastrophic event ever recorded in the area. It destroyed many surrounding towns and killed between 4000 and 10 000 people and affected thousands more as they fled from the calamity toward the nearby towns. The eruption produced ash and pumice fall, pyroclastic flows in the form of *nuèe ardentes*, extensive *lahars, tsunamis* in the Bay of Naples, and inundations on Campanian Plain. The 1631 eruption is well documented in the letters of Vatican clergy, abbots of monasteries such as Monte Casino, missives of bureaucrats and lawyers that reported the damages and litigations, chronicles from different locations around Vesuvius, travelers, scholars, paintings, engravings, and modern volcanological studies (Braccini, 1632; Carafa, 1632; Alfano and Friedlaender, 1929; Rolandi et al., 1993a; Rosi et al., 1993; Marturano and Scaramella, 1997).

Before 16 December 1631 Vesuvius is described as an innocuous mountain covered with trees and very small fumaroles silently releasing the gas on the inside of its funnel-like crater. The precursors or signs for this eruption are poorly defined since they lack independent confirmations. Alfano and Friedlaender (1929) report that Campania experienced earthquakes in July 1564, 31 December 1568, 5 June 1575, May 1582, and all of 1594. Mercalli (1883) explains that 'from July to December [1631] many earthquakes agitated from time to time the surrounding area. During the first half of December the tremors became more frequent and were accompanied by underground rattling and howling'. Braccini (1632) also notes that from the 10th of December the mountain roared and the inhabitants of Massa di Somma, Pollena Trocchia, and San Sebastiano al Vesuvio had difficulties sleeping from the noise, water from the wells became murky and in short supply, crater filled with material to its rim 2 weeks before the eruption, and that a herder of cows saw at the base of the mountain 'earth cleave in two places, and smoke and fire issue from the openings'.

The eruption thus began near the base at the western side of the cone of Vesuvius on 16 December around 7 a.m. It rapidly produced a plinian cloud which expanded high into the atmosphere and spread principally toward the east. Ash and pumice fall reached Taranto (250 km away) in 6 h and more distant places, possibly even Constantinople (Rosi et al., 1993). The plinian-type column lasted for about 10 h before turning into explosions which produced strombolian and lava fountaining activity at the summit. In the morning of 17 December the rain produced flooding of the northern Campanian Plain. Violent earthquakes during the night of 16 and 17 of December caused the decapitation of the cone of Vesuvius and produced *nuèe ardentes* (or debris flows from the breakup of the cone) which rapidly reached the sea. The towns completely destroyed were Torre del Greco, Resina, Portici, Boscoreale, Torre Annunziata, San Giovanni a Teduccio, Ottaviano, and San Giorgio. Somma, Nola, Sarno, San Anastasia, Palma, S. Maria Pugliano, and Pietra Bianca (modern Pietrarsa) were only partially destroyed (Tortora, 1997). During the following days the ash and rain from the volcanic cloud and ash on the ground produced more flooding and *lahars* all around the volcano, causing additional damage. At least 40 000 people sought refuge in Naples and many thousands in other less-afflicted towns. A *tsunami* caused damage in the Bay of Naples as its 2–5 m high return wave slammed onto the shore. Sarno and Nola, which are more than 15 km away, were under several meters of ash and mud. More than 4000 people perished from pyroclastic flows, *nuèe ardentes*, and *lahars*, while hundreds more died or were severely injured after the eruption because of building collapses caused by ash and mud, or because they imprudently attempted to walk over the hot volcanic debris. An unknown number of people perished from asphyxiation by inhaling volcanic ash. Many dismembered corpses found in the debris and those who escaped death by hiding in buildings also attest that the flows descending from the mountain toward the sea on 17 December were mostly *nuèe ardents*. They were directed along the valleys of the volcano and flowed around obstacles, such as garden walls, churches, and sturdy buildings. 'Those who escaped right away saved themselves, and those who didn't perished from the ash and flames' (cited from chronicles in Tortora, 1997). Several days later the volcanic activity subsided, but the volcano continued spitting ash, causing more *lahars* and destruction of the territory. Small earthquakes, strombolian activity, and *lahars* continued into the following years.

To protect themselves from the roaring volcano people sought safety in churches where they gave confessions and prayed for salvation. Many from Torre Annunziata escaped to Stabia and those from Torre del Greco, Ercolano and Portici escaped to Naples. Naples was also affected by the ash and pumice, and the obscurity caused the local clergy to organize processions and calling for the liquefaction of blood of San Gennaro as a sign to end the calamity. The calamity caused open public confessions and display of public penitence with all sorts of instruments, as well as the consummation of carnal sins. The eyewitnesses of the catastrophe describe horrible scenes of mutilated bodies found in the debris and many displaced individuals who wandered aimlessly all over the ravaged area. This caused the viceroy of Naples to send rescue ships into the area and exempt the towns from paying taxes for several years; the towns partially destroyed were exempted for only 5 years. The calamity also produced economic and social tensions in Naples, leading to a riot in 1647 (Marciano and Casale, 1994).

The eruption of 1631 filled substantially the Atrium (*Atrio del Cavallo*) with new material, and as early as 1632 Carafa (1632) reported that the cone of Vesuvius was lowered by 471 m and that its new crater rim has a diameter of 1656 m. A chronicle reported that the mouth of Vesuvius had a 'great theater' on 17 December, which substantiates the fact that the eruption caused the destruction of the cone by several hundred meters and that it produced a large crater. Pyroclastic deposits of 1631 eruption confirm the existence of a plinian opening phase which deposited tephra principally on the eastern sector of the volcano. The maximum thickness of this deposit is about 1 m at Monte Somma and 10 cm 20 km away. The fine tephra erupted on 16 December. The coarse tephra fell during the night of 16 December and the following day, when the activity of the volcano shifted from plinian to explosive. After the *nuèe ardentes* in the morning of 17 December that destroyed many coastal towns, a new ash/surge/lahar eruptive phase followed and left thick deposits along some of the valleys (4 m of ash and 5 m of *lahar* at Villa Inglese in Torre del Greco, 8 m of ash and 2 m of *lahar* at Pozzelle quarry in Boscoreale, 1 m of ash and 3 m of *lahar* at S. Leonardo on the northeast of the volcano) (Rosi et al., 1993). A 30-cm-thick surge deposit overlies the tephra fall layer in Lagno Amendolare quarry (Somma Vesuviana) (Rolandi et al., 1993a). This phase occurred from a violent interaction of magma with underground water, causing the decapitation of the cone. The volcano may have erupted as much as 1 km^3 of material (Rolandi et al., 1993a).

1631 to 1944 eruptions

Following the catastrophe of 1631 Vesuvius continued with 'open-conduit' eruptions which were considerably less powerful than those of 79, 472, or 1631. These eruptions produced lava flows, lava fountains, and strombolian explosions from the summit crater (terminal or summit eruptions), along the fractures of Gran Cone (lateral eruptions), or from the fractures of Somma below its caldera rim (eccentric eruptions). By being protected on the north by Monte Somma relief, Vesuvius' lava flows were confined within Valle del Gigante and along the western, southern, and, eastern slopes of Monte Somma. These flows invaded most of the towns on the side of Bay of Naples: S. Sebastiano al Vesuvio, Massa di Somma, San Giorgio a Cremano, Portici, Ercolano, Torre del Greco, Torre Annunziata, Boscotrecase, Boscoreale, and Terzigno. Tephra products from the strombolian activity of these eruptions affected, however, all of the territory surrounding the volcano and many distant places such as Nola on the north, Sarno on the east, Gragnano and Castellammare di Stabia on the southeast, and Naples on the west. The eruptions between 1632 and 1944 built and destroyed the Gran Cone several times, and some of them were rather devastating to the territory, like the eruption of 1794 whose lava flow inundated Torre del Greco and reached the sea, and the eruption of 1906 which produced *lahars* on the east and north of Vesuvius and caused considerable damage to the cultivated lands. A more complete summary of the eruptions between 1631 and 1944 is provided in Nazzaro (1997). The older works are also largely consistent with this compilation.

1944 eruption

The activity that began in 1913 culminated with the eruption of 1944. This activity gradually increased by building a cone inside the crater of 1906 eruption until this filled with lava and scoriae. As early as 1940 lava began overflowing the crater rim and by February 1944 the Gran Cone had a height of 1260 m, and on 18 March the volcano announced its reawakening with explosions and formation of an eruption column (Nazzaro, 1997). The eruptive phases of this eruption were devised by Imbò (1949) who at that time directed *Osservatorio Vesuviano*.

Phase I: Effusive Phase, 18–21 March

The eruption started at 4:30 p.m. on 18 March with a strong increase of strombolian activity and lava overflowing the crater rim toward the east, north, and south. On 21 March one of the flows invaded Massa di Somma and San Sebastiano al Vesuvio. The lava flows ceased on 22 March as the eruptive style of Vesuvius changed a day earlier, from effusive to explosive.

As early as 18 and 19 March Imbò began alerting the administrative authorities of the territory of the possible danger of lava flows to Massa di Somma and San Sebastiano al Vesuvio. On 20 March the Allied Military Government (AMG) of occupation forces evacuated about 15 000 people from San Sebastiano al Vesuvio, before the lava flows invaded this town in the early hours of 21 March. Mayor Cantor of AMG in Naples also considered the evacuation of Portici, Ercolano, Torre del Greco, and Torre Annunziata if the situation worsened. At the time there were about 250 000 people exposed to the hazard and 'the Anglo-American organization was rapid and efficient to confront the emergency and the Allies did nothing less than what they would have done in their own homes if confronted with a similar calamity' (Pesce and Rolandi, 1994, p. 66).

Phase II: Lava Fountaining Phase, 21–22 March

At about 5 p.m. on 21 March Vesuvius began producing lava fountains which ended the effusion of lava. This violent activity ejected lava bombs to great heights and distributed the pyroclastic material toward the southeast. The ash from the eruption column was dispersed over 200 km toward the east and southeast, and 5–10 lava fountains intermittently reached heights up to 4 km. This phase of the eruption also covered the Allied Base in Terzigno under 1 m of scoriae and lapilli, and caused a great deal of damage to many B25 bombers (Pesce and Rolandi, 1994; Nazzaro, 1997). The Allies were clearly unprepared for the effects of Vesuvius on their war machinery.

Phase III: Mixed Explosions Phase, 22–23 March

Shortly after midnight on 22 March the eruptive style changed again with the discharge of darker ash and bombs and fall of lapilli. In addition to juvenile or magma the erupted material also consisted of rocks from the volcanic edifice. The ash cloud rose over 5 km and partial column collapses produced small pyroclastic flows and *nuèes ardentes* along the slopes of the volcano. Imbò reports that the seismic activity on 22 March was so intense that it was extremely difficult to walk inside the observatory. At about 6 p.m. on the same day the volcano became quiet and only 3 h later began with a renewed activity that produced 'majestic cypresses or peaks of fantastic domes' (Nazzaro, 1997, p. 210). Throughout the night the eruption cloud displayed fantastic lighting flashes and in the morning of 24 March began violent earthquakes. The wind directed the eruption products toward the southeast and damaged Terzigno, Pompei, Scafati, and other towns.

Phase IV: Seismo-Explosive Phase, 23–30 March

Violent earthquakes in the morning of 23 March pre-announced a new eruptive phase which has been interpreted as due to the 'partial obstruction of the magmatic conduit'. This phase is characterized by discontinuous launches of incandescent material, *nuèes ardentes*, electrical discharges, and large columns of smoke and ash that transported the pyroclastic material as far as Bari and Brindisi. The eruption products damaged Torre Annunziata, Castellammare di Stabia, Pompei, Poggiomarino, Terzigno, Ottaviano, and other towns along the direction of tephra dispersal. On 24 March the volcano ejected fine and white ash that whitened the Gran Cone. On 25 March a strong wind from north-northeast prevented the volcanic cloud to rise and this blanketed the towns to the southeast with a thick rain of ash. By 30 March the eruption was essentially over and produced a 300-m-deep chasm and a crater with diameter of about 1 km. Subsequent landslides in the crater apparently sealed the conduit, and from 7 April 1944 Vesuvius has stopped showing its external activity. Only low-level seismicity and fumarole activity have been occuring since, except for a notable earthquake on 9 October 1999 (Marturano, 2006).

The eruption of 1944 did not affect Naples because the wind directed the erupted material toward the southeast. In some places along the direction of debris dispersal the pyroclastic deposits reached 1 m in thickness and caused total losses of crops. The AMG provided food, medicine, and even agricultural experts to the population. Bulldozers, scrapers, and trucks were used to remove the volcanic debris from streets and roads, and in one day most of the communication routes were cleared.

Food was even trucked to feed the animals and the population did not exhibit panic during or after the eruption (Pesce and Rolandi, 1994). In spite of these efforts, 47 people were killed and carbon dioxide was emitted from the ground in Portici, Ercolano, Torre del Greco, and Torre Annunziata until the end of 1944.

The eruption of Vesuvius in 1944 produced about 30 and 70 million m^3 of lava and pyroclastic products, respectively (Imbò, 1949). It also left a crater of about one-third of the size of the 1906 eruption. This crater is currently about 150 m deep and some very faint fumaroles within it attest that the volcano is indeed alive. The eruption of 1944 occurred from the summit of Vesuvius, as opposed from the lateral or eccentric mouths located along the fractures of Gran Cone or Satura of 1631. This was also observed by Imbò, but is probably not the determining factor why the volcano has remained silent for over 50 years. The eruption started with lava flows, continued with lava fountains, and terminated with eruption columns and fall of fine white ash. This may be explained as follows. The eruption of lava at the beginning of the eruption suggests that magma inside the volcano and close to the surface lost most of its gas before it erupted, for otherwise it would have produced explosions from magma fragmentation and not lava effusions. Loss of gas from magma occurs within the internal fractures of the volcano when magma is subjected to low pressures close to the surface. Magma at greater depths is subjected to higher pressures which dissolve greater quantities of gas and tends to fragment when it rapidly ascends toward the surface. The initial lava flows of the 1944 eruption were, therefore, produced by the ejection of gas-poor magma from the superficial regions of the volcano.

The eruption of 1944 can thus be summarized as follows: (1) effusion of superficial gas-poor magma produced lava flows (Phase I), (2) ascent of gas-rich magma produced lava fountains (Phase II), (3) collapse and enlargement of conduit wall(s) caused the ejection of lithics with magma and termination of lava fountains (Phase III), and (4) intermittent opening and closing of water pathways produced by the ascending magma caused further conduit wall erosion and intermittent explosions (Phase IV). The last phase (seismo-explosive) persisted until the magma supply was exhausted. The eruption of fine white ash near the end of the eruption suggests that the efficiency of magma–water interaction increased with time, as less and less magma became available to interact with water or less and less water became available to interact with magma. Further studies are obviously required to quantify the described eruption scenarios and whether the eruption of 1944 'tightly' sealed the volcanic conduit. If this is the situation, as recent geophysical studies suggest (Note 54), it will most likely require the accumulation of a large quantity of magma within the volcano to reopen the conduit(s) and thus cause another plinian or subplinian eruption cycle.

4. Dobran et al. (1994) and Dobran (1994b, 1995b) performed computer simulations of the propagation of pyroclastic flows along the slopes of Vesuvius following the collapse of subplinian and plinian eruption columns. The results from these studies demonstrate that at about 20 s after the beginning of a large-scale plinian eruption of gray magma the volcanic column reaches a height of about 3 km above the vent and then collapses by spreading radially propagating pyroclastic flow. At

60 s this flow reaches a distance of about 2 km from the vent, at 120 s it reaches 4 km, and at 5 min the flow enters the Tyrrhenian Sea at 7 km from the crater. Even the 1300-m-high Monte Somma relief to the north of Gran Cone cannot stop this flow. The pyroclastic flows from subplinian eruptions can also cross Monte Somma, while the flows from smaller eruptions cannot and reach the sea in about 16 min.The results from these simulations are consistent with eruption deposits around the volcano and from 79 and 1631 chronicles (Nazzaro, 1997).

5. VESUVIUS 2000 (1995) was prepared during 1994 and 1995 and submitted for a support to European Union's Division of Environment and Climate in April 1995. The participants on VESUVIUS 2000 involved 50 scientists from Global Volcanic and Environmental Systems Simulation (GVES), University of Naples Federico II, University of Trieste, University of Perugia, University of Salerno, University of Lancaster, University of Grenoble Joseph Fourier, National Polytechnic Institute of Grenoble, University of Genoa, Association for Geology and Environment, Geopolitical Institute 'F. Campagna', Young Volunteer Services, University of Paris V, Geaprogram, European Center for Cultural Studies, and New York University. For a summary of this work plan see Dobran and Luongo (1995) and GVES (1998). VESUVIUS 2000 was scheduled to be completed in 2000.

6. On 25 September 1995 the undersecretary of Italian Civil Protection Franco Barberi promoted within the media his Vesuvius Evacuation Plan (Protezione Civile, 1995). According to *Protezione Civile*'s document number 247 of 1 February 1996, the architects of this plan include the geologists F. Barberi, P. Gasparini, L. Civetta, L. Lirer, M. D'Ascia, R. Santacroce, A. Cherubini, E. Giangreco, M. Martini, M. Rosi, G. Orsi, and T. Pareschi.

7. The issues involved in predicting the eruption of Mt. St. Helens in 1980 are reported by Swanson et al. (1983). This volcano has the composition of magma which is similar to that of Vesuvius (Papale and Dobran, 1993, 1994). Both of these volcanoes are explosive and produce high rising volcanic columns which can collapse and produce ground-hugging and deadly pyroclastic flows.

8. The eruption of Mt. Pinatubo in The Philippines is reported in Pinatubo (1999). The eruption of Mount Ruapehu in New Zealand in 1996 set plumes of ash and steam 16 km high into the atmosphere only 6 days after the scientists declared that its volcanic activity had subsided (NYT, 1996). In 1993 six volcanologists studying the Galeras Volcano in Colombia lost their lives when the volcano exploded with lava, ash, and incandescent boulders (Fisher et al., 1997). In 1995 a small volcanic island of Montserrat in Central America began to come alive and most of 11 000 residents of the capital city of Plymouth were evacuated to the northern part of the island, as far as possible from the volcano. Some choose, however, to stay and, unexpectedly, on 25 June 1997, 19 people were killed (NYT, 1997). This eruption occurred without warning and the British Governor was debating whether to evacuate everybody from the island that was once considered a paradise of the Caribbean.

Volcanologists base eruption forecasts on the information or data from eruption history and volcano monitoring (deposits, seismicity, deformation of the volcanic cone, gas emissions, hydrological regimes, and magnetic, electric, and gravity fields) (Wright and Pierson, 1992). A change of the seismicity or earthquake activity of a volcano can be associated with the rearrangement or rise of the molten rock material within the system. This kind of activity fractures rocks and produces earth motions which can be detected by delicate instruments on or within the Earth. Seismicity does not, of course, always lead to the conclusion that a volcano has become restless, because seismic signals can also be produced by the tectonic motions of the region where the volcano is situated and may have nothing to do with the volcano itself. Nevertheless, a volcano in the process of erupting produces seismic signals that are sufficiently representative of an 'eruption in progress' and can serve as precursory signals that some sort of external activity will take place. Similarly, ground movements are good indications that the volcano is preparing for an eruption, especially when these movements become large in comparison to the background noise or instrument errors. Changes in electrical conductivity and magnetic and gravity fields can trace molten rock movements inside a volcano and may be detected even when a volcano is not erupting. Changes of the chemical composition of the emitted gas from fractures may be related to the rearrangement of the molten rock within the volcano or gas escape routes through the fractured medium. Moreover, changes of groundwater temperature, water levels in wells or lakes, snow and ice accumulation, and concentration of sediments in the streams around the volcano are also useful signals for judging the state of a volcano. In the case of 18 May 1980 Mt. St. Helens eruption 'the abrupt onset of deep earthquakes and ground deformation' on 17 May caused the scientists to issue the eruption forecast (Swanson et al., 1983). The eruption of Pinatubo in 1991 was forecasted two days before, based on 'intense unrest, including harmonic tremor and/or many low frequency earthquakes' (Pinatubo, 1999).

9. The government of *Regione Campania* is headed by the former mayor of Naples Antonio Bassolino and promoting VESUVIA (2004), with Franco Barberi, Paolo Gasparini, and Giovanni Macedonio as technical consultants. This government is politically tied to the proponents of Vesuvius Evacuation Plan and as such VESUVIA attempts to save this plan from total failure. VESUVIA ('away from Vesuvius') promises to provide 300 million euros to 10 000 families who are willing to leave the Vesuvius area, but it does not addresses the issues of what happens to the dwellings left behind by these families and how to deal with the rest of 500 000 or so Vesuvians. The principal objective of VESUVIA is patronage, which produces votes and privileged positions in state institutions for its proponents and supporters. This kind of activity is regularly practiced on the territory in order to win elections (Di Donna, 1984). As of December 2005, *Regione Campania* terminated financing VESUVIA.

10. History of Naples and surroundings is described in Gleijeses (1990) and Sullivan et al. (1994). A history of modern Italy is presented in Clark (1996) and summarized in Chapter 2 (Dobran, 2006; Note 6). Additional historical notes are provided in Note 48 of the same chapter.

11. There are numerous articles and books on the Italian *mafia* and Neapolitan *camora*. See, for example, Falcone (1991) and Violante (1997). For the illegal business of *camora*, see Di Riccardo (1995).

12. The demographic data are published by *Istituto Centrale di Statistica* (ISTAT, 1991, 2001) and are regularly updated at www.demo.istat.it. Geographic and

demographic studies can be found in Il Libro (1987), Santoro (1992), Di Donna (1998, 2006), among others.

13. The 18 communities surrounding Vesuvius are Boscoreale, Boscotrecase, Trecase, Pompei, Torre Annunziata, Torre del Greco, Ercolano, Portici, San Giorgo a Cremano, San Sebastiano al Vesuvio, Massa di Somma, Cercola, Pollena Trocchia, San Anastasia, Somma Vesuviana, Ottaviano, San Giuseppe Vesuviano, and Terzigno.

14. Results from the first volcanic risk survey in the Vesuvius area are presented in Dobran and Sorrentino (1998). About half of 3000 people surveyed are primary, intermediate, and secondary school children. The remaining half are adults with about one-third of them being schoolteachers. The people surveyed are from Ercolano, Portici, San Giorgio a Cremano, Torre del Greco, and Castellammare di Stabia.

15. Pucci (1998) provided me with some of these observations.

16. Limocia (2004) lists several regional plans that have been put forward recently to stimulate the territorial development, but no feasibility studies are available for these plans nor the lay public is being involved in their development. Such initiatives are often put forward on the territory, but they have little meaning beyond their intended use for patronage activities.

17. Voltaire (1966).

18. I gave seminars at the University of Naples on 5 May 1997 and 2 and 3 April 1998 on both the evacuation plan and VESUVIUS 2000 in order to provoke critical discussions. Only few academics attended the seminars and the students lacked both the knowledge and interest in the issues.

19. The former and present directors of *Osservatorio Vesuviano*, Lucia Civetta and Giovanni Macedonio, respectively, are close allies of Franco Barberi and Paolo Gasparini, the principal architects of Vesuvius Evacuation Plan.

20. On 23 and 24 November 1980 the earthquake in Campania and Basilicata produced 2735 deaths and 8850 wounded, and the state set aside more than 50 million euros for reconstruction aid. Ten years later there were still 28 572 victims of earthquakes living in pre-fabricated houses or containers while the largest part of relief went to the local mafia or *camora* organizations (Violante, 1994, p. 356).

21. May (1998).

22. See, for example, *Per noi fa testo solo l'Osservatorio* (for us only the observatory counts). *24 Ore*, 28 January 2003.

23. Franco Tonani from University of Palermo has for many years criticized *Gruppo Nazionale per la Vulcanologia*'s (GNV) policies. Based on GNV documents Tonani argues (Letters of 13 April 1997; 6 October 1998) that its leaders are projecting a false image of its mission and capabilities in front of the Italian functionaries and politicians, because they falsely claim that GNV includes the most competent scientists, that the government must listen only to this group, and that this group requires no supervision of its activities. Such a view was also expressed by Giuseppe Luongo (*Il Giornale del Sud*, 5 May 1998), a former director of *Osservatorio Vesuviano*.

24. The following is an incomplete list of such reports: Mt Vesuvius eruption could disrupt 1 million lives, *Associated Press*, 9 February 1994; Hawkes, N., Vesuvius

threatens a million, *The Times*, 10 February 1994; Vesuvius study, *Chicago Sun Times*, 10 February 1994; La minaccia del Vesuvio, *America Oggi*, 10 February 1994; Sheridan, M.F., From models to reality, *Nature* 367, 10 February 1994; Bianucci, P., Vesuvio, prove di un'Apocalisse, *La Stampa*, 11 February 1994; Greco, P., Il Vesuvio: dalla cenere alla cenere, *L'Unità*, 11 February 1994; Perils of Mount Vesuvius, *Rocky Mountains News*, 11 February 1994; Il computer prevede e tiene d'occhio gli improvvisi capricci del Vesuvio, *Il Giorno*, 11 February 1994; Simulati gli effetti di una eruzione del Vesuvio nel computer, *Il Tirreno*, 13 February 1994; Erforscht und erf unden, *Die Zeit*, 4 March 1994; Schultz, E., Asche aufs Haupt, *Bild der Wissenschaft*, May 1994, 108–109; Alda, A., Scientific American Frontiers, *Public Television Station*, July 1994; Manacorda, E., E in un quarto d'ora Napoli non c'è più, *L'Espresso*, 7 October 1994; Beekman, G., Als de reus ontwaakt, 1, *Wetenschap Techniek*, April 1994, 39; Dobran, F., Cronaca di un'eruzione annunciata, *Sapere*, November 1994; Prattico, F., Pompei duemila, *La Repubblica*, 21 January 1995; Ravizza, V., Sul rischio Vesuvio: scontro di vulcanologi, *La Stampa*, 15 February 1995; Koppeschaar, C., Onbetrouwbare Heethoofden, *Kijk*, March 1995, 5–9; Falanga, C., Attenti al mito! Il Vulcano esiste, *Il Giornale di Napoli*, 30 June 1995; Vesuvio, pensiamoci adesso, *Il Mattino*, 1 July 1995; Una 'fiction' per l'allarme Vesuvio, *Il Giornale di Napoli*, 9 July 1995; Avvisati, C., Il grande sonno, *Il Giornale di Napoli*, 22 August 1995; Di Casola, M.T., Attracco nei porti dove la lava fumò, *Il Giornale di Napoli*, 25 August 1995; Mancusi, F., Sulla rotta di Plinio il Vecchio, *Il Mattino*, 25 August 1995; Bocciato il Piano Vesuvio: Attenti alla deportazione, *Il Giornale di Napoli*, 5 October 1995; Born, M., Appointment with Vesuvius, *The European*, 5 October 1996; Masood, E., Row erupts over evacuation plans for Mount Vesuvius, *Nature*, 12 October 1995; Ravizza, V., Se esplode il Vesuvio: Il piano di emergenza e i suoi contestatori, *La Stampa*, 17 October 1995; Andreossi, R., VESUVIUS 2000, *La Torre*, 24 October 1995; Peccato, tanti milioni sprecati, *Il Tempo*, 29 November 1995; Russo, A., Il piano di evacuazione è tutto da rifare, *Napoli Notte*, 17 December 1995; Dobran, F., VESUVIUS 2000: Un progetto per la prevenzione della catastrofe, *Osservatore Romano*, 25 January 1996; Sotto il vulcano senza paura: Ma non tutti sono d'accordo, *Scienza e Vita*, April 1997; Vesuvio: Il piano va rifatto, *Corriere della Sera*, 5 October 1997; Ravizza, V., Vesuvio, la paura rimossa, *La Stampa*, 15 October 1997; Vesuvio e sicurezza: Via a cinque seminari per educare al rischio, *Il Mattino*, 20 November 1997; Allarme Vesuvio: L'analisi del professor Flavio Dobran, *Roma*, 29 November 1997; Vesuvio, un piano inaffidabile, *Metropolis*, 7 January 1998; Vesuvius, *Canadian Broadcasting Corporation*, 1998; The Planets Time Bombs, *Discovery Channel*, March 1998; Malafronte, S., Vesuvio, quel piano inefficace, *Metropolis*, 8 April 1998; Gallo, M., Allarme inglese: Il Vesuvio può esplodere, *Corriere del Mezzogiorno*, 14 April 1998; Laudisi, A., Dagli inglesi l'ultima sul Vesuvio, *Il Mattino*, 14 April 1998; Dobran, F., Vesuvius 2000, *Il Giornale del Sud*, 18 April 1998; Pocobelli, G., Dobran: quel piano è tutto da rifare, *Il Giornale del Sud*, 18 April 1998; Dobran F., C'è pure un rischio Barberi, *Il Giornale del Sud*, 5 May 1998; Luongo, G., Più infido del Vesuvio è il Piano, *Il Giornale del Sud*, 5 May 1998; Dobran, F., E se fosse esploso il Vesuvio?, *Il Giornale del Sud*, 8 May 1998;

Dobran, F., Il Vesuvio più sottovalutato delle frane, *Il Giornale del Sud*, 12 May 1998; Dobran, F., Poveri Vesuviani, *Metropolis*, 13 May 1998; Dobran, F., Quei misteri di Barberi sul 'rischio Vesuvio', *Il Giornale di Napoli*, 19 May 1998; Dobran, F., Educare i Vesuviani ad autogestire il rischio vulcanico, *Il Giornale del Sud*, 21 May 1998; Dobran, F., Segreti sul Piano evacuazione, *Il Giornale di Napoli*, 25 May 1998; Dobran, F., Il piano Vesuvio: perde la logica, *Roma*, 3 June 1998; Dobran, F., Perché non insospettirono boati e strani fenomeni premonitori delle frane?, *Il Giornale del Sud*, 3 June 1998; Sanderson, W., Is Naples ready for Vesuvius?, *Stars and Stripes*, 22 November 1998; Dobran, F., Vesuvio: sarà una strage annunciata, *Il Giornale di Napoli*, 7 December 1998; Matthews, R.A.J., The Vesuvius Dilema, *Sunday Telegraph*, 12 April 1998; Longobardi, A., Non vi fidate del piano di evacuazione, *Metropolis*, 5 January 2000; SOS eruzione, 1 September 2000; Russo, E., IL VESUVIO: Esplosione catastrofica a momenti, *Roma*, 2 September 2000; Sorrentino, S., I sogni son desideri ..., *Torrese*, 15 November 2002; Sorrentino, S., Vesuvius 2000: Vulcanologi al confronto, *Torrese*, 10 January 2003; *Teletorre*, January 2004; Rischio-Vesuvio esperti a convegno, *Il Mattino*, 21 January 2004; Di Donna, G., Dobran: Il Vesuvo da 'calcolare'; *Ephemerides*, 6 February 2004; Dortucci, A., Barriere contro la lava, *Metropolis*, 21 January 2004; *Discovery Channel*, www.discoverynews.com, 7 May 2004; Vesuvio: Esperti a confronto, *Il Mattino*, 31 August 2004; Vesuvio: Avremo tre giorni per scappare, *Metropolis*, 3 September 2004; Minghelli, D., Polveriera Vesuvio: Gli abitanti sono troppi, *Napoli Più*, 3 September 2004; *Radio Televisione Italiana*, 3 September 2004.

25. Margolis (1996).
26. Kasperson and Stallen (1991, p. 133).
27. Margolis (1987, pp. 9–24).
28. In the late 1980s and early 1990s I attempted to convince the Italian geological and geophysical communities to collaborate on the development of Global Volcanic Simulator for Vesuvius (Dobran, 1993, 1994a, b). After demonstrating that many volcanic processes can be accurately modeled and that the development of the simulator progresses rapidly (Dobran, 1992, 1995a; Dobran and Papale, 1993; Dobran et al., 1993, 1994; Papale and Dobran, 1993, 1994; Giordano and Dobran, 1994; Macedonio et al., 1994; Neri and Dobran, 1994; Coniglio and Dobran, 1995; Dobran and Coniglio, 1996), this collaboration was abruptly terminated by the autocrats of these communities. In part this is because of different backgrounds of naturalists and engineers and from the mistrust which, after an initial enthusiasm, many scientists show for disciplines unknown to them. Another reason is that the development of the simulator requires reliable geological and geophysical data which these communities cannot produce and feel threatened by the prospect of failure.
29. Thomas Kuhn in his famous book on the Structure of Scientific Revolutions identifies a 'paradigm' as an achievement that attracts an enduring group of adherents away from competing modes of activity and being sufficiently open-ended leaves problems for the redefined group of practitioners to resolve (Kuhn, 1996, p. 10). A 'paradigm shift' can produce a revolutionary change in the methods that a group uses as its tools of trade (Kuhn, 1996, p. 92). The new tradition that emerges from the old one is not only incompatible but often 'incommensurable' with the old

one (Kuhn, 1996, p. 103). Incommensurability is a blindness or a 'barrier' to seeing what the other side is saying.
30. The Copernican discovery, namely that the Sun (heliocentric), not the Earth (geocentric), is at the center was difficult to accept, because the Ptolemaic (geocentric) system had deep entrenched sense that this science yields insights into the nature of the world in spite of some oddities in this system that could not be explained. For Ptolemaic Renaissance astronomers this system was enormously successful. After all, the calendar showed an error of only 18 h a century and changing the 300-year-old astronomical tables was not an enterprise taken lightly in the sixteenth century. And rebuilding astronomy on radically different theory and retraining so many familiar with the knowledge of the old system was not being viewed as plausible. For more on this, see Margolis (1993).
31. Darwin (1996) was convinced of gradual transformation of species after sailing on the Beagle for 3 years around the world and studying Lyell's geology (Lyell, 1997) of uniformitarianism. The principle of uniformitarianism assumes that Earth in the past had been subjected to the same natural laws as it is subjected at the present. How the evolution took place was, however, more difficult to explain and required confidence in proposing that it follows natural selection. For this confidence Darwin not only had his scientific bible of Lyell's geology, but also those of Newton (1974) and Smith (1976). He wrote the first version of 20 pages in 1844 and by the time he published his grand scheme he worked on his theory for over 20 years by trying to answer its objections. Adam Smith (1723–1790) believed that the most persistent and the most universal man's motives was the pursuit of his own interests and that the free market or *laissez faire* economics leads to the wealth of a nation. The works of Copernicus, Brahe, Kepler, and Galileo were finally synthesized by Isaac Newton (1642–1727) in his three laws of motion involving the fundamental concepts of mass, acceleration, inertia, and action/reaction. Newton also employed calculus to explain his discovery that was published in 1687 in Principia. The triumph of Newton's discovery lies in its simplicity: Every particle of matter in the universe attracts every other particle with a force which varies inversely with the square of the distance between them and is directly proportional to the product of their masses. Unlike Copernicus and Galileo, Newton was widely praised during his lifetime, largely because of the ground work of his predecessors who made science a more acceptable discipline. The bibles of Newton, Smith, and Darwin are important because they marvelously describe an efficient system where the nature appears from long continuing processes going on all around, providing only local (and sometimes catastrophic) incentives to individuals without the need from a grand design.
32. The German scientist Alfred Wegener (1880–1930) proposed in 1912 that the Earth's land masses had once been joined together into a supercontinent. Wegener (1966) called his supercontinent Pangaea (from the Greek, 'all lands'), and the northern and southern parts Laurasia and Gondwanaland, respectively. Laurasia derives from Laurentia, an old name for the Precambrian (older than 550 million years core in Canada), and from Eurasia, a combined name for Europe and Asia. Gondwanaland derives from a distinctive group of rocks found in central India.

Similar rocks are found in Africa, Antartica, Australia, and South America (Skinner and Porter, 1992).
33. Planck (1936).
34. Kaplan (1997).
35. Probability curves express uncertainty, and since we always have uncertainty we need to agree that the probability curves represent the truth which is vital to the decision process. Probability is a 'one-shot' situation and its quantification represents a failure or degree of confidence in that situation, like a success of going to war.
36. As an example, consider the problem of deciding whether or not to evacuate people from the Vesuvius area based on a set of premonitory signals that we choose to call evidence. These signals or parameters can be deformation of volcanic cone, change of chemical composition of crater gas, landslide from the cone, earthquakes above the background level, etc. If the eruption is denoted by A and the evidence base by E, the (posterior) probability of eruption given the evidence, $P(A/E)$, is given by Bayes theorem

$$P(A/E) = P(A)P(E/A)/P(E)$$

where $P(A)$ is the probability of eruption prior to learning E. Given A and $\sim A$ (not A), the probability must satisfy

$$P(A) + P(\sim A) = 1$$

since probabilities are always numbers between 0 and 1. The next step is to identify possible scenarios, such as small-, medium-, and large-scale eruptions, each with its associated likelihood probabilities computed through Bayes theorem based on evidence. Since each scenario has its own consequences (cost, benefit, damage), each consequence must be represented by its probability curve and the value of each outcome maximized. But since different people will have different reasons (value judgments) for choosing options, the decision to evacuate or not to evacuate will depend on the interests being affected. In the Vesuvius area a false decision to evacuate will be very costly and a decision to postpone the evacuation until the last minute will be catastrophic in terms of the number of victims (Dobran, 2001, pp. 524–530).
37. Margolis (1996, p. 76).
38. False security messages from experts have often appeared in the press of the Vesuvius area. Some of these are: Pocobelli, G., Civetta, L.: Il piano può essere migliorato, *Il Giornale del Sud*, 4 April 1998; Carillo, P., Lo scienziato [Giuseppe Rolandi] avverte: Sul rischio Vesuvio troppo allarmismo, *Il Mattino*, 11 April 1998; Boschi, E.: Niente paura il vulcano è sorvegliato, *Il Mattino*, 14 April 1998; Pocobelli, G., Barberi, F.: Il Vesuvio è sotto controllo, *Il Giornale del Sud*, 29 April 1998; De Vivo, B.: Il Vesuvio? Dormirà ancora per secoli, *Corriere della Serra*, 24 March 2004. Conflicting messages confuse the public and those that are too tranquilizing produce a false sense of security among the people.
39. Hippocrates of Cos (c. 460–375 B.C.) taught the medical art and spurred quite a following that introduced the scientific point of view in the cure of diseases, and the beginning of scientific medical literature and clinical archives (Sarton, 1993, pp. 337–347).

40. Margolis (1996, p. 167).
41. Prugh and Assadourian (2003) define sustainability in terms of human survival, biodiversity, equity, and life quality.
42. Prugh and Assadourian (2003, p. 17).
43. Hughes (2004) provides a compelling view of the history of modern technology and technological culture, and discusses the dynamic interplay between technology and society.
44. In Note 23 some false claims of this sort have been documented by others.
45. Bugliarello (2002) discusses some of the requirements and engineering challenges in constructing sustainable modern cities. His biosomic city includes materials, energy, and information as the key engineering parameters that need to be confronted with the city's biological, machine, and social components. Pradhan and Pradhan (2002) discuss hybrid cities where the emphasis is on relatively small, governable, and manageable environments coexisting in harmony with nature.
46. In a socially sustainable environment, the levels of consumption and security are such that they meet the basic human needs of food, water, and space, as well provide the opportunities to enjoy socio-political rights, health, education, and well-being (Daily and Ehrlich, 1999). Another important aspect of social sustainability is equitable distribution of resources. Inequitable distribution of wealth can lead to social instability and disruption (Richard, 2002).
47. Physical models are constructed from the laws of conservation of mass, momentum, and energy expressed in mathematical forms (Dobran, 1991, 2001; Dobran and Ramos, 2006). These are then converted into algebraic forms by using suitable numerical techniques and programming languages, and solved on high-speed computers by the so-called 'computer codes'. There is thus an essential distinction between 'code verification' and 'code validation'. Code verification deals with solving accurately on the computer the mathematical forms of physical models. Code validation requires solving the correct forms of physico-mathematical equations pertaining to the phenomena being modeled. The distinction between these two operations is often confused in the scientific literature (Roache, 1998, pp. 19–61), and in the geological literature in particular.
48. The construction of Central Artery/Tunnel (CA/T) in Boston is a good example how the public, engineers, and construction industry collaborated on one of the most important and largest infrastructure projects in the United States. This $13 billion project required not only the solution of many unique technical or engineering problems, but also the involvements of politicians, environmentalists, and the public. Federal, state, and local governments, as well as numerous local interest groups, had their voices in shaping the realization of this project (Hughes, 2003, pp. 168–170; Chandra and Ricci, 2000).
49. The development strategy of Global Volcanic Simulator is described in more detail in Dobran (1993, 1994a) and Chapter 7 (Dobran and Ramos, 2006).
50. A system is a region in space set aside for investigation and we are free to choose it as we like. It can be a region where magma accumulates within a volcano, one or more conduits or fractures along which magma ascends toward the surface, a

region in the atmosphere above the surface of the volcano, or a combination of one or more of these regions. Global Volcanic Simulator models volcanic processes in all of these regions concurrently, and by exchanging data between these regions provides an interaction between the processes within the global system. The initial data specify the properties of the global system at the beginning of simulation. The boundary conditions, on the other hand, specify the properties of the system on its boundaries. The goal is to choose those systems which require minimal set of parameters for their description.

51. Casio Dione (Renna, 1992, p. 65) reports that during his trip to Capua in 203 'Vesuvius was blazing in an enormous fire'.

52. The eruption of 472 is described in Rolandi et al. (1998, 2004) and Mastrolorenzo et al. (2002), whereas that of 1631 by Rosi et al. (1993) and Rolandi et al. (1993a). Arnò et al. (1987) and Nazzaro (1997) report eruptive histories of the volcano for the last 35 000 years. See also Note 3.

53. A magma chamber model and simulation of 30 000 years of Vesuvius' activities is presented in Dobran (2001, pp. 395–410).

54. The volcanic deposits around Vesuvius contain limestones, various thermometamorphosed marble and skarn lithic ejecta, and suggest that the location of magma chamber and/or magma fragmentation levels lies within the Mesozoic carbonate basement, somewhere between 3 and 5 km below the surface of the volcano (Barberi et al., 1981, 1989). The subplinian deposits do not contain carbonate lithic ejecta, suggesting that magma reservoirs and/or magma fragmentation levels were located above this basement whose top lies at a depth of about 3 km (Bruno et al., 1998). Geophysical experiments at Vesuvius using seismic tomography do not, however, validate the volcanological data and suggest that magma should exist at depths that are greater than 5 km below the sea level (Zollo et al., 1996, 1998: greater than 10 km; Auger et al., 2001, and Civetta et al., 2004: greater than 8 km; De Natale et al., 1998, and Scarpa et al., 2002: greater than 5 km; De Natale et al., 2004: greater than 6 km; Guidarelli et al., 2006: greater than 10 km). Based on petrological studies, Lima et al. (2003) argue that 'Mt Somma–Vesuvius plumbing system is made up of small magma chambers at depths greater than 3.5 km and that possibly a larger chamber exists at or below 12 km'. Clearly, there is a significant discrepancy in these results, due both to the poor quality of petrologic data and the inverse problems of seismology which reflect the combined effect of the source and medium, neither of which is known exactly. The techniques of earth sciences 'often infer only a "big picture" from grossly limited and insufficient data' (Stein and Wysession, 2003) and one must be cautious in accepting the results without knowing the details of data processing. The magma below Mt. Vesuvius may be close to the crystallization state in the superficial regions and molten state in deeper regions of the volcano. If so, this is an unstable situation that depends on source permeability and can become rapidly unstable, either due to the source inertia or perturbative forces from local tectonics or magma injection through the crust (Dobran 2001, pp. 415–419).

55. Some of these constraints are available in Bacon and Druitt (1988), Ryan (1988), De Vivo and Bodnar (2003), and Civetta et al. (2004).

56. The eruption of Mt. St. Helens on 18 May 1980 was caused by magma–water interaction. A plug of magma heated the groundwater and caused it to expand and the north face of the mountain to bulge outward. This produced a landslide and the superheated water depressurized with an enormous explosion that decapitated a large part of the volcano. The plinian column rose high into the atmosphere and terminated the eruption (Decker and Decker, 1989). An interaction between magma and water may have caused decapitation of the cone of Vesuvius by several hundred meters on 17 December 1631 (Rosi et al., 1993). Celico et al. (1998) identified two principal aquifers below Somma–Vesuvius, one superficial and one deep. The superficial aquifer is situated among the pyroclastic and lava flow products of the volcano and the deep one among the carbonate rocks which make up the substructure of the volcanic complex. Water from the nearby mountains percolates through the carbonate rocks and charges the deep aquifer at 2–3 km below the sea level. This water then percolates upwards and feeds the superficial regions of the volcano. Some physical modeling aspects of magma–water interaction are available in Dobran (2001, pp. 441–461).

57. One should, for example, protect certain parts of the ruins of Pompeii, Herculaneum, Villa Oplonti, etc., and certain key structures of latter periods pertaining to the Bourbon regime of the eighteenth and nineteenth centuries. The ruins of Pompeii and Herculaneum represent, in miniature, a unique period in time where we can almost touch the daily life of 2000 years ago. How exactly to protect such structures requires an extensive engineering study involving Global Volcanic Simulator. The simulator calculates the forces from different eruption scenarios and thus permits the design of appropriate structures for protection from pyroclastic flows, lava flows, and from the fall of tephra (Dobran, 1993, 1994a,b). By using results obtained with the pyroclastic flow model of Dobran et al. (1993), Spence et al. (2004) and Petrazzuoli and Zuccaro (2004) performed some vulnerability studies of concrete reinforced structures in the Vesuvius area and determined that at 4–5 km from the vent these structures can withstand the overpressure from pyroclastic flows, while the majority of (aseismic) structures cannot. These results give credence that some parts of the territory can, indeed, be protected from eruptions (see Note 58).

58. A preliminary scientific study aimed at protecting the towns between Vesuvius and the sea is described in Dobran (2001, pp. 532–533). Computer simulations of this study are available in (Dobran, 1995b) and have been successfully shown on the territory for over a decade. According to this work, both the subplinian- and plinian-type pyroclastic flows of Vesuvius can be stopped at about 3–5 km from the crater by constructing appropriate structures that transform the radial into vertical motions of these flows. In this manner, the 500-degree-Celsius material rushing down the slopes can be cooled in the atmosphere before falling to the ground at low temperatures. These so-called 'barriers' do not have to be walls, but can be architecturally and environmentally pleasing structures and parks that are useful for protecting industrial and service facilities. People should not live in such structures, but should use them to conduct business and commerce.

59. The politicized leadership of Italian volcanological and geophysical communities is largely responsible for the lack of collaboration of the scientists associated with these patrons. While some Neapolitan institutions participated on VESUVIUS 2000, *Osservatorio Vesuviano* did not. This institution was once autonomous, but lost this autonomy under the directorship of Lucia Civetta. The observatory is now subservient to *Istituto Nazionale di Geofisica e Vulcanologia* under the directorship of Enzo Boschi from Bologna.
60. De Vanssay (1994) and De Vanssay and Colbeau-Justin (1998) carried out sociological studies in Antilles. The former study deals with 1975–1977 volcanic crisis of Guadeloupe, and the later with 1995–1997 volcanic crisis of Montserrat. The volcano at Montserrat erupted unexpectedly in 1997 when a number of people were killed and the population was subsequently grudgingly displaced to another part of the island.
61. Ferruccio Ferrigni's contributions to the project are explained in more detail in VESUVIUS 2000 (1995).
62. Bourbons ruled the Kingdom of Naples during the second half of the eighteenth century and first half of the nineteenth century, and learned how to cope with Vesuvius during its many open-conduit eruptions of this period. They planted tries on the slopes of volcano to prevent soil erosion, and built and maintained an efficient system of canals along which lava and mud flows were channeled. They also constructed magnificent villas which survive to this day. Today, there are few trees on the slopes of Vesuvius and the canals on the lower slopes are planted with roads and dwellings.
63. The natural capital includes goods and services supplied by natural ecosystems and the mineral resources in the ground. Some of these resources are renewable (forests, fishery, agricultural soil, water resources, and the like) while other are non-renewable (mineral and other deposits). Both resources represent wealth of the area. Human resources include human capital (population and physical, psychological, and cultural attributes), social capital (social and political environment that people create for themselves in a society), and knowledge assets (the codified and written fund of knowledge that can be transferred to others across space and time). The three classes of assets usually compliment each other as they are called to improve the human well-being (Wright, 2005, pp. 613–614).
64. Limitted studies of this nature are available in Cagliozzi (1999) and Chapter 3 (Di Donna, 2006).
65. For more on volcanic risk education, see Dobran (1998a, b) and Chapter 2 (Dobran, 2006).
66. Vesuvius Evacuation Plan architects divided Vesuvians into different colors. Those who are in the immediate vicinity of the volcano and close to the sea are colored red, those who live in more protected areas (shielded by Monte Somma relief) are colored orange, and those in between these areas and the territories of Naples, Caserta, Avellino, and Salerno are colored yellow. In order to evacuate, the red and orange Vesuvians will have to step over the yellow Vesuvians! The consequences of this scenario have not been considered.
67. Further details are provided in Piemontese (1993).

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