Journal of volcanology and geothermal research

ELSEVIER Journal of Volcanology and Geothermal Research 115 (2002) 411–435

www.elsevier.com/locate/jvolgeores

Volcanic hazard assessment in western Europe

David K. Chester [a,*], Christopher J.L. Dibben [b], Angus M. Duncan [c]

[a] Department of Geography, University of Liverpool, Liverpool L69 3BX, UK
[b] Department of Social Policy and Social Work, Barnett House, University of Oxford, Oxford OX1 2ER, UK
[c] Centre for Volcanic Studies, University of Luton, Luton LU1 3JU, UK

Received 1 December 2001; accepted 27 December 2001

Abstract

Volcanology has been in the past and in many respects remains a subject dominated by pure research grounded in the earth sciences. Over the past 30 years a paradigm shift has occurred in hazard assessment which has been aided by significant changes in the social theory of natural hazards and the first-hand experience gained in the 1990s by volcanologists working on projects conceived during the International Decade for Natural Disaster Reduction (IDNDR). Today much greater stress is placed on human vulnerability, the potential for marginalisation of disadvantaged individuals and social groups, and the requirement to make applied volcanology sensitive to the characteristics of local demography, economy, culture and politics. During the IDNDR a methodology, broadly similar to environmental impact analysis, has emerged as the preferred method for studying human vulnerability and risk assessment in volcanically active regions. The characteristics of this new methodology are discussed and the progress which has been made in innovating it on the European Union laboratory volcanoes located in western Europe is reviewed. Furnas (São Miguel, Azores) and Vesuvius in Italy are used as detailed case studies.

Keywords: hazard reduction; European Union; volcanoes; International Decade for Natural Disaster Reduction (IDNDR)

1. Introduction: The changing character of volcanology

Over the past three decades there has been a profound change in the content and scope of volcanology. Published in 1972, Gordon A. Macdonald's seminal textbook, *Volcanoes*, shows a subject dominated by pure research and strongly rooted in the earth sciences. Just one of Macdonald's 16 chapters is devoted to *Volcanoes and Man* (sic). Despite its strong grounding within the earth sciences, there has also been a well established tradition of applied research within volcanology. As long ago as the 1669 eruption of Mount Etna in Sicily, which threatened the city of Catania, one Diego Pappalardo and his friends attempted to divert a lava flow (Chester et al., 1985; Scarth, 1999); in 1855 L. Palmieri, working on Vesuvius, recognised that seismic activity preceded many eruptions (Hoernes, 1893); in Indonesia there are examples of hazard mapping which date from the 1920s and 1930s (Neumann van Padang, 1960); and in Hawaii, during the 1940s and 1950s, attempts were made to divert lava flows (Macdon-

* Corresponding author. Fax: +44-151-794-2866.
E-mail address: jg54@liverpool.ac.uk (D.K. Chester).

0377-0273/02/$ – see front matter
PII: S0377-0273(02)00210-X

ald, 1958). More recent decades have seen many volcano-related emergencies and there have been numerous examples of civil authorities intervening both to reduce the impact of eruptions and to aid recovery. Such initiatives have ranged from the generally successful, e.g. 1973 Heimaey, Iceland (Chester, 1993, pp. 266–269), 1980 Mount St. Helens, USA (Lipman and Mullineaux, 1981), 1991 Mount Unzen, Japan (Chester, 1993, pp. 256–260) and 1995–8 Montserrat (Clay et al., 1999), to the disastrous, e.g. 1982 El Chichòn, Mexico (Duffield et al., 1984; Carey and Sigurdsson, 1986; Espíndola et al., 2000) and 1985 Nevado del Ruiz, Colombia (Scarth, 1999). What is demonstrated by these and many other examples is that successful responses correlate strongly with the degree to which policies of hazard reduction are already in place before an eruption occurs. Such policies are often termed 'proactive'. More usually responses have been put together hurriedly during the precursory phases of an eruption and in its immediate aftermath and are 'reactive' in character (Chester, 2002). Not all reactive responses have been unsuccessful and the 1991 eruption of Mt Pinatubo in the Philippines is one such example. Pinatubo had not erupted for more than 500 years and was not considered to be amongst the Philippines' most dangerous volcanoes. Scientific attention was not drawn to Pinatubo until steam explosions occurred on April 2 and 10 weeks later there occurred one of the largest eruptions of the 20th century. During the 10-week period volcanologists from the Philippines Institute of Volcanology and Seismology (PHILVOLCS), with assistance from the United States Geological Survey (USGS), mobilised an extremely effective response (Newhall and Punongbayan, 1997). Within this short time, hazard assessment was undertaken and a mass evacuation organised which saved many thousands of lives. This success reflects the fact that, though not well resourced financially, through experience on other volcanoes for which pre-eruption planning had been carried out, PHILVOLCS responded extremely well to the emergency.

Not surprisingly and notwithstanding the Pinatubo experience, there has been a desire throughout the world further to develop proactive planning, and over the past 20 years interest in carrying out risk assessments of volcanoes and evaluating the vulnerability of people living in their vicinities has burgeoned. The lessons learnt by the volcanological community following successful responses have not, however, been the sole cause of the observed change in the scope and content of volcanology. Change has also resulted from the recognition that people are becoming increasingly more exposed, both to natural hazards in general and to eruptions in particular (Chester, 2002). From classical times calderas open to the sea, in the Aegean, the Campi Flegrei region of southern Italy and in the Aeolian Islands north of Sicily, have been used as natural harbours. Since the permanent occupation of towns and villages began with the onset of the agricultural revolution of the Eurasian Neolithic, volcanoes have attracted human settlement and in many parts of the world it has often been claimed that high rural population densities are supported by the intrinsic fertility of volcanic soils (Macdonald, 1972). An evolving body of research is, however, increasingly challenging this simplistic and over-deterministic assertion, with stress now being placed on the close relationships which exist between potential fertility on the one hand, and well adjusted systems of farming, conservation and long-term sustainability on the other (Fisher et al., 1997, chapter 13; James et al., 2000; Chester, 2002). Volcanoes are proving to be increasingly attractive for human settlement and for reasons which have little to do with their agricultural and/or resource potential. Hazard is the probability of an area being affected by potentially destructive volcanic processes and products. Risk, the interface between hazard and a vulnerable human population (Tilling, 1989), is increasing and is not primarily a function of the direct attraction of volcanic regions. Underlying processes of attraction to volcanic regions are rather indirect and usually independent of volcanic activity. Attraction represents an interplay between often deep-seated economic, social and cultural forces which are reflected in population growth, the in-migration of people and changes in the distribution of wealth and poverty both within individual countries and globally (Burton et al., 1978; Dicken, 1986; Hamilton, 1991; Degg, 1998). Around the Bay of Naples in southern Italy population increase, government-sponsored schemes of economic development and rural to urban migration encouraged by cheap, but often illegal, house building in potentially dangerous areas (King, 1985, pp. 292–296; Barone et al., 1994; Gumbel, 1998; Dobran, 2000) have resulted in an increased risk over the past 50 years. Today at least 700 000 people are threatened by a future eruption of Vesuvius (Fig. 1 and Dobran, 1995a). Similar forces of attraction have affected many other volcanic regions in Europe, though to a lesser extent and with the addition of factors which are of local significance. Hence, on Furnas Volcano in the Azores (Chester et al., 1999a), Etna in Sicily and on Santorini in Greece (Fytikas et al., undated), growth in tourism is a significant factor in increasing hazard exposure. Second homes have also grown up in the vicinities of these volcanoes, but changes in hazard exposure are more complex. In the case of Etna, although potential prop-

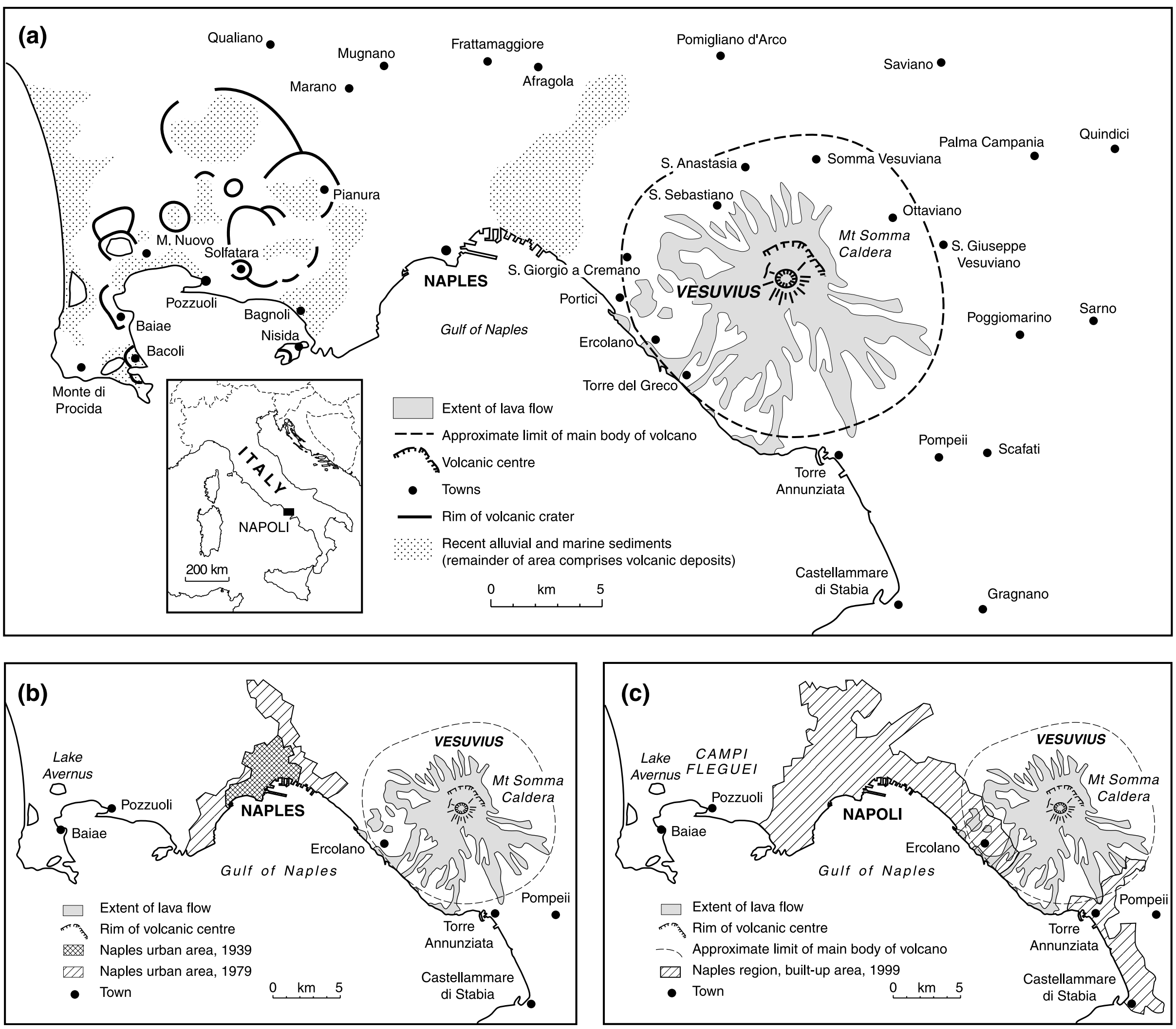

Fig. 1. Geography of the region of the Bay of Naples. (A) Location map showing principal settlements and volcanic centres (based on information in Degg and Doornkamp, 1991). (B) Extent of built-up area 1939 and 1979 (based on various sources). (C) Extent of built-up area 1999 (based on various sources).

erty losses in many villages have increased, for much of the year the exposed population is reduced and, consequently and in contrast with the situation when these settlements were predominantly agricultural, an eruption will not threaten the livelihoods of as many people.

Over a decade ago it was estimated by Don Peterson (1986) that some 10% of the world's population – then around 360 million people – lived either on or in the vicinity of the 600 or so volcanoes which are known to be capable of renewed activity (Peterson, 1986). ''By the year 2000 the population at risk ... is likely to increase to at least 500 million, comparable to the estimated world population at the beginning of the seventeenth century'' (Tilling and Lipman, 1993, p. 279). Diagrams produced by Martin Degg (1992) are particularly instructive, and potential exposure to future eruptions at the time affected 10 of the world's 100 largest cities. Of the 50 fastest growing cities in the world, nine are to be found in areas of active volcanism and at the close of the 20th century four of the 20 largest cities in the world – Mexico City, Tokyo, Jakarta and Manila – are potentially exposed (UNESCO, 1993; United Nations, 1996; Chester et al., 2001). In 1987 and reacting to the increasing global exposure of populations to extreme natural events, the General Assembly of the United Nations designated the 1990s the International Decade for Natural Disaster Reduction (IDNDR). Under the stimulus of this designation investigations were initiated throughout the world on a number of themes which are related to the hazard assessment of active volcanoes and the reduction in the risk of people living in their shadows. Indeed, during the 1990s it has been possible to discern not merely a transformation but a Kuhnian paradigm shift in the scope, content and disciplinary focus of volcanology. This is evident if the contents of recently published volcanological textbooks are compared with those of Gordon Macdonald's volume of 1972 (Table 1). Gradually a more strongly applied, interdisciplinary and socially sensitive methodology is emerging, which is orientated strongly to the proactive reduction of human vulnerability to eruptions.

In this paper the nature of this new methodology of volcanic risk assessment is discussed and illustrated by examining the progress which has been made in the past decade in achieving the goals of the IDNDR in the countries of western Europe.

2. Volcanic risk assessment and human vulnerability: The evolving international consensus

The evident success of proactive planning and the recognition that secular changes in the spatial patterning of wealth, poverty and population in areas of the world which are subject to eruptions

Table 1
Changing contents of selected volcanological textbooks between 1972 and 2000

Book	Contents devoted to pure research (%)	Contents devoted to applied, social and historical topics (%)
G.A. Macdonald: *Volcanoes* (1972)	95	5
H. Williams and A.R. McBirney: *Volcanology* (1979)	95	5
D.K. Chester: *Volcanoes and Society* (1993)	50	50
R. Decker and B. Decker: *Volcanoes* (1997, 3rd edn.)	73	27
R.V. Fisher, G. Heiken and J.B. Hulen: *Volcanoes: Crucibles of Change* (1997)	47	53
H. Sigurdsson (Ed.): *Encyclopedia of Volcanoes* (2000)	67	33

Estimates are based on the authors' evaluation of the contents.
'Pure research' refers to: the study of planetary volcanism; volcanoes and tectonics; the generation of magma and eruptive mechanisms; lava flows; the generation and emplacement of the pyroclastic suite and volcanic gases.
'Applied research' refers to: the human impact of volcano-induced climatic change; predicting eruptions; volcanoes and society (theoretical frameworks and the resource endowment of volcanic regions) and responses/adjustments to hazards in different countries and regions.

are not the only factors which have led to a paradigm shift in applied volcanology. Two additional factors have been important in helping to shape this new international consensus: (a) developments in social theory, with experience in major disasters in poor countries (e.g. famines and droughts), slowly defusing through hazard analysis more generally; and (b) the lessons which have been learnt during the course of the IDNDR.

2.1. Developments in social theory

Before the 1980s there was one approach to the study of natural hazards and their effects which overshadowed all others. This became known as the 'dominant' approach and was first developed in the 1940s by the American scholar and humanitarian Gilbert White, when he considered possible policies which could be introduced to reduce flood losses in the USA (White, 1942). Over the subsequent 50 years, Gilbert White was joined by like-minded scholars and their approach was developed into a set of procedures which were used not only to study flooding in the USA, but also the totality of natural hazards occurring in the world. These scholars quickly achieved a commanding influence on the research literature and this in turn influenced the ways in which policies of hazard reduction were framed by national governments, the United Nations Disaster Relief Office and, more recently, academics and policy makers addressing the agenda set for the IDNDR. The characteristics of the 'dominant' approach are complex and further information may be gleaned from Burton et al. (1978), Chester (1993) and Hewitt (1997) but, although it is admitted that no risk can exist unless there is a human population to be affected, the primary emphasis of the 'dominant' approach is on physical processes, particularly the magnitude and frequency of extreme events. ''These are considered to be the first order determinants of a disaster and differences between societies are relegated to a lower, albeit still significant, level of importance'' (Chester, 1993, pp. 237–238). A physically deterministic hue may be seen in the mission statements of agencies in many countries which are given the responsibility for reducing the vulnerability of their populations to the effects of volcanic eruptions, this being a particular feature of statements published up to the middle of the 1990s. The aims and objectives of the United States Volcano Hazards Program (Filson, 1987, p. 294; Wright and Pierson, 1992, p. 6) were, for instance, remarkably similar to those of Argentina (Zupka, 1996) and many other Latin American countries (Anon., 1994).

Under the 'dominant' agenda the roles of national governments and international agencies are defined largely in terms of the transfer of the technology and administrative experience from areas where responses are observed to have been successful to those where they are either non-existent or perceived to have failed. Internationally this means from rich countries to poor countries, nationally from economically successful to economically less developed regions. In the early years of the IDNDR the 'dominant' approach retained its pre-eminence and some of the leading contemporary hazard analysts placed great stress on technological transfer. For Professor Michel Lechet, at the time a member of the United Nations IDNDR Scientific and Technical Committee (Lechet, 1990, p. 1) technology transfer was one of the principal objectives of the decade and for many, but significantly not all, participants at international conferences held early in the decade it was a factor of overwhelming importance (e.g. Anon., 1992, 1993).

At first sight the acceptance of a model of loss reduction which has been successful in rich countries as a universal international panacea may appear to be justified both intuitively and from an humanitarian perspective. This is disputed by more 'radical' critics. The research of 'radical' scholars is heavily focused on poor countries and natural disasters, like droughts, which have a long onset time, are of long duration and cause damage to large areas. Although the arguments used by the 'radical' critics are again complex (see Hewitt, 1983, 1997; Chester, 1993, pp. 238–244), the idea of fundamental importance is that most disasters in poor countries have more to do with political and economic power than with the extreme character of physical processes. The people who suffer most in disasters are those who are often marginalised in three ways: economically (i.e. they are poor), geographically (i.e. they live in areas which are prone to disaster losses), and politically (i.e. that are unable to participate in and influence political decision making). Relief aid and technological transfers have the in-built tendency to benefit those who are already well off and this can lead to the further marginalisation of the poorest sections of a community.

Some of the points raised by the more radical of the 'radical' critics, such as Susman et al. (1983, pp. 279–280), have found favour neither with international agencies nor with volcanic hazard analysts. Within the 'radical' corpus there are, nevertheless, ideas of considerable value and these have gradually made their presence felt in applied volcanology during the course of the IDNDR. At first sight this may appear somewhat perverse, because volcano-related disasters are quite unlike droughts and many other classes of hazard in the so-called Third World. Volcanic eruptions are usually of short onset; apart from global effects on weather and climate, volcanoes affect limited areas and actual events are typically of short duration. What has proved to be important about the 'radical' critique is that it emphasises the uniqueness of place: Hawaii is not Etna and Iceland is not the Azores. Even when discussion is restricted to economically developed countries like those in western Europe, successful hazard reduction depends critically not only on understanding volcanological processes per se, but also on the impacts these will have on: (a) the wider physical environment and (b) the fine detail of the socio/economic conditions and cultural milieu of the society in question. Responses and adjustments must be sensitive to the physical environment and 'incultured' if they are to be successful (Degg, 1998).

The 'dominant' approach still provides a useful initial framework for translating volcanological research into policies aimed at loss reduction, through techniques of risk assessment and volcano surveillance, but it is equally vital that the uniqueness of place and the reasons why populations are vulnerable should be evaluated. Although some general principles of hazard reduction apply equally to all volcanoes regardless of location, the complex interactions between an eruption, its environment and the economy and society of the people who live in its vicinity make all volcanic regions unique and demand an approach to hazard reduction which is more subtle than has often been the case in the initial years of the IDNDR. Piers Blaikie has argued that an integration of conventional hazard analysis (i.e. mapping) with what he terms vulnerability analysis is required. Whereas hazard mapping is concerned with physical mechanisms, vulnerability analysis concerns "everything else: monitoring changes in root causes ..., and understanding how these are channelled into unsafe conditions for specific subgroups in the population by social and economic mechanisms" (Blaikie et al., 1994, p. 225)[1]. In terms of volcanic hazards, it is becoming increasingly apparent – both within the worldwide volcanological research community and in Europe – that integration involves a conflation of conventional volcanic hazard assessment (i.e. through techniques of risk assessment and volcano surveillance) with the parallel study of those aspects of economy, demography and society which either increase or decrease susceptibility to losses.

2.2. Lessons being learnt during the IDNDR

Even in 1990 at the start of the IDNDR it was notable that the volcanological community eschewed the 'dominant' paradigm in its purest form, with the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI Task Group, 1990) defining a more affordable, culturally sensitive and more socially aware programme of hazard reduction than was the case in some other areas of hazards research. Volcanology has always been internationalist in outlook and the proposed programme showed an awareness of the cultural, political and social differences between places, yet at the same time

[1] The concept of vulnerability to hazard is a complex topic, much discussed in the social science literature. Bankoff (2001) and Pelling (2001) provide excellent recent reviews.

sought to innovate good scientific and administrative practice (Table 2). It is interesting that the strongly 'incultured' tone of Table 2 did not become the common currency of hazard analysis until much later in the IDNDR, as is clear from the Yokohama Strategy published following the World Conference on Natural Disaster Reduction held in 1994 (United Nations, 1995).

Since the programme outlined in Table 2 was published, further lessons have been learnt by and disseminated through the volcanological community. In a corpus stretching back to the mid-1980s several American scholars (e.g. Peterson and Tilling, 1993; Self and Mouginis-Mark, 1995) have been studying responses to eruptions, through the identification of those factors which influence their success or failure. Special attention has been focused on the often critical issue of effective communication between scientists, officials and the public at large and it is argued that this factor alone can make the difference between a successful and an unsuccessful response. In particular, difficulties are seen to occur when there are significant departures from what is termed an idealised scenario, which has the following attributes:

"(a) scientists have the personnel, equipment and other resources enabling them to progress effectively towards their major goals of understanding the past through geological studies, the present through monitoring and the future utilising the interpretations built from the past and present; (b) *the scientists maintain full communications with civil authorities and other members of the community and the region*, all of whom are actively interested in and responsive to the information; (c) the authorities of the community and the region respond to the scientific information by developing a land-use plan that is cognizant of the hazards, and they also develop and regularly rehearse emergency plans" (Peterson and Tilling, 1993, p. 347, our italics).

Table 2
Initiatives proposed at the beginning of the IDNDR by the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI Task Group, 1990; modified and updated from Chester, 1993, p. 309)

Initiative	Details
Hazard and risk mapping	Reconnaissance mapping of hazards and risks at previously unmapped volcanoes
Volcano surveillance	Baseline monitoring and minimum surveillance at dangerous volcanoes that are not presently monitored. Emphasis on affordable procedures and involvement of local people
Public education	Improved education about volcanic hazards (e.g. community talks, films, videos, community field trips, observatory open days, workshops in schools, involvement of local volunteers in surveillance, symposia for public officials and decision makers, simulation of evacuations and establishment of relationships between two cities with similar threats)
Dialogue with public officials	Scientists should discuss emergencies and land use planning
'Decade Volcano' demonstration projects	Proposed that $\sim$10 volcanoes be chosen for integrated, multinational and multidisciplinary study, to demonstrate the range of activities required for mitigation
IAVNET	Electronic mail to be used to allow co-operation and advice before and during an eruption
Reference materials	Development of archives on dangerous volcanoes
Training	For both new and established scientists, civil-defence officials and planners
Low-cost equipment	For poor countries, equipment should be developed which is affordable, reliable and easy to repair
Satellite monitoring	To collect: images of geological features and SO_2 plumes etc. Satellites to be used to secure communications during eruptions
Crisis assistance	(a) Supplement local personnel during a crisis, (b) build up local expertise, (c) help local scientists and officials prepare for eruptions during periods of calm and (d) help national scientists become self-sufficient
Seed money	Encourage local initiatives and encourage the local generation of finance
Publication	Wide dissemination of lessons learnt from eruptions

It is perhaps not coincidental, considering the strongly 'incultured' tone of this document, that the committee which drew up the programme had six out of its 11 members drawn from countries of the so-called Third World (Chester, 1993, p. 308).

Increasing complexity

Technique	Features	Comments on and examples of applications in volcanic regions
Checklist	Lists all the factors - physical, economic, cultural and societal - which need to be considered. Cause/effect relationships are implied but not specified in detail.	The US Geological Survey's programme, Living with Volcanoes (Wright and Pierson 1992: 6) and many initiatives in other countries involve, either implicitly or explicitly, a checklist approach (see also Anon 1994b). It is the evolving norm of the IDNDR.
Overlays	Traditionally this has relied on overlay maps showing physical, social, historical aspects of the region. Today Geographical Information Systems (GIS) are commonly used.	There is much scope for this approach to be used in volcanic regions, because many of the variables are spatial and capable of being either mapped or incorporated into a GIS. The impact of satellite based systems, significant at present, is likely to be much more prominent in the future (Wadge 1994). GIS based studies have been used in the Azores (Baxter et al. 1994)
Matrices	Matrices are used to identify first-order cause/effect relationships.	At the present time variables are not sufficiently well specified to enable matrices and network based studies to be carried out. There may be much scope in the future.
Networks	Used to identify 'chains' of complex interactions. Ideally this approach requires mathematical modelling.	

Fig. 2. The evolving framework for the study of volcanoes and society. Close parallels with EIA should be noted (adapted from Chester, 2002 and based on several sources; see Mitchell, 1979, p. 241 for further details).

2.3. The evolving consensus

As the IDNDR drew to a close a new more integrated approach to volcanic risk assessment was slowly emerging. This has not only taken on board developments in social theory and current best practice in responding to eruptions, but has also focused on the study of volcanic regions both during eruptions and in periods of quiescence. Additionally frameworks of study have increasingly taken account of new technological developments, including techniques of satellite data recovery (Wadge, 1994; Tárranga et al., 2001) and Geographical Information Systems (GIS: Gómez, 1996; Gómez-Fernández, 2000). As argued elsewhere (Chester, 2002), what has emerged is an approach which is methodologically similar to Environmental Impact Analysis (EIA). EIA was developed following legislation passed in many economically more favoured countries from the late 1960s to assess the impact on the environment of large projects (Mitchell, 1979;

Jones and Hollier, 1997,, pp. 338–340). In terms of their effects on physical environments and social systems, volcanoes are analogous to such projects and there are close parallels between EIA and the frameworks currently being developed to study volcanoes and society. As Fig. 2 shows for all volcanoes the myriad of social and physical factors which need to be studied may be expressed in terms of checklists, while the overlay approach is increasingly being used to compare data with a spatial dimension.

3. Risk assessment and human vulnerability: Progress in western Europe

One of the major IAVCEI initiatives during the IDNDR was the identification of 'decade volcanoes' (Table 2). The selected decade volcanoes represent different styles of activity, are located in a variety of countries – some 'rich', others 'poor' – and are intended to be the focus of "intensive, integrated and multidisciplinary research involving international co-operation" (Mc Guire, 1995, p. 404). No specific funds were allocated to support research on the decade volcanoes. Vesuvius and Etna in Italy are decade volcanoes. Running alongside the decade volcanoes are the European Union/European Science Foundation's 'laboratory volcanoes'. In 1992 and 1993 the European Union allocated research funds in line with specific research objectives to fulfil aims which were broadly similar to those of the decade volcanoes initiative. The volcanoes chosen for detailed study were: Mount Etna (Sicily); Furnas (São Miguel, Azores); Piton da la Fournaise (Réunion, Indian Ocean)[2]; Teide (Tenerife) and Santorini (i.e. ancient Thera, Greece). Later Krafla in Iceland was added.

At first sight European progress in addressing the new more socially aware agenda of risk assessment and human vulnerability appears to have been disappointing. Fig. 3 shows the results of a citation analysis of articles on the European laboratory and decade volcanoes published in science, social science and humanities journals between the start of 1982 and the end of 2000. Whereas overall output increased steadily during

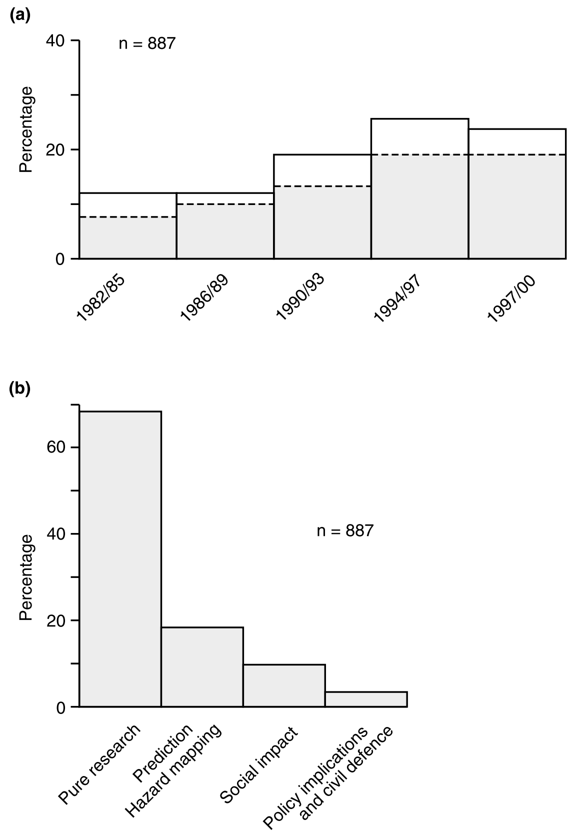

Fig. 3. European laboratory volcanoes plus Vesuvius: output of science, social science and humanities research papers and scientific proceedings 1982–2000. The classification into different categories is based on the authors' appraisal of the published abstracts. In panel a the broken lines indicate pure research papers as a proportion of the total. In panel b papers are classified according to content. Data were compiled in September 2000 and are derived from the Institute for Scientific Information (ISI) with permission).

[2] Réunion in the Indian Ocean is an overseas Département of France. Because it is not geographically in western Europe, the basaltic shield of Piton da la Fournaise Volcano is not considered in detail in the present paper. At the start of the IDNDR, hazard assessment and civil defence planning was given a significant boost in the aftermath of eruptions in 1972, 1973, 1975–6, 1977, 1981, 1983–4, 1985–8 and 1990 and an impressive Civil Defence Plan was published (SIRDPC, 1992). During the 1990s flank eruptions have occurred just as frequently in 1991, 1992 1998 and 1999 (Staudacher, 2000). Research has concentrated on producing baseline geological and geophysical studies which have hitherto been lacking (Barberi et al., 1995; Lénat et al., 2000).

the review period, with some 55% of all papers being published between 1994 and the end of the decade, even in 2000 output is still dominated by the concerns of pure research. Although the proportion of applied papers increased after 1990, from a low point of only ~1% between 1986 and 1989, it still remains a relatively small percentage of the total. Much of the material on social impact and civil defence is, however, published as official reports, conference papers and increasingly on web sites, but this in turn raises a further issue. This 'grey literature' is often not widely known outside its country of origin and there has been a tendency for important advances not to be widely disseminated within the international volcanological community. The exception is Vesuvius, where the mass media (e.g. Gumbel, 1998) and even specialised scientific journalists (e.g. Masood, 1995) have focused on actual and perceived differences between research groups, rather than upon advances which have been made in civil defence planning in this socially complex and highly populated region.

Furnas, Etna and Vesuvius may be used to illustrate the progress that has made and the issues which are raised by introducing the new more 'incultured' methodology of volcanic hazard assessment. Although both Furnas and Vesuvius volcanoes are potentially explosive and any future eruption is likely to devastate extensive areas in their vicinities, sociologically, economically and politically the regions are very different. The Furnas region (Fig. 4) is rural, the total population which would have to be evacuated is unlikely to exceed 23 000, sociologically the area is fairly homogeneous and, under the most probable future eruption scenario, evacuees could be accommodated within the island of São Miguel (Chester et al., 1995). The region of Vesuvius (Fig. 1) is in contrast predominantly urban, the population requiring evacuation could well exceed 700 000 (Dobran, 1995a) and sociologically the region is characterised by high levels of unemployment, social deprivation, a lack of respect for government and its agencies, a legacy of 'clientism' in official appointments and the ever present heavy hand of

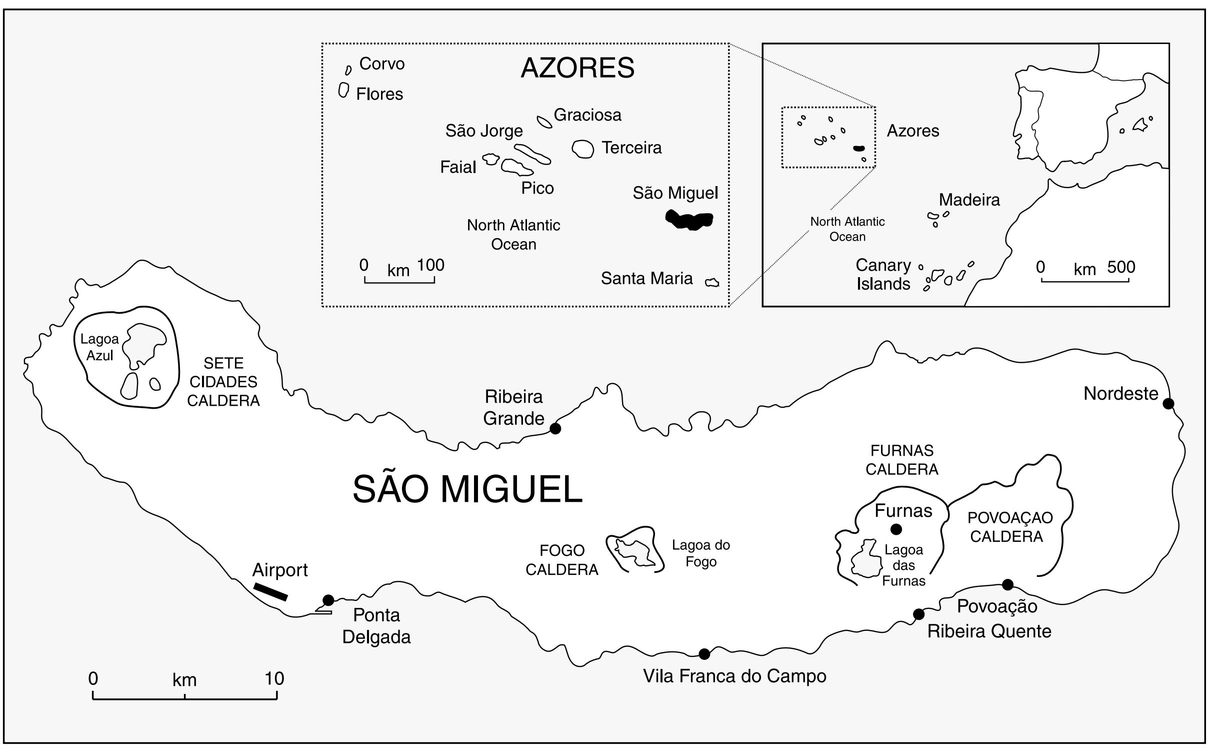

Fig. 4. Furnas: general location map (from Chester et al., 1995).

organised crime (Barone et al., 1994; Dobran and Sorrentino, 1998; Donna, 1998; Gumbel, 1998; Dobran, 2000).

The hazard posed by Etna is quite different from that presented by Furnas and Vesuvius, it being a continually active basaltic volcano. The historical records of its flank eruptions date back to the Classical Era and are continuous from the 15th century and show few deaths, but frequent damage to agricultural land and less frequent damage to property and livelihoods (Chester et al., 1985). In the past century major flank eruptions causing significant damage to property and/or agricultural land have occurred in 1910, 1911, 1923, 1928, 1971, 1981, 1983, 1991–3 and 2001, the 1928 event which destroyed a major village and effectively 'sterilised' ~1.6 km^2 of land being the most destructive (Chester et al., 1999b). During 1999 and 2000, Etna has given rise to short-lived vigorous strombolian/fire-fountaining events from the summit craters, which distributed tephra on the flanks of the volcano, often causing damage to crops and disruption in towns and villages. When the dispersal of tephra has been to the south-southeast this has affected Catania airport, and during the July 2001 eruption the airport was closed by ash on several occasions. On 26 April 2000 a jet airliner flew into a plume generated by strong fire-fountaining from the South East Crater, its windscreen was badly scratched and it had to make an emergency landing (Anon., 2000). The main threat posed by Etna, therefore, is to the financial and social well-being of this increasingly important economic area in southern Italy.

3.1. Furnas

Research on the hazard and risk posed by Furnas Volcano (Fig. 4) has been carried out by two

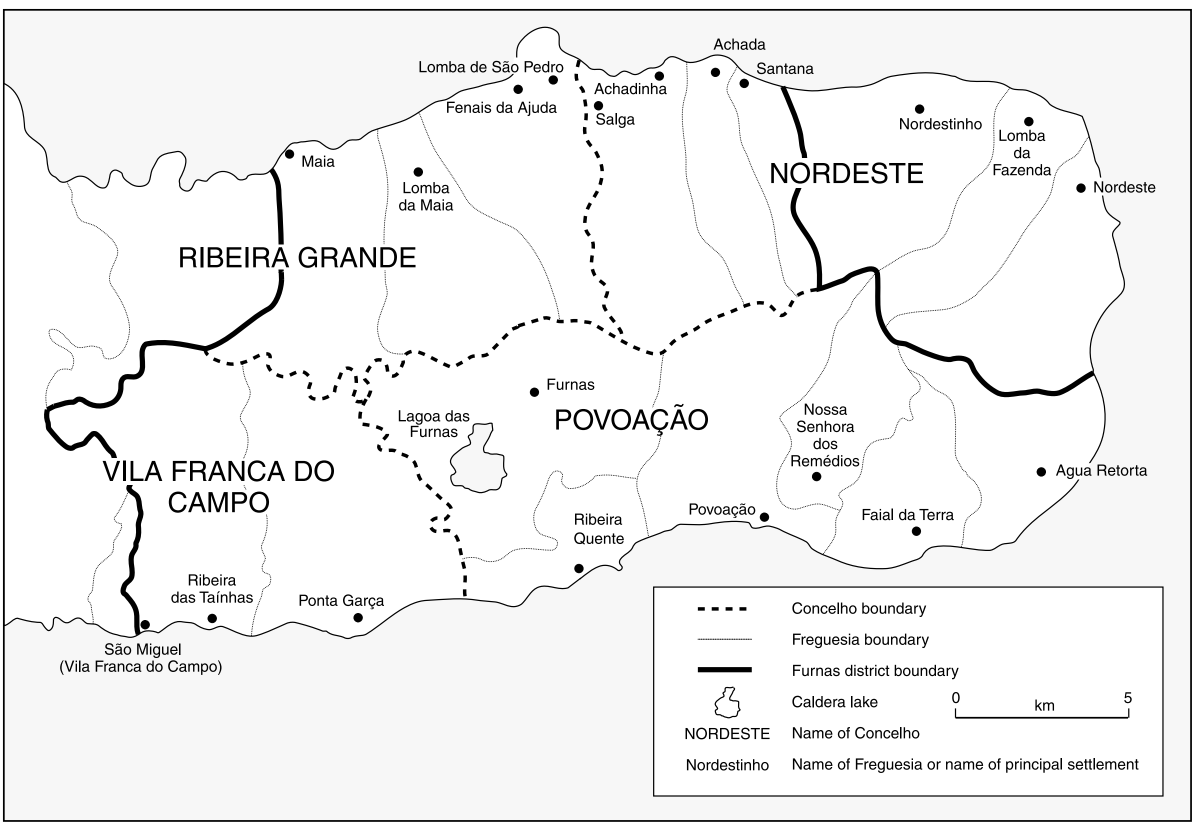

Fig. 5. The limits of the Furnas District (from Chester et al., 1995).

research teams who have combined conventional hazard mapping with detailed studies of human vulnerability. One team has focused on medical aspects of risk and on the built environment, specifically: the dangers of gas emission both at present and during any future eruption (Baxter et al., 1999); the relationships between building type, construction quality and tephra fall/seismic hazards; and communications, particularly those between scientists, decision makers and civil defence officials (Pomonis et al., 1999). One notable feature of this research is the use being made of GIS-based overlay techniques (see Fig. 2 and Baxter et al., 1995).

The second team has been concerned with linking hazard mapping to social and cultural aspects of evacuation planning (Chester et al., 1995, 1999a). Hazard analysis and mapping have demonstrated that the most probable future eruption scenario is, at minimum, an event similar in magnitude to the last eruption of 1630 (Guest et al., 1999; Cole et al., 1999). It is predicted that such an event could cover the towns of Povoação and Ponta Garça (Figs. 4 and 5) with a maximum of 1 m of ash, as well as devastating all the region within the caldera with pyroclastic flows (sensu lato) and thick ash/lapilli falls. This scenario will require rapid evacuation of the caldera area and the surrounding towns. Precursory earthquakes could also do serious damage to housing and roads. Outside the caldera pyroclastic flows could reach the towns of Povoação and Ponta Garça (Fig. 5), depending upon the exact location of the eruption. The high walls of the caldera to the east and north may prevent flows spreading outside the caldera in these directions (Fig. 4). Depending on wind direction, it is likely that virtually the whole island will suffer some tephra fall. If the next eruption were larger than that of 1630, tephra ash fall would be more extensive and problems for communications even greater, and alternative scenarios have been constructed to cover these eventualities.

EIA stresses that interactions between eruptions and other factors of the physical environment should be considered in hazard analysis, and on Furnas it is clear that any future eruption will have an impact on hydrology. In particular a study of likely interactions shows that the timing and magnitude of previous rainfall events could either increase or decrease associated landsliding and flooding risks (see Chester et al., 1995, for further details).

It might be thought that moving from the above to a fully developed evacuation plan is simply a matter of logistical planning, but mindful of both the 'radical' critique and the documented experience of many eruptions worldwide, the two research teams have been concerned to modify this essentially managerial approach, since it carries with it the danger that local people may be forgotten in the rush to devise and publish a plan. Following study of published materials on the demographic, socio/economic and cultural/behavioural characteristics of the communities which comprise the Furnas District (Fig. 5), it became apparent that before any firm recommendations could be made to policy makers there was a need further to consider a range of non-volcanological and non-environmental factors. This impression was supported not only by interviews with local administrators and politicians, but also by social surveys carried out in the region. An area was defined, the Furnas District (Fig. 5), which comprises *concelho* (i.e. municipalities) and *freguesia* (i.e. parishes) for which statistical data are available. The Furnas District corresponds to the administrative areas of the towns and villages which would be at risk if an eruption typified by the 1630 scenario were to recur. Some of the major demographic, socio/economic and cultural/behavioural features of the Furnas District are listed in Table 3. Failure to be aware of the local milieu could seriously damage the effectiveness of any planned evacuation, and relevant aspects of society and culture need to be brought to the attention of policy makers. Four characteristics in particular require special emphasis. First, because of a large transient population and the consequent inflation of population numbers particularly in summer, it was strongly recommended that policy makers commission further research on the maximum number of people requiring evacuation at different times of the year. A second recommendation is also concerned with demography. Although population is concentrated in villages,

Table 3
A summary of the main demographic, socio/economic and cultural/behavioural factors which could complicate an evacuation at Furnas Volcano, São Miguel, Azores

Factor	Details
Demographic	The Furnas District had a resident population of 22 644 in 1991, accommodated in 5693 houses. These figures do not, however, capture: (a) the large number of visitors, especially in summer and (b) the under-occupancy of many houses for most of the year. These are inhabited for some of the time by weekend residents, return migrants from mainland Portugal and abroad and by tourists. Since the Portuguese census date is 15 April, a month of relatively low resident population, far more people would potentially require transporting to safety at certain times of the year than the published figures suggest. A further demographic factor which could complicate evacuation is the degree to which population is either clustered within the principal settlement of the local authority area, or widely dispersed over its area
Socio/economic	Traditionally an agricultural/fishing area, alternative employment opportunities are limited. This is reflected in recent decades by the permanent or temporary out-migration of many people in the economically active cohort, with the result that 'dependency ratios' (i.e. per cent under 15+per cent over 65 in the population) range from 38 to 46% across the district. The percentage of the population classed as economically active is never greater than 36% of the total in any administrative area
Cultural/behavioral	As a result of an aged population and the fact that before the 1974 Portuguese Revolution many people did not receive even an elementary education, illiteracy ranges from 8 to 23% of the total population, across the Furnas District. Behavioral factors are important and include close links between many of the inhabitants and the land, as a result of both active and traditional family-based agricultural ties. At its most simple and bearing in mind that cattle rearing and fattening dominate contemporary agriculture, large numbers of livestock – both living and dead – could block roads in the event of an eruption, whilst at another close attachment of people to village, land and farm could cause some inhabitants to resist evacuation

Adapted from Chester et al., 1999a and Dibben and Chester, 1999) and based on numerous additional sources and social surveys carried out in the area.

special attention needs to be given to people living in isolated dwellings. These people should be located and detailed plans devised to ensure their safety. Thirdly, because of high illiteracy rates and dependency ratios, many people are very young, very old and/or not able to follow written instructions. As a consequence many people will require considerable assistance in the event of an evacuation. Finally, many inhabitants of Furnas feel an intense psychological attachment to the town and have a large proportion of their economic and social resources – not least land and livestock – located within the area. Great care will have to be taken to ensure that inhabitants comply with requests to evacuate and stay out of threatened areas. As argued more fully by Chester et al. (1995) and Dibben and Chester (1999), identifying local leadership is vital if certain sections of the community are not to be marginalised during any planned evacuation.

At the present time the results which have emerged from the European Union/European Science laboratory volcanoes initiative are being integrated into civil defence plans both for the Azores as a whole and for each individual *concelho*. A good example is the recently published plan for Vila Franca do Campo (fig. 5, Wallenstein et al., 1999).

3.2. Vesuvius

In 1995 a comprehensive hazard evaluation and evacuation plan was published for Vesuvius (Dipartimento della Protezione Civile, 1995), based on an AD 1631 eruption scenario. Using a combination of the areal distribution of AD 1631 eruption products and computer-based hazard mapping and modelling of likely Plinian fall and pyroclastic flow emplacement (Barberi et al., 1990), the plan envisages the evacuation of

700 000 people following a 7-day warning period (Fig. 6), the rationale being that before the 1631 eruption earthquakes were felt for at least 15 days. Today the volcano is extensively monitored by seismographs and other geophysical devices (Rolandi et al., 1993; Rosi et al., 1993) and it is claimed that around 20 days would elapse between the first warning and the start of an eruption. It is a matter of conjecture, however, how many of these '20 days' would elapse before scientists were able to identify that these precursory signs were those of an impending eruption. It is clear that specific eruption prediction is still at an embryonic stage and, though from monitoring precursory phenomena (e.g. seismicity) it is possible to recognise that a volcano is showing signs of impending activity, it is not possible to predict when an eruption will occur.

Since it first appeared the evacuation plan has been the subject of much controversy, not only within the Italian volcanological and political communities, but also amongst the people living in the shadow of the volcano. Some of the criticisms relate to the eruption scenario and centre upon whether an eruption can be predicted within 20 days, the accuracy of the 1631 eruption scenario, the durability of seismic monitoring stations in the days leading up to an eruption (Ma-

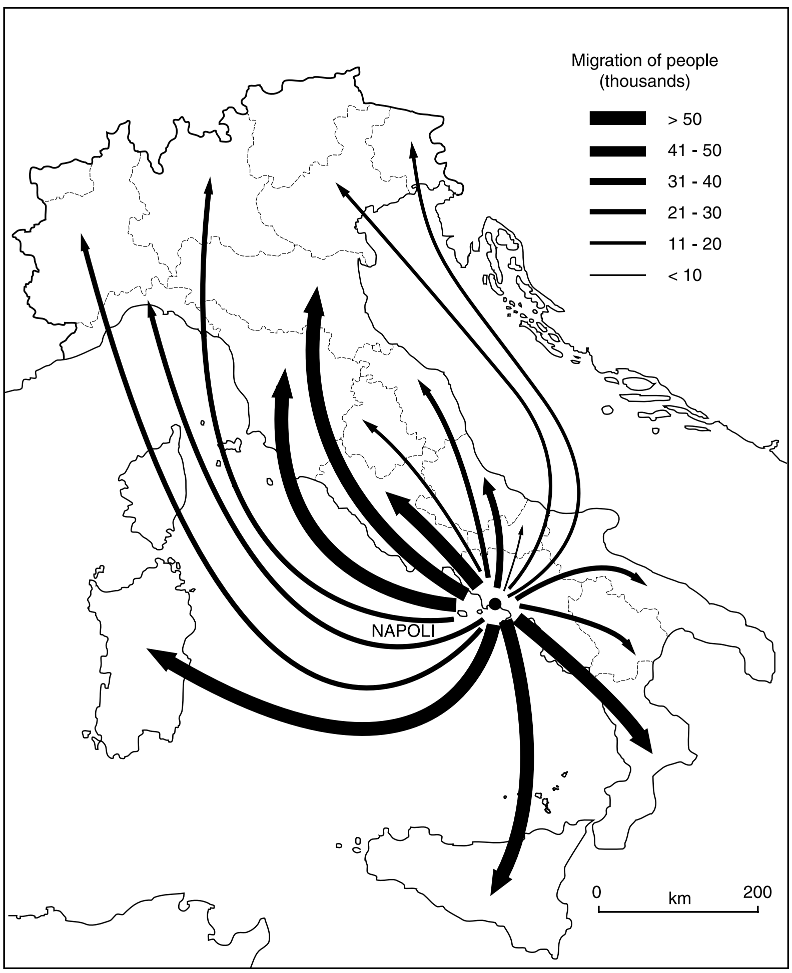

Fig. 6. The Vesuvius evacuation plan: proposed destinations of evacuees (based on information in Dipartimento della Protezione Civile, 1995).

sood, 1995) and the justification for assuming that prevailing winds from the west will be the actual winds at the time of eruption. According to the 1995 plan, evacuation of the local authority areas (*comuni*) which are located on the slopes of Vesuvius is envisaged, but if at the time of the eruption winds were blowing from the east or southeast, then more widespread evacuation – including some parts of Naples (population ~1.2 million) – would have to be considered (Fig. 1). At present neither this eventuality, nor the possibility of either a smaller- or a larger-magnitude eruption, forms part of the plan.

The publication in 1994 of an alternative eruption scenario by Flavio Dobran produced a rift in the Italian earth sciences community which has not healed and since that time criticism has become increasingly personal, vituperative and political (Dobran et al., 1994; Dobran, 2000). In 1994 Dobran and his colleagues argued that both the largest eruptions of Vesuvius, typified by the AD 79 event which devastated Pompeii and Herculaneum, and medium-scale events, such as the eruption of 1631, have the potential to develop extremely quickly and if repeated would place up to 1 million people at risk with less than 15 min warning (Baxter et al., 1998). Since 1994, criticism has hardened, being aired not only in scientific journals (e.g. Masood, 1995), but also in the national and international press (e.g. Anon., 1996; Gumbel, 1998. Criticism has focused on whether evacuation is logistically possible (Valentine and Heiken, 1995; Newhall, 1996; Matthews, 1998), with some 600 000 people requiring evacuation in just one week using 81 ships, 4000 cars and 40 trains each day (Fig. 6). In addition 16 500 people would be required to manage the evacuation. In 1995 an independent research group was set up by Flavio Dobran (Dobran, 2000), which he named the Association for Global Volcanic and Environmental Systems Simulation (GVES), further to publicise his misgivings about the hazard plan for Vesuvius and its region. At the heart of the GVES critique is the view that the government's plan is preoccupied with trying to predict an eruption, whereas it should be concerned with broader questions of disaster management. In particular it is posited that the 1995 plan is not sufficiently 'incultured' and "raises many questions, such as the threat to life, lifestyle, culture and centuries of tradition. The population should be educated in different risk scenarios posed by a potential eruption and then given the choice to decide how it wants to react" (quoted by Masood, 1995, p. 471). Although there is undoubted truth in some of the criticism, it should not be forgotten that the published evacuation plan is a draft document and is being continually revised by its principal author, Professor Lucia Civetta (Director of the Vesuvius Volcano Observatory, Civetta, 1998, personal communication), following comments which she has collated from interested parties. At the present time (2001), there is a renewed focus on the education of, and dialogue with, local people about the hazards posed by Vesuvius and a limited trial evacuation has successfully been carried out.

In May 1998 30 h of continuous rainfall in the Vesuvius area caused the re-mobilisation of tephra and the generation of debris flows, which killed more than 150 people in the vicinity of the town of Sarno (Fig. 6). This event focused the attention of the *Dipartimento della Protezione Civile* on the threat posed to people in the wider region by events of this type. Since 1998 research has not only been concerned with reconstructing past events, of which there have been many examples in the historical record (Pareschi et al., 2000a), but also on making hazard assessments using GIS-based mapping techniques (Pareschi et al., 2000b).

Overall and in view of the local milieu, in which scientists are having to deal with severe problems of unplanned and often illegal urban growth (Fig. 1), a long-standing denial by much of the population that Vesuvius poses any threat at all, organised crime and a history of corrupt government, it is easy to agree with Christopher Newhall (1996) that, despite many flaws, the evacuation plan at least tackles difficult issues which have long been recognised and are only now being adequately addressed. As Table 4 shows, the Bay of Naples is perhaps unique in Europe in displaying all the detailed aspects of disaster vulnerability which have been recently discussed by David

Table 4
Aspects of disaster vulnerability in the region of the Bay of Naples

Nature of vulnerability	Characteristics of the region of the Bay of Naples
Total vulnerability, e.g. of the poor	Population densities in Naples and many towns and villages are very high, and housing conditions of the poor are amongst the worst in Europe
Economic vulnerability, e.g. of the marginally employed	Many families survive by members having part-time, often casual employment within the non-official economy. The non-official economy is fuelled by perennially high unemployment and under-employment
Technological vulnerability, e.g. of the rich. High absolute losses will be suffered, but will not be fundamental to their survival	Economy and society is strongly dualistic and amongst the poverty there is also much new wealth within the emergent middle classes. Even the latter, however, often live in illegally built housing and so aspects of newly generated vulnerability are evident across the whole society
Newly generated vulnerability, e.g. new construction in hazard zones and residents having little experience of the hazards they face. This also includes environmental degradation	Illegal housing has been a constant feature of the region from 1945 to 1993, when corruption scandals and trials brought this to a standstill. New towns have been built and much illegal settlement has occurred on the potentially hazardous slopes of Vesuvius (see Fig. 1). This is combined with illegal land clearance in valleys and has increased the risk of flooding and landsliding, as occurred at the towns of Quindici and Sarno in 1998 (Fig. 1)
Residual un-ameliorated vulnerability, e.g. old buildings not adjusted to contemporary notions of risk	Many of the older towns, especially those on the coast (Fig. 1), are not adjusted to the eruption threat and are identified as being at great risk in a future eruption. It is from these towns that populations would have to be evacuated. Housing conditions in older towns and in Naples are poor and there has been a lack of investment in sewage and water treatment and in air pollution abatement
Delinquent vulnerability, e.g. flouted safety norms, and the geography of corruption	Weak and corrupt government throughout much of the post-Second World War period has allowed speculative building and a lack of urban planning. Organised crime syndicates, including the *Camorra*, are involved in most aspects of corruption and maladministration

Framework based on Alexander, 1997, p. 292; information from: Agnew and Baillie (1988); King (1988); Barone et al. (1994); Dipartimento della Protezione Civile (1995); Donna (1998); Dobran and Sorrentino (1998); Gumbel (1998).

Alexander (1997). When viewed in this context, progress at Vesuvius is more impressive than it might appear at first sight.

3.3. Etna

Furnas has not erupted since 1630 and Vesuvius not since 1944 and, according to the perceptions of the vast majority of people living in the vicinities of these volcanoes, neither is regarded as active. Etna, in contrast, is one of the few volcanoes in the world which is continually active; attitudinal survey showing a widespread public awareness of danger (Dibben, 1999, pp. 189–197) and hazard maps outlining those areas most at risk have been available for more than 20 years (Guest and Murray, 1979; Duncan et al., 1981; Forgione et al., 1989). At the time the hazard maps were compiled, most of the population was concentrated in compact towns and villages (Fig. 7), which were located in places of relative safety. Over the past 20 years and especially during the decade of the IDNDR, rapid economic growth has expanded urban development away from historic cores, a process which has been particularly marked on the southern flanks of the volcano (Dibben, 1999, pp. 151–156). Indeed there are recent reports that some villages within a 50-km radius of Catania (Fig. 7) are experiencing a boom because of the growth of computer technology companies, causing the area to be given the inaccurate and prosaic title 'Etna Valley' (Lister, 2000). With the exception of some planning restrictions being in place at high altitudes within the Etna National Park, there has been a conspicuous lack of integration of development and disaster planning based on existing hazard maps.

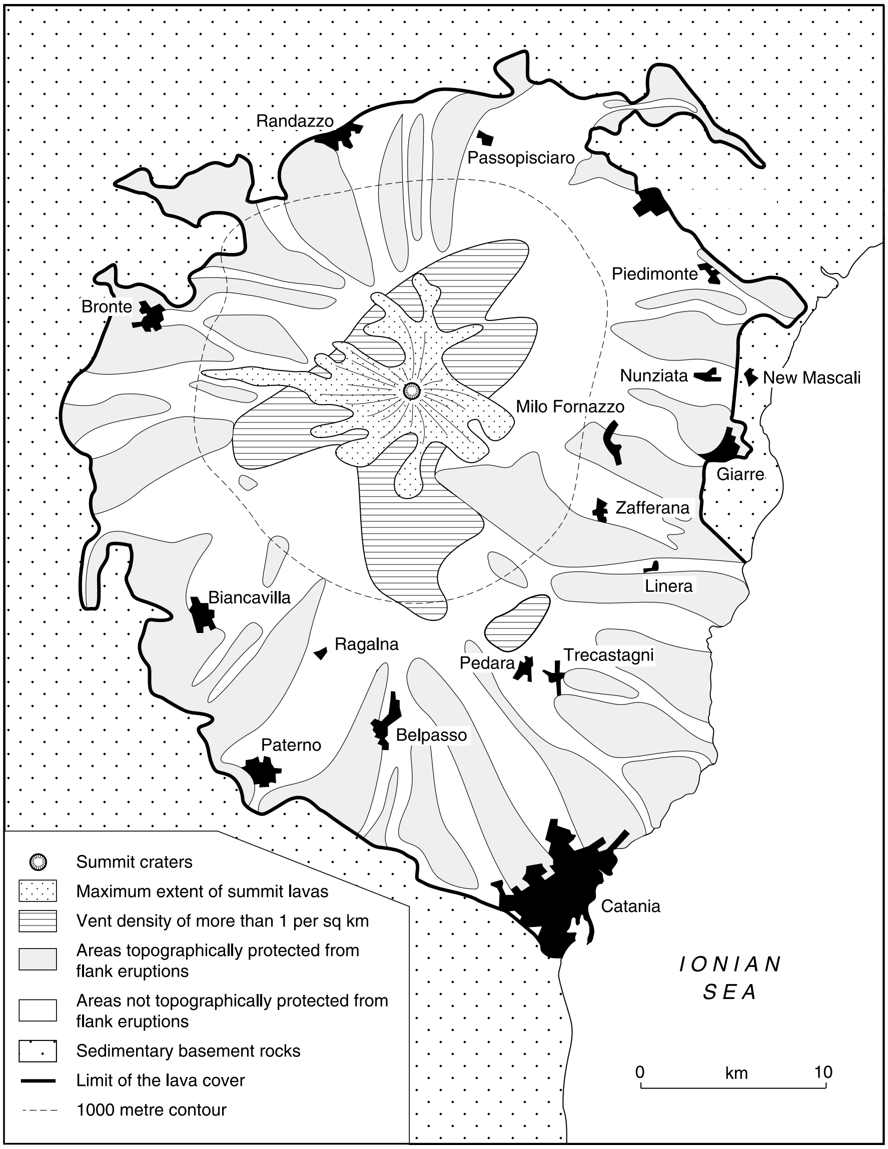

Fig. 7. Hazard map of Etna (Duncan et al., 1981).

A further issue concerns the nature of the hazard response. Following a series of débâcles, when the Italian response to such events as earthquakes in western Sicily (1968) and Avellino, Campania (1980) and the bradyseismic crises in the Phlegraean Fields volcanic region, north west of Naples (1970), was noteworthy for its corruption, incompetence and clientism, the structure of civil defence underwent a root and branch reform. Volcanic hazard evaluation was made the joint responsibility of a newly created scientific group – the National Group for Volcanology – and a Ministry of Civil Protection (Barberi et al., 1984). As the authors have argued elsewhere (Chester et al., 1999b), although the responses of the authorities to eruptions in the last 20 years are generally considered to have been successful (Newhall, 1996), being characterised by orderly evacuation, high profile attempts to divert lava flows and effective aid mobilisation, they remain essentially reactive. The 1983 and 1991–3 eruptions developed slowly and the authorities had plenty of time to marshall their resources of people and equipment. Eruptions in 1923, 1928 and 1981 were, in contrast, typified by their high eruption rates and rapid lava emplacement, and in dealing with events of this type a more proactive approach is required (Villari, 1998).

During the IDNDR many projects have been carried out on Etna and are summarised by Barberi et al. (1995) and have included EtnaTech – concerned with techniques of volcano monitoring and data handling, further study of the 'plumbing' system of Etna, the construction of a Digital Elevation Model (Favalli et al., 1999) and magma and lava flow modelling. Progress has been impressive (Barberi and Villari, 1995), but one criticism which has been raised and has some weight is that there is still too much emphasis on pure research and insufficient on integrating this with hazard mapping, land use zoning and civil defence. As Flavio Dobran (1994, 1995b) has argued, only 8% of the funds available for the Etna Laboratory Volcano Project have been devoted to this end.

Even so, the dominant approach is still being following with an emphasis on the application of new technology and improved mechanisms of civil administration and planning. In order to facilitate the new more 'incultured' agenda, we decided in the early 1990s to initiate an investigation into the response and attitudes of the population to the hazard posed by Etna. It began with a study of the impact of the 1928 eruption which overwhelmed the town of Mascali. This eruption was selected for two reasons: it was the only example in the last 200 years of a town being destroyed by Etna; and in the middle 1990s it was also still possible to gather eyewitness accounts. The 1928 eruption provides a valuable case study, allowing a better understanding to emerge of the impact of Etnean eruptions on rural communities and the reactions to the subsequent responses of the civil authorities (Duncan et al., 1996; Chester et al., 1999b). The evacuation of Mascali was effectively organised and the orderly use of troops and military transport ensured that the inhabitants were able to remove their personal possessions and even parts of the fabric of their homes. On two counts, however, the approach of the local community differed from that of the civil authorities: first, religious processions – calling for divine intervention – were conducted in front of the lava, this being significantly less successful than the official response and, secondly, the displaced population was largely accommodated in nearby villages by extended families and did not require the use of official resettlement camps. In short, the official response was not in tune with the local cultural norms, despite the claims of Mussolini's Fascist press corp.

To investigate perceptions of the present-day population of Etna to volcanic risk, a survey was conducted in the large agricultural village of Trecastagni (Fig. 7). Trecastagni, with a population of around 7000, is located at 550 m (asl) some 18 km southeast of the summit. The survey was carried out using semi-structured telephone interviews and a sample of 200 respondents were contacted. Full details of the methodology are provided by Dibben (1999). It was clear from the survey that there was a 'duality' in attitudes towards the volcano. As one respondent put it, Etna "is beautiful although everyone fears it to some extent". Strongly weighed against the risk from eruptive and seismic activity are the perceived benefits of mountain air, lack of crime and the potential for agriculture and the development of tourism. Eighty-three per cent of the respondents did not consider that the volcano represented a danger and earthquakes were feared much more, which is understandable because the nearby village of Fleri was badly damaged by an earthquake only a few years before the survey was conducted. Indeed, when asked generally about what problems existed in the town, most people mentioned 'everyday' concerns such as unemployment or difficulties commuting to work and not issues related to natural hazards. A smaller majority of respondents (62%) felt that there was no real danger of the town being destroyed by lava, whilst $\sim$50% felt that lava might come close but would miss the town, a perception strongly reinforced by the 1992 lavas which stopped within just 0.5 km of the village of Zafferana (Fig. 7).

It is interesting that 71% of respondents avoided areas of active volcanism, whilst at the same time not being prepared to ''move from a town that might be destroyed by lava''. This conflict between perceptions, which is termed cognitive dissonance, involves individuals justifying their active decision to reside in Trecastagni by a belief that the town is not under threat, but rather that the threat occurs elsewhere. This means that the complex issues of moving from Trecastagni do not have to be addressed and life can go on as normal. Reflective of this attitude is the fact that very few respondents had household insurance.

Over 90% of respondents felt that the State was responsible for reconstruction following a disaster, comments such as ''the State takes taxes and therefore should offer security'' and people ''construct their houses in accordance with the law (and) therefore they should be guaranteed health'' being typical. Some 94% of respondents felt that the State should forbid construction in areas of high risk, but did not feel that this applied either to them or to Trecastagni. It is interesting that around 70% of the respondents believed it was possible for the State to control lava flows. A summary of nine attitudinal statements asked within the survey is presented in Table 5, and full details of the survey can be found in Dibben (1999).

3.4. The other laboratory volcanoes

Krafla, Teide and Santorini, though raising their own unique problems, have some characteristics in common with the three case studies and may be reviewed on a comparative basis. For Krafla much less has been published in the 1990s on risk assessment and vulnerability than is the case for any of the three case study volcanoes. At the start of the IDNDR in 1990, the Icelandic authorities already had a head start in, and a commendable track record of, civil defence planning. For several decades responses to eruptions in Iceland have been grounded in an impressive awareness of local culture and politics (see Chester, 1993, pp. 261–269) and in 1989, several years in advance of the other laboratory volcanoes, a Civil Defence planning document had been published (Icelandic Civil Defence, 1989). An important new area of research involves the retrospective evaluation of how events at Krafla were handled during the 1975–1984 crisis. This crisis was caused by extensive rifting, producing lava, and represented a re-awakening of Krafla

Table 5
Some findings of an attitude survey carried out in the village of Trecastagni (from Dibben, 1999)

Statement	Strongly agree (%)	Agree (%)	Neither agree nor disagree (%)	Disagree (%)	Strongly disagree (%)
Do you believe that there is a danger that the town will be destroyed by lava?	1	61	24	16	
The chance of lava coming close to the town is very high		25	22	52	2
I would suffer great financial hardship if the town were to be destroyed by lava			29	24	48
It would be a great loss for me if this town were destroyed by lava	16	73	11		
I have taken precautions to limit the extent of damage if the town were to be destroyed by lava		5	3	93	
I do not believe that the volcano represents a danger to the inhabitants of this town	3	80	7	12	
The chance of me, or a member of my family, being close to a dangerous eruption is high		32	28	41	
Being close to a lava flow is not dangerous		23	19	58	
I avoid areas of volcanic activity	5	66	11	16	3

The percentage values do not always sum to 100% because of rounding.

after a period of quiescence lasting 247 years (see Sigvaldason, 1996).

In common with the Bay of Naples and the Etna region, Tenerife has shown considerable growth in its population and economic activities in recent years. In the 1920s Tenerife had a population of less than 200 000 and its increase to more than 750 000 today reflects a mushroom growth of tourism, especially since the 1960s. Both for the Canary Islands as a whole and specifically for Teide laboratory volcano on Tenerife, considerable progress has been made in addressing the new 'incultured' agenda of hazard reduction. Using a broadly similar approach to that employed in the Azores, impressive amounts of applied research have been carried out (Gómez, 1996; Ortiz, 1996; Sansón-Cerrato, 1996; Araña et al., 2000); for example GIS has been used to relate eruption probabilities and scenarios to civil defence and evacuation planning (Gómez-Fernández, 2000). One problem to emerge is that members of the public often remain unaware of the risks they face and much effort has been focused on educational extension, especially amongst school children (Ortiz, 1996). Another issue, highlighted by Solana and Aparicio (1999), is that the Canary Islands have many natural and technological hazards (e.g. forest fires, flash floods and coastal flooding) and there has been an unwillingness on the part of the authorities to pay sufficient attention to the less immediate, but no less real, threats of earthquakes and volcanic eruptions. Finally, like the situation in the Azores, it is being realised that 'classic' hazard assessment based on mapping (e.g. Booth, 1979; Carracedo et al., 1990) needs to be related not only to detailed civil defence planning, but also to a greater awareness of society, economy and culture (Araña, 1989; Araña and Ortiz, 1993). In 1996 a new law was enacted which set minimum standards for emergency plans (Solana and Aparicio, 1999) and a detailed assessment of the organisational structure of civil defence was carried out in the same year (see Sansón-Cerrato, 1996).

Santorini, ancient Thera, has been the focus of intense international geological and volcanological research because of scholarly interest in its cataclysmic explosive eruption of ~1600 BC, which had a severe – in the opinion of some terminal – impact on Minoan civilisation. It is because of this long-standing geoarchaeological research that Santorini has some of the most complete and detailed geological, petrological and volcanological background information of any western European volcano. Recently these data have been summarised, evaluated and published by the Geological Society of London (Druitt et al., 1999). In fact some preliminary work on hazard assessment had been carried out just before the start of the IDNDR (Fytikas et al., 1990; Papadopoulos, 1990; Papazachos, 1990). Since Santorini's designation as a European laboratory volcano, an observatory has been established there with a strong commitment not only to developing monitoring networks and collecting baseline data, but also to planning programmes of hazard reduction, mitigation and education. The study of vulnerability is integral to this research and several issues have been addressed. First, and like the situation on Teide, tourism is vital to the island's economy and a resident population of ~10 000 is swelled by over 850 000 visitors each year. Dangers have been exacerbated by unrestricted urban development which has made the island progressively more exposed to eruption-related losses. Local people mistrust, resent and resist hazard evaluation which they perceive will highlight the island's dangers, so blighting its reputation as a benign tourist destination. During the 1990s there has also been a problem of rumour masquerading as fact, because the news media have been responsible for disseminating several false alarms of impending eruptions. This has led to a deep-seated public mistrust of scientists (Fytikas, 1995; Fytikas et al., undated). In spite of these difficulties, much progress has been made in planning programmes of educational extension, to foster good relationships between scientists on the one hand and local people, political leaders and representatives of the mass media on the other.

4. Conclusion

In comparison with the situation that obtained before 1990, considerable progress has been made in Europe in addressing the research agendas of IACVEI (IAVCEI Task Group, 1990) and the IDNDR. As the present account makes clear (see Fig. 3) progress in applied research has not been as impressive as that made in pure research. Also when compared with research currently being undertaken in other economically developed parts of the world, most notable in the USA (e.g. Scarpa and Tilling, 1996), human aspects of volcanic risk and human vulnerability have not been emphasised to the same degree. In the latter half of the decade the European Union attempted to redress this shortcoming by sponsoring workshops both to facilitate the interchange of information between investigators from the six laboratory volcanoes (e.g. Barberi et al., 1995; Barberi et al., 1996) and to educate new hazard analysts (Anon., 1998).

At the present time the international community is planning successor arrangements to follow the IDNDR (United Nations, 1999). Termed the International Strategy for Disaster Reduction (ISDR), this was adopted by the United Nations General Assembly in 1999. Key words and phases in this new strategy are: public awareness; moving from cultures of reaction to cultures of prevention; vulnerable groups and maintaining the sustainability of hazard-prone areas. Applied volcanology both in western Europe and elsewhere is likely to become an even more important part of volcanology than it has been hitherto.

In conflating 'scientific' and 'social' perspectives to produce more effective hazard research additional difficulties arise. As is clear from the research which has been carried out on several laboratory volcanoes, especially on Vesuvius and Santorini, the hazard analyst is forced to enter the political sphere where he or she may have to challenge existing elites, structures of domination and economic interests. They may also have to accept that local inhabitants, despite having an accurate understanding of the risks they face in continuing their existing lifestyles, are happy to accept these, being highly resistant to any interference. To the scientist pure research may seem a lot 'cleaner' and more attractive, and may be part of the reason why there has been only a partial movement towards a fully integrated programme of volcano disaster planning in western Europe.

Acknowledgements

An earlier version of this paper was presented at the European Union-sponsored Advanced Studies Course on Volcanic Hazard Assessment, held in the Azores in June 1998. The authors wish to thank colleagues working on projects on the European laboratory and decade volcanoes for their helpful replies to enquiries about unpublished information and government reports. The views expressed in this written submission are, however, solely those of the authors. Thanks are due to Sandra Mather for expertly drafting the figures.

References

Agnew, J., Baillie, S., 1988. Spaghetti junction. Geogr. Mag. 60, 31–36.

Alexander, D., 1997. The study of natural disasters, 1977–1999: Some reflections on a changing field of knowledge. Disasters 21, 284–304.

Anon., 1992. Opportunities for British involvement in the International Decade for Natural Disaster Reduction (IDNDR). Proceedings of a workshop held on 27 March 1992. The Royal Society and The Royal Society of Engineering, London.

Anon., 1993. Medicine in the International Decade for Natural Disaster Reduction (IDNDR). Proceedings of a workshop at The Royal Society, London. The Royal Society and The Royal Society of Engineering, London.

Anon., 1994. A World Safe from Natural Disasters: The Journey of Latin America and the Caribbean. Pan-American Health Organization, Washington, DC.

Anon., 1996. See it and don't die. Economist 2, 94.

Anon., 1998. Volcanic hazard assessment, monitoring and risk mitigation, S. Miguel Island, Azores, 7–14 June 1998 (Abstr.). Universidade dos Açores, Centro de Vulcanologia, Ponta Delgada, Azores.

Anon., 2000. Etna. Bull. Glob. Volcan. Network 25, 6–8.

Araña, V., 1989. Evaluación del riesgo volcánico en la zona de Santiago del Teide. European Science Foundation (ESF), Proceedings of the ESF Meeting on Canarian Volcanism, Brussels, pp. 260–266.

Araña, V., Ortiz, R., 1993. Riesgo volcánico. In: Araña, V., Marti, J. (Eds.), La Volcanologia Actual. Consejo Superior de Investigaciones Cientificas, pp. 277–385.

Araña, V., Felpeto, A., Astiz, M., García, A., Ortiz, R., Abella, R., 2000. Zonation of the main volcanic hazards (lava flows and ash fall) in Tenerife, Canary Islands. A proposal for a surveillance network. J. Volcanol. Geotherm. Res. 103, 377–391.

Bankoff, G., 2001. Rendering the world unsafe: 'Vulnerability' as western discourse. Disasters 25, 19–35.

Barberi, F., Villari, L., 1995. Volcano monitoring and civil protection problems during the 1991–1993 Etna eruption. In: Barberi, F., Casale, R., Fratta, M. (Eds.), The European Laboratory Volcanoes, Workshop Proceedings, Aci Castello (Catania), 18–21 June 1994. European Commission, Brussels, pp. 40–48.

Barberi, F., Corrado, G., Innocenti, F., Luongo, G., 1984. Phlegraean Fields 1982–1984: Brief chronicles of a volcano emergency in a densely populated area. Bull. Volcanol. 47, 175–185.

Barberi, F., Macedonio, C., Pareschi, M.T., Santacroce, R., 1990. Mapping the tephra fallout risk: An example from Vesuvius (Italy). Nature 344, 142–144.

Barberi, F., Casale, R., Fratta, M. (Eds.), 1995. The European Laboratory Volcanoes. Workshop Proceedings, Aci Castello (Catania), 18–21 June 1994. European Commission, Brussels.

Barberi, F., Casale, R., Fantechi, R. (Eds.), 1996. The mitigation of volcanic hazards. Environment and Climate Programme, Proceedings of the Course. European Commission, Brussels.

Barone, G., Piaz, A.D., Lirer, L., Marselli, G.A., 1994. Naples Past, Present and Future: Metropolitan Area and Sustainable Development. Alfredo Guida, Naples.

Baxter, P.J., Baubron, J.-C., Chester, D.K., Davies, F.B.M., Dibben, C.L., Cole, P.D., Coutinho, R., Petersen, G., Pomonis, A., 1995. Assessing vulnerability at Furnas Volcano, São Miguel, Azores. In: Barberi, F., Casale, R., Fratta, M. (Eds.), The European Laboratory Volcanoes: Workshop Proceedings, Aci Castello (Catania), 18–21 June 1994. European Commission, Brussels, pp. 206–208.

Baxter, P.J., Neri, A., Todesco, M., 1998. Physical modelling and human survival in pyroclastic flows. Nat. Hazards 1, 163–176.

Baxter, P.J., Baubron, J.-L., Coutinho, R., 1999. Health hazards and disaster potential of ground gas emissions at Furnas Volcano, Sao Miguel, the Azores. J. Volcanol. Geotherm. Res. 92, 95–106.

Blaikie, P., Cannon, T., Davis, I., Wisner, B., 1994. At Risk: Natural Hazards, People's Vulnerability and Disasters. Routledge, London.

Booth, B., 1979. Assessing volcanic risk. J. Geol. Soc. London 136, 331–340.

Burton, I., Kates, R.W., White, G., 1978. The Environment as Hazard. Oxford University Press, New York.

Carey, S.N., Sigurdsson, H., 1986. The 1982 eruptions of El Chichon volcano, Mexico (2): Observations and numerical modelling of tephra-fall distribution. Bull. Volcanol. 48, 127–141.

Carracedo, J.C., Soler, V., Rodriguez-Badiola, E., Hoyos, M., 1990. Zonificación del riesgo para erupciones de baja magnitud en la Isla de Tenerife. Proceedings of the V Reunión Nacional de Geologia Ambiental y Ordenación del Territorio (Gijón), Septiembre 1990, pp. 65–72.

Chester, D.K., 1993. Volcanoes and Society. Edward Arnold, London.

Chester, D.K., 2002. Volcanoes and society. In: Marti, J., Ernst, G.J. (Eds.), Volcanoes and the Environment. Cambridge University Press, Cambridge, in press.

Chester, D.K., Duncan, A.M., Guest, J.E., Kilburn, C.R.J., 1985. Mount Etna: The Anatomy of a Volcano. Chapman and Hall, London.

Chester, D.K., Dibben, C., Coutinho, R., 1995. Report on the evacuation of the Furnas District, São Miguel, Azores, in the event of a future eruption. Planetary Image Centre, University College London. Furnas Open File Report 4.

Chester, D.K., Dibben, C., Coutinho, R., Duncan, A.M., Guest, J.E., Baxter, P.J., 1999a. Human adjustments and social vulnerability to volcanic hazards: The case of Furnas Volcano, Sao Miguel, Azores. Geol. Soc. London Spec. Publ. 161, 189–207.

Chester, D.K., Duncan, A.M., Dibben, C., Guest, J.E., Lister, P.H., 1999b. Mascali, Mount Etna, Sicily: An example of *Fascist* planning during the 1928 eruption and its continuing legacy. Nat. Hazards 19, 29–46.

Chester, D.K., Degg, M., Duncan, A.M., Guest, J.E., 2001. The increasing exposure of cities to the effects of volcanic eruptions: A global survey. Environ. Hazards 2, 89–103.

Clay, E., Barrow, C., Benson, C., Dempter, J., Kokelaar, P., Pillaia, N., Seaman, J., 1999. An evaluation of HMG's response to the Montserrat Volcanic Emergency. Department for International Development, London, Evaluation Report EV635.

Cole, P.D., Guest, J.E., Queiroz, G., Wallenstein, N., Pacheco, J.M., Gaspar, J.L., Ferreira, T., Duncan, A.M., 1999. Styles of volcanism and volcanic hazards on Furnas volcano, São Miguel, Azores. J. Volcanol. Geotherm. Res. 92, 39–53.

Decker, R., Decker, B., 1997. Volcanoes. Freeman, New York.

Degg, M., 1992. Natural disasters: Recent trends and future prospects. Geography 77, 198–209.

Degg, M., 1998. Natural hazards in the urban environment: The need for a more sustainable approach to mitigation. In: Maund, D.R., Eddleston, M. (Eds.), Geohazards in Engineering Geology. Geological Society, London, Eng. Geol. Spec. Publ. 15, 329–337.

Degg, M.R., Doornkamp, J.C., 1991. Earthquake Hazard Atlas 3. Italy. London Insurance and Reinsurance Market Association (LIRMA), London.

Dibben, C., 1999. Looking beyond Eruptions for an Explanation of Volcanic Disasters: Vulnerability in Volcanic Environments. Unpubl. PhD Thesis, University of Luton.

Dibben, C., Chester, D.K., 1999. Human vulnerability in volcanic environments: The case of Furnas Volcano, São Miguel, Azores. J. Volcanol. Geotherm. Res. 92, 133–150.

Dicken, P., 1986. Global Shifts: Industrial Change in a Turbulent World. Harper and Row, London.

di Donna, V., 1998. Analisi socio-economica dell'area vesuviana. In: Dobran, F. (Ed.), Educazione al Rischio Vesuvio.

Global Volcanic and Environmental Systems Simulation, Naples, pp. 39–48.

Dipartimento della Protezione Civile, 1995. Pianificazione Nazionale d'Emergenza dell'Area Vesuviana. Prefettura di Napoli, Naples.

Dobran, F., 1994. Magma and Lava Flow Modelling and Volcanic System Definition Aimed at Hazard Assessment at Etna. Giardini, Pisa.

Dobran, F., 1995a. A risk assessment methodology at Vesuvius based on the global volcanic simulation. In: Horlick-Jones, T., Amendola, A., Casale, R. (Eds.), Natural Risk and Civil Protection. E. and F.N. Spon, London, pp. 131–136.

Dobran, F., 1995b. Magma and lava flow modelling and volcanic system definition aimed at hazard assessment at Etna. In: Barberi, F., Casale, R., Fratta, M. (Eds.), The European Laboratory Volcanoes. Workshop Proceedings, Aci Castello (Catania), 18–21 June 1994. European Commission, Brussels, pp. 87–95.

Dobran, F., 2000. Mitigation of volcanic disasters in densely populated areas. Web-site http://www2.ios.com/–dobran/publ.htm (accessed 30/11/01).

Dobran, F., Sorrentino, G., 1998. Sondaggio sull'educazione al rischio Vesuvio. In: Dobran, F. (Ed.), Educazione al Rischio Vesuvio. Global Volcanic and Environmental Systems Simulation, Naples, pp. 49–62.

Dobran, F., Neri, F., Tedesco, M., 1994. Pyroclastic flow hazard at Vesuvius. Nature 367, 551–554.

Druitt, T.H., Edwards, L., Mellors, R.M., Pyle, D.M., Sparks, R.S.J., Lanphere, M., Davies, M., Barriero, B., 1999. Santorini Volcano. Geol. Soc. London Mem. 19.

Duffield, W.A., Tilling, R.I., Canul, R., 1984. Geology of El Chichón Volcano, Chiapas, Mexico. J. Volcanol. Geotherm. Res. 20, 117–132.

Duncan, A.M., Chester, D.K., Guest, J.E., 1981. Mount Etna Volcano: Environmental impact and problems of volcanic prediction. Geogr. J. 147, 164–179.

Duncan, A.M., Dibben, C., Chester, D.K., Guest, J.E., 1996. The 1928 eruption of Mount Etna Volcano, Sicily, and the destruction of the town of Mascali. Disasters 20, 1–20.

Espíndola, J.M., Macías, J.L., Tilling, R.L., Sheridan, M.F., 2000. Volcanic history of El Chichón Volcano (Chiapas, Mexico) during the Holocene, and its impact on human activity. Bull. Volcanol. 62, 90–104.

Favalli, M., Innocenti, F., Pareschi, M.T., Pasquarè, G., Mazzarini, F., Branca, S., Cavarra, L., Tibaldi, A., 1999. The DEM of Mt. Etna: Geomorphological and structural implications. Geodin. Acta (Paris) 12, 279–290.

Filson, J.R., 1987. Geological hazards: Programs and research in the USA. Episodes 10, 292–295.

Fisher, R.V., Heiken, G., Hulen, J.B., 1997. Volcanoes: Crucibles of Change. Princeton University Press, Princeton, NJ.

Forgione, G., Luongo, G., Romano, R., 1989. Mount Etna, Sicily: Volcanic hazard assessment. In: Latter, J.H. (Ed.), Volcanic Hazard Assessment and Monitoring. Springer, Berlin, pp. 137–150.

Fytikas, M., 1995. Santorini Volcano Laboratory. In: Barberi, F., Casale, R., Fratta, M. (Eds.), The European Laboratory Volcanoes. Workshop Proceedings, Aci Castello (Catania), 18–21 June 1994. European Commission, Brussels, pp. 174–183.

Fytikas, M., Vougioukalakis, G., Dalabakis, P., Bardintzeff, J.-M., undated. Final Scientific Report on the Volcanic Hazard Assessment, Risk Evaluation, Public Information and Civil Protection Planning on Santorini. Santorini Volcano Laboratory, Unpublished Report, Contract EV5V-CT93-0185.

Fytikas, M., Kolios, N., Vougioukalakis, G., 1990. Post-Minoan volcanic activity of the Santorini Volcano. Volcanic hazard and risk, forecasting possibilities. In: Hardy, D.A., Keller, J., Galanopoulos, V.P., Flemming, N.C., Druitt, T.H. (Eds.), Thera and the Aegean World II, Vol. 2, Earth Sciences. The Thera Foundation, London, pp. 183–198.

Gómez, F., 1996. Los sistemas de información geográfica (GIS) en la evaluación del riesgo volcánico. In: Ortiz, R. (Ed.), Riesgo Volcánico. Servicio de Publicaciones, Cabildo de Lanzarote: Consejeria de Cultura, Serie de Los Volcanes 5, pp. 123–153.

Gómez-Fernández, F., 2000. Application of a GIS algorithm to delimit the areas protected against basic lava flow invasion on Tenerife Island. J. Volcanol. Geotherm. Res. 103, 409–423.

Guest, J.E., Murray, J.B., 1979. An analysis of hazard from Mount Etna Volcano. J. Geol. Soc. London 136, 347–354.

Guest, J.E., Gaspar, J.L., Cole, P.D., Queiroz, G., Duncan, A.M., Wallenstein, N., Ferriera, T., Pacheco, J.-M., 1999. Volcanic geology of Furnas Volcano: São Miguel, Azores. J. Volcanol. Geotherm. Res. 92, 1–29.

Gumbel, A., 1998. After the deluge: The mudslides that devastated central Italy were just the start. The real catastrophe is waiting to happen. The Independent (London), 13 June, p. 1 and p. 13.

Hamilton, F.E.I., 1991. Global economic change. In: Bennett, R.J., Estall, R.C. (Eds.), Global Change and Challenge. Routledge, London, pp. 80–102.

Hewitt, K. (Ed.), 1983. Interpretations of Calamity. Allen and Unwin, London.

Hewitt, K., 1997. Regions of Risk: A Geographical Introduction to Disasters. Longman, Harlow.

Hoernes, R., 1893. Erdbebenkunde. Verlag Veit, Leipzig.

IAVCEI Task Group, 1990. Reducing volcanic disasters in the 1990s. Bull. Volcanol. Soc. Jpn. 35, 80–95.

Icelandic Civil Defence, 1989. Neydłaráætlun Vegna Kröfluelda. Icelandic Civil Defence, Reykjavik.

James, P.A., Chester, D.K., Duncan, A.M., 2000. Soils of Quaternary volcanic lavas: Some archaeological considerations. Geol. Soc. London Spec. Publ. 171, 317–338.

Jones, G., Hollier, G., 1997. Resources Society and Environmental Management. Chapman, London.

King, R., 1985. The Industrial Geography of Italy. Croon and Helm, Beckenham.

King, R., 1988. The system is dead: Long live the system. Geogr. Mag. 60, 19–23.

Lechet, M.F., 1990. The international decade for natural disaster reduction. Disasters 14, 1–6.
Lénat, J.-F., Fitterman, D., Jackson, D.B., 2000. Geoelectrical structure of the central zone of Piton de la Fournaise volcano (Réunion). Bull. Volcanol. 62, 75–89.
Lipman, P.W., Mullineaux, D.R. (Eds.), 1981. The 1980 Eruptions of Mount St. Helens, Washington. US Geol. Surv. Prof. Pap., Washington, DC, 1250 pp.
Lister, D., 2000. Revolution in the shadow of Etna. The Times, London, August 28.
Macdonald, G.A., 1958. Barriers to protect Hilo from lava flows. Pacif. Sci. 12, 258–277.
Macdonald, G.A., 1972. Volcanoes. Prentice-Hall, Englewood Cliffs, NJ.
Masood, E., 1995. Row erupts over evacuation plans for Mount Vesuvius. Nature 377, 471.
Matthews, R., 1998. The Vesuvius Dilemma. Sunday Telegraph, London, April 12, p. 21.
Mc Guire, W.J., 1995. Prospects for volcano surveillance. In: Mc Guire, W.J., Kilburn, C., Murray, J. (Eds.), Monitoring Active Volcanoes. UCL Press, London, pp. 403–410.
Mitchell, B., 1979. Geography and Resource Analysis. Longman, London.
Neumann van Padang, M., 1960. Measures taken by the authorities of the Volcanological Survey to safeguard the population from the consequences of volcanic outbursts. Bull. Volcanol. 23, 181–192.
Newhall, C., 1996. IAVCEI/International Council of Scientific Unions' Decade Volcano Projects: Reducing Volcanic Disaster. Status Report, US Geol. Surv., Washington, DC.
Newhall, C.G., Punongbayan, R.S., 1997. Fire and Mud: Eruptions and Lahars of Mount Pinatubo, Philippines. University of Washington Press, Seattle, WA.
Ortiz, R., 1996. Riesgo Volcánico. Servicio de Publicaciones, Cabildo de Lanzarote. Consejeria de Cultura, Serie de Los Volcanes, 5.
Papadopoulos, G.A., 1990. Deterministic and stochastic models of seismic and volcanic events in the Santorini Volcano. In: Hardy, D.A., Keller, J., Galanopoulos, V.P., Flemming, N.C., Druitt, T.H. (Eds.), Thera and the Aegean World II, Vol. 2, Earth Sciences. Thera Foundation, London, pp. 151–159.
Papazachos, B.C., 1990. Long- and short-term prediction of volcanic eruptions in Santorini. In: Hardy, D.A., Keller, J., Galanopoulos, V.P., Flemming, N.C., Druitt, T.H. (Eds.), Thera and the Aegean World II, Vol. 2, Earth Sciences. Thera Foundation, London, pp. 224–228.
Pareschi, M.T., Favalli, M., Giannini, F., Sulpizio, R., Zanchetta, G., Santacroce, R., 2000a. May 5, 1998, debris-flows in the circum-Vesuvian areas (southern Italy): Insight for hazard assessment. Geology 28, 639–642.
Pareschi, M.T., Cavarra, L., Favalli, M., Giannini, F., Meriggi, A., 2000b. GIS and volcanic risk management. Nat. Hazards 21, 361–379.
Pelling, M., 2001. Natural disasters. In: Castree, N., Braun, B. (Eds.), Social Nature: Theory, Practice and Politics. Blackwell, Oxford, pp. 170–188.
Peterson, D.W., 1986. Volcanoes: Tectonic setting and impact on society. In: Active Tectonics. National Academy Press, Studies in Geophysics, Washington, DC, pp. 231–246.
Peterson, D.W., Tilling, R.I., 1993. Interactions between scientists, civil authorities and the public at hazardous volcanoes. In: Kilburn, C.R.J., Luongo, G. (Eds.), Active Lavas. UCL Press, London, pp. 339–365.
Pomonis, A., Spence, R., Baxter, P., 1999. Risk assessment of residential buildings for an eruption of Furnas Volcano, São Miguel, the Azores. J. Volcanol. Geotherm. Res. 92, 107–131.
Rolandi, G., Barella, A.M., Borelli, A., 1993. The 1631 eruption of Vesuvius. J. Volcanol. Geotherm. Res. 58, 183–201.
Rosi, M., Principe, G., Vecci, R., 1993. The 1631 Vesuvian eruption: A reconstruction based on historical and stratigraphical data. J. Volcanol. Geotherm. Res. 58, 151–182.
Sansón-Cerrato, J., 1996. La proteción civil ante en riesgo de erupciones volcánicas. In: Ortiz, R. (Ed.), Riesgo Volcánico. Servicio de Publicaciones, Cabildo de Lanzarote, Consejeria de Cultura, Serie de Los Volcanes 5, pp. 197–216.
Scarpa, R., Tilling, R.I. (Eds.), 1996. Monitoring and Mitigation of Volcanic Hazards. Springer, Berlin.
Scarth, A., 1999. Vulcan's Fury: Man Against the Volcano. Yale University Press, New Haven, CT.
Self, S., Mouginis-Mark, P.J., 1995. Volcanic eruptions, prediction, hazard assessment, remote sensing and social implications. Rev. Geophys. (Suppl.), July, pp. 257–262.
Sigurdsson, H. (Ed.), 2000. Encyclopedia of Volcanoes. Academic Press, San Diego, CA.
Sigvaldason, G.E., 1996. Precursors to the Krafla rifting episode and human reactions: A case history. In: Barberi, F., Casale, R., Fantechi, R. (Eds.), The Mitigation of Volcanic Hazards. European Commission, Brussels, Environment and Climate Programme (EUR 16804 en), Proceedings of Course (Vulcano 12–18 June 1994), pp. 443–450.
SIRDPC, 1992. Plan de Secours Specialisé 'Eruptions Volcaniques'. Prefecture de la Réunion and Service Interministériel Régional de Défence et de Protection Civile, Réunion.
Solana, M.C., Aparicio, A., 1999. Reconstruction of the 1706 Montaña Negra eruption. Emergency procedures for Garachico and El Tanque, Tenerife, Canary Islands. In: Firth, C.R., McGuire, W.J. (Eds.), Volcanoes in the Quaternary. Geol. Soc. London Spec. Publ. 161, 209–216.
Staudacher, T., 2000. An eruption at Piton de la Fournaise. Geotimes 45, 29.
Susman, P., O'Keefe, P., Wisner, B., 1983. Global disasters, a radical interpretation. In: Hewitt, K. (Ed.), Interpretations of Calamity. Allen and Unwin, London, pp. 263–283.
Tárranga, M., Garcia, A., Ortiz, R., Abella, R., Pena, J., 2001. SANARIS Project: A satellite network for natural risk monitoring. Nat. Hazards 23, 417–429.
Tilling, R.I. (Ed.), 1989. Short Courses in Geology, Vol. 1: Volcanic Hazards. United States Government Printing Office, American Geophysical Union, Washington, DC.
Tilling, R.I., Lipman, R.W., 1993. Lessons in reducing volcanic risk. Nature 364, 277–280.

UNESCO, 1993. Environment and Development, Brief 5: Disaster Reduction. United Nations Educational, Scientific and Cultural Organisation, Paris.

United Nations, 1995. Yokohama Strategy and Plan of Action for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation. United Nations, New York.

United Nations, 1996. An Urbanising World: Global Report on Human Settlements 1996. United Nations, New York.

United Nations, 1999. International Decade for Natural Disaster Reduction: Successor Arrangements. United Nations, New York.

Valentine, G., Heiken, G., 1995. Volcanoes in Town, 27–30 September 1995. IAVCEI Comm. Explos. Volcan. Newsl. 27, 3–4.

Villari, L., 1998. Volcanic warning systems and civil protection preparedness in Italy. In: Volcanic Hazard Assessment, Monitoring and Risk Mitigation, S. Miguel Island, Azores, 7–14 June 1998 (Abstr.). Centro de Vulcanologia, Universidade dos Açores, Ponta Delgada, pp. 35.

Wadge, G. (Ed.), 1994. Natural Hazards and Remote Sensing. The Royal Society and The Royal Society of Engineering, London.

Wallenstein, N., Gaspar, J.L., Queiroz, G., Ferreira, T., Alves, P., 1999. Plano Municipal de Emergéncia Concelho de Vila Franca do Campo. Açores, Câmara Municipal de Vila Franca do Campo Serviçpo Regional de Protecção Civil dos Açores e Centro de Vulcanologia da Universidade dos Açores, Ponta Delgada.

White, G.F., 1942. Human Adjustment to Floods: A Geographical Approach to the Flood Problem in the United States. Department of Geography, University of Chicago, Research Paper 29.

Williams, H., McBirney, A.R., 1979. Volcanology. Freeman Cooper, San Francisco, CA.

Wright, T.L., Pierson, T.C., 1992. Living with Volcanoes: The US Geological Survey's Volcano Hazards Program. United States Geological Survey, Washington DC, Circular 1073.

Zupka, D., 1996. Working to reduce volcanic risks in Argentina. Stop Disasters 29, 26–27.