Title Looking beyond eruptions for an explanation of volcanic disasters: vulnerability in volcanic environments

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Looking beyond eruptions for an explanation of volcanic disasters: Vulnerability in volcanic environments.

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ABSTRACT

'Natural' disasters have traditionally been viewed as the result of an extreme physical environment. A radical backlash against this dominant view, in the nineteen seventies and eighties, moved the debate to the opposite extreme and in doing so replaced physical with social determinism. Vulnerability analysis is proposed as a methodology that bridges these extremes. It takes into account individual decision making, social milieu and physical hazard when describing human habitation in areas of volcanic activity. It is argued that vulnerability should be defined in terms of universal human needs in order to avoid it simply being a measure of the chance of death and injury or losing its meaning in the uncertainty of cultural relativism. Once vulnerability is identified it is important to explore why it has come to exist. A contextual theory of vulnerability change is presented.

Vulnerability to volcanic activity was explored in the area around Mt. Etna in Sicily (Italy) and Furnas volcano San Miguel in the Azores (Portugal) using a case study methodology. This included: collecting data through interviews (semi-structured and structured) and field surveying, utilising census and other secondary data sources, and examining historical documents and texts. The volcanic hazard on Mt. Etna is related to regular (4-7 years) effusive lava flows which threaten property and land rather than people. Living in a European state, it is likely that a victim of Mt. Etna will have their basic needs provided for in the long-term and therefore they are not vulnerable. In contrast the irregular explosive eruptions of Furnas, last eruption 1630, not only damage property and land but also endanger lives. The limited ability of individuals to protect themselves in the event of an eruption and organisations to aid them in this means that, in spite of state insurance, many around Furnas are vulnerable.

The production of vulnerability around Etna and Furnas is strongly related to the socio-economic nature of the region and wider European and global contexts. Opportunities and constraints that exist across socio-physical space encourage behaviour and forms of life which, in turn, produce various levels of vulnerability. Individuals seem to cognitively diminish their perceptions of this threat within a context of social representations of low risk. They, and society as a whole, rarely seem to engage directly with the risk itself.

For my Grandmother

Eleanor

CONTENTS

LIST OF FIGURES

PREFACE

During the course of this thesis, a number of papers have been published by the author within journals and presented at conferences:

Dibben, C. and Chester, D.K. (1999) Human Vulnerability in Volcanic Environments: the Case of Furnas, San Miguel, Azores. *Journal of Volcanology and Geothermal Research*, (in press).

Chester, D.K., Duncan, A., Dibben, C; Guest, J. and Lister, P. (1999) Mascali, Mount Etna Region, Sicily. *Natural Hazards,* (accepted subject to revisions).

Chester, D.K., Dibben, C., Coutinho, R., Duncan, A.M, Cole P.D., Guest, J. and Baxter, P.J. (1999) Human Adjustments and Social Vulnerability to Volcanic Hazards: The Case of Furnas Volcano, Sao Miguel, Azores. *Special publication of the Geological Society of London*, (in press).

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

Dibben, C. (1995) Review of: Scarth, A., Volcanoes. *Progress in Physical Geography*, 19 (3), 423-424.

Dibben, C. and Chester, D. (1997) Conceptualisations of volcanic environments: implications for the communication of information during crisis and non-crisis periods. Paper presented at: *Extreme Natural Disasters: Mitigating strategies for the 21st century*, the Royal Society, London. A UK contribution to the IDNDR sponsored by the Royal Society.

Chester, D., Dibben, C., Duncan, A. and Guest, J. (1996) The 1928 eruption of Mount Etna and the destruction of the town of Mascali: Hazard implications of short-lived, high effusive eruptions. *In*: Gravestock, P. and McGuire, W. (eds.) *Etna: Fifteen years on.* Conference Proceedings, Cheltenham & Gloucester College of Higher Education, Cheltenham. A UK contribution to the IDNDR sponsored by the Royal Society, 58-60.

Dibben, C. and Chester, D. (1995) Volcanic Hazard - Tools and Techniques for Community Vulnerability Analysis. Paper presented at: *The Assessment of Community Vulnerability in Hazard Prone Areas* Workshop, Royal Society, London 31 March: Committee for UN IDNDR.

Chester, D. and Dibben, C. (1994) Evacuation routes from Furnas Volcano - San Miguel, Azores. Paper presented at *British Laboratory Volcano workshop*, British Antarctic Survey, Cambridge.

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A special thanks to my parents for proof reading the final draft of my thesis, my brother for lending me his computer and to Palvi for keeping me smiling when the end looked far away.

DECLARATION

I declare that this thesis is my own unaided work. It is being submitted for the degree of Doctor of Philosophy at the University of Luton. It has not been submitted before for any degree or examination in any other University.

Some of the information drawn upon in this thesis originated from joint work, as demonstrated by the papers listed in the preface. Where I feel that the arguments presented are not solely my own, I have referenced the relevant paper. All field work was carried out independently of other projects. The only exception was the survey of roads out of the Furnas caldera which was carried out jointly with Dr David Chester.

Chris Dibben
9th January 1999

CHAPTER ONE: INTRODUCTION

1.1 PRELUDE

Despite advances in many spheres of human life, an increasing number of people are dying or suffering because of so called 'natural' disasters. The total number of people killed between 1969-89 was 1,490,129 compared to 441,855 between 1947-67 (Degg, 1992, p. 201). The average number of people killed in each event has also increased, as has the proportion of the dead originating from outside Western Europe and North America (94% between 1947-67 compared to 99% between 1969-89). In response to this trend the United Nations decided that the 1990's should become a designated decade for natural disaster reduction. This gave an impetus to a great number of projects that were to analyse many aspects of natural disasters. This thesis was written during the *International Decade for Natural Disaster Reduction*. It attempts to shed light on a process that throughout history has caused the death of thousands and that, today, threatens millions, namely volcanic eruptions.

Volcanoes have produced a great many different landscapes and take, during periods of activity, a variety of different forms. These active processes are sometimes regular and predictable while at others times they are far less so. It is generally true that the most destructive types of volcanic eruptions are unpredictable and take place at irregular intervals. A majority of volcanoes, situated in areas where human settlement is possible and attractive, do have people living on or around them. This often raises the question, for those who live in areas of less visually obvious hazard, of why people choose to live in such an environment. A second question is why volcanic disasters happen. To the observer the answer seems quite straight forward; it is the result of a highly destructive force of nature. The impressive nature of volcanic eruptions means that they are often vividly portrayed within the media, literature and indeed culture generally. But, just as the sight of an eruption would tend to dominate one's attention, so the study of volcanic disasters has often been dazzled by the volcanic eruption to the exclusion of other factors. The aim of this thesis is to look beyond, as well as at, an eruption as the cause of volcanic disasters.

It is important to see a volcanic disaster as more than just a physical event acting upon a passive population. At present volcanic hazard mitigation is dominated by exercises in primary geological and geophysical research, monitoring and 'knee-jerk' emergency management all aimed at trying to understand and respond, primarily, to volcanic processes. This thesis will evaluate the effectiveness of the accepted dominant approach and propose a more comprehensive framework with which to study regions affected by volcanic activity.

1.2 THE AIM OF THE RESEARCH

The main aim of this thesis is:

- To produce a more comprehensive framework with which to explain volcanic disasters.

In order to do this two objectives need to be achieved. These are:

- To develop an approach that is capable of identifying what antecedent conditions tend to precipitate volcanic disasters.

- To develop a theory capable of explaining the production of these conditions.

These are the main objectives for Part One of this thesis. The objective for Part Two is:

- To test the approach and theory in the context of two case studies. To examine whether vulnerability is increasing or decreasing in these areas. To suggest how vulnerability in these regions might be reduced.

The two case studies, one of the region around Mount Etna volcano (Sicily) in Italy and the other the region around Furnas volcano (Azores) Portugal, will allow trends in the changing situation of vulnerability to be identified. This will apply specifically to a European context. The work is constrained in this way in order to allow meaningful comparisons to be made in terms of volcanism (eg. explosive vs. effusive type eruptions). This requires other aspects within the area of research to be similar. While economic or social conditions are not constant across Europe, there is enough similarity, especially with on going European integration, to talk in terms of a European condition. From this information it will be possible to return to the central research question and propose a number of reasons why volcanic disasters happen.

1.3 STRUCTURE OF THE THESIS

There are two distinct parts to this thesis. In **Part One** (chapters 2-6) an approach for identifying the conditions necessary for a volcanic disaster to take place is developed and a theory to explain why these conditions come to exist is advanced. In **Part Two**, (chapters 7-10) this approach is used to explore vulnerability in two volcanic areas. Both parts of the thesis involve original work. In part one this is predominantly theory development. In part two it is field based research with some theory development.

In **chapter two** the literature on natural hazards is introduced. The development of the area of research will be examined chronologically. Three main phases in the work are suggested, the ecological, radical and integrative traditions. The argument is made that the literature points towards integrative approaches as the most effective way of studying natural hazards and disasters.

In **chapter three** the concept of vulnerability is presented as an integrative approach to examining volcanic hazard and disasters. A method for vulnerability analysis in volcanic hazards is developed in **chapters four, five** and **six**. A number of bodies of literature will be brought together to achieve this goal. This includes *inter alia* theories of: basic needs, social deprivation, risk behaviour, risk perception, risk cultures, disaster behaviour, place, social representation, attitude formation, decision making and society.

In **part two** of the thesis the vulnerability approach developed will be applied to the two case study regions. Within **chapter seven** the methodology used to collect and analyse the data within the two case studies is outlined. The two case studies are then described in **chapters eight** and **nine**. The first of these is the region around Mount Etna (Sicily) in Italy and the second the region around Furnas volcano (Azores) Portugal. In each case study, volcanic activity in the region is described, its interaction with the population examined and the reasons for changes in vulnerability identified. Various methods were used to collect the data for this analysis, these included: interviewing, examination of secondary data sources and scrutiny of historical documents and texts.

A discussion, in **chapter ten,** aims at critically assessing both the theories developed within the thesis and to examine the broader issue of vulnerability mitigation. The themes discussed include: behaviour and risk perception, the importance of routine, place and space, the importance of specific spatial forms:

islands, valleys and the city, opportunity and constraint, time-space distanciation, a European disaster context and, lastly, technology as a source of volcanic threat. The implications for vulnerability mitigation of these and other findings are then considered.

In the conclusion to the thesis, **chapter eleven**, it will be argued that: [1] an approach that is capable of identifying what antecedent conditions tend to precipitate volcanic disasters has been developed. This approach resolves around the interface between physical and human systems. [2] A theory capable of explaining the production of these conditions has been developed. Within this theory, volcanic vulnerability is seen principally as a function of historically given dynamic social conditions as they exist within and across various hierarchies of space. [3] The approach and theory have been tested in the context of two case studies. The approach revealed the nature of personal vulnerability in these areas and the theory provided a credible explanation why this should be. [4] The case studies have more to tell us about the general problem of vulnerability in volcanic environments. It has shed light on the relationship between factors such as technology, international economics, democracy, welfare polices, urbanisation, economic growth, regional geography with vulnerability. [5] The final issue, how vulnerability can be reduced, is the most problematic. It is suggested that a programme of vulnerability reduction incorporating an empowered vulnerable and others in a debate on technological, political and economic measures should be developed.

PART ONE

CHAPTER TWO: DISASTER AND HAZARD RESEARCH

2.1 INTRODUCTION

This chapter gives an overview of research into natural hazards. It outlines the main findings and also the critiques pertaining to the various strands of work. It starts with an overview of disasters as perceived by cultures in the pre-science era and then summarises the main approaches to 'natural disaster' used since then up to the present day.

2.2 THE HISTORICAL BACKGROUND

Extremes of nature have, at various times and in various places, had a profound effect on humans. Attempts to interpret, understand and explain the phenomenon have developed parallel to the events themselves. It was common before the Enlightenment to interpret natural hazards within the context of traditional systems of belief and indeed tales of floods, earthquakes and eruptions have often been incorporated into the laws and traditions of various peoples. Stories of catastrophic events exist within most cultures. Floods, for example, can be identified within the oral and written traditions of Judeo-Christianity, the Babylonian civilisation, the Zapotecs of Mexico, the Aboriginal people of Australia and the native Hawaiians (Bryant, 1991). Often a religious interpretation of disasters is given within the tradition:

> And the LORD said unto Moses, stretch out thine hand toward heaven, that there may be darkness over the land of Egypt, even darkness *which* can be felt. And Moses stretch forth his hand towards heaven; and there was a thick darkness in all the land of Egypt for three days; ....and Pharaoh called unto Moses, and said, Go ye, serve the LORD; only let your flocks and your herds be stayed: let your little ones also go with you. (Authorized version, 1611, Exodus 10, verses 21 to 22 and 24).

The interpretation of the disaster frequently involves some sort of moral instruction. Disasters are often associated with the displeasure of a deity or deities with the behaviour of a people or a particular individual.

Although it is difficult to say definitely, it seems likely that large disaster events may have affected a number of societies and that these have each integrated the event into their own cultural traditions. Foster and Ritner (1996), for example, note that many scholars propose that the Thera - Santorini - eruption (1470 BC) has been preserved in many of the mytho-historical traditions of peoples within the Mediterranean basin. They suggest that reference to it is typically of a propagandistic, moralistic or pseudo-historical nature. The references include: the Atlantis legend, parts of the Argonauts stories, elements of the Odyssey and the biblical book of Lamentations. Where a natural hazard is a regular feature of an environment, the meaning of the hazard event may change with the changing nature of the local culture. Chester *et al.* (1996), analysing the interaction of volcanism and belief systems on Mt. Etna (Sicily) from the classical period up to the end of the eighteenth century, argue that the 'pre-industrial' beliefs about volcanism centred around the relationship with a deity. Before the advent of Christianity in Sicily, incense was burnt for the gods that controlled the volcano. With the beginning of the Christian period theological thought, heavily influenced by Augustine and Irenaeus, viewed volcanic activity as a result of human sinfulness. Although the religious tradition of the area had changed, as had the spiritual clothing of the physical event, the moral mechanism at play - the relationship between behaviour and punishment - had not. The relationship between disaster and religion in the eighteenth century was such, that the 1755 Lisbon earthquake led to dramatic Christian revival throughout Europe (Kendrick, 1956; Keegan, 1993).

Disasters also have an affect on popular culture. The bubonic plague that swept through Europe several times between the fourteenth century and the seventeenth is recalled in the Nursery rhyme 'ring-a-ring o'roses':

> Ring-a-ring o'roses,
> A pocket full of posies,
> A-tisho! A-tisho!
> We all fall down.
> (Cohen, J. and Cohen, M, 1981, p. 273)

The usual early symptoms of the plague, sneezing, leading to death 'we all fall down'. Within literature and drama extreme natural events often have a metaphorical role. Thus the great storm in Shakespeare's King Lear reflects the emotional state of someone of great significance, a King. The storm reflects the gravity that is implicit in the fall of a tragic figure.

The cultural interpretation of environmental extremes continued after the sixteenth century, but during this period scientific explanations of the physical events that precipitated disasters were being sought. It was not until the early part of the twentieth century, though, that systematic, 'scientific', research into disasters began (ie. the interaction between a physical event and a human population). The first work in this field is generally thought to have originated from Barrow's school of human ecology (Mitchell, 1990). The concern for this group was the interaction between the physical environment and the distribution and activities of people. One of the central concepts was human adjustment. The theory purported that a changing physical environment would require a reflexive change amongst the populations affected. The extent to which a population adjusted would determine whether it prospered or not after the environmental change. It was this tradition that informed the work of G. F. White, who started studying floods during the 1930's - a period when, in the USA, enormous efforts were being made to tackle the problem of flooding and which culminated in the 1936 Flood Control Act. It was he who pioneered work on natural hazards.

Hazard and disaster research developed within three main domains after the Second World War: *natural hazard research, disaster research* and *risk analysis* (Mitchell, 1990). Natural hazard research grew out of the school of human ecology as outlined above. *Disaster research* was generally carried out by sociologists. Organisational behaviour during disaster periods was a major theme of this work. The work carried out had a strong applied nature, which was reflected in the fact that the main sponsors of the work were the American military and civil defence authorities. The last of the main research domains to emerge was that of *risk analysis*. It originally grew out of a need, within the insurance industry and civil authorities, for a quantification of risks as well as public concern with environmental problems generally and industrial accidents specifically. The aim was to provide information that would enable profitable and fair decisions to be made about issues such as the level of insurance premiums or the sighting of potentially dangerous industrial complexes. This led to consideration of the question 'how safe is safe enough?', over time the legitimacy of this question has been debated and a rival question has been suggested: 'How fair is safe enough?'.

While the work carried out in the field of *disaster research* and *risk analysis* is important and will be discussed in the sections dealing with the development of a framework of vulnerability analysis, the field of *natural hazard research* will be examined first. It has only been this field of research that has attempted to tackle the totality of disasters. The other two only endeavour to capture aspects of the phenomena.

2.3 HUMAN ECOLOGY AND THE DOMINANT APPROACH

Human ecology was the first research approach to be applied in the field of *natural hazard* research. From the work of G.F. White and colleagues (White, 1945; White, 1960; White, 1974; Burton *et al.,* 1993[1]) work it is possible to identify a number of research themes. Chester (1993, p. 229) lists five main research objectives of the dominant approach derived mainly from White (1974) (figure 2.1).

Five main research objectives of the dominant approach
1. To estimate the extent and nature of human occupancy in areas subject to extreme natural events .
2. To determine the range of possible adjustments by social groups to these extreme events.
3. To examine how people perceive extreme events and the hazards resulting from them.
4. To examine the process by which damage-reducing adjustments are chosen.
5. To estimate the effects of varying public policy upon a set of responses.

Figure 2.1: Outline of the dominant approach (from Chester, 1993, p. 229).

The primary point of analysis for the human ecologists was the individual decision maker. It was their response to: (1) a potential hazard event and (2) the policy of authoritative bodies and market forces, that created a situation where a extreme natural event would have a more or less devastating affect.

In an early paper, 'Human adjustments to Floods', White (1945) demonstrated the use of these objectives in the analysis of a resource problem and in the drawing up of recommendations for future research and policy work. In the paper he identified three types of approach to the problem of floods that were taken by: the engineer, the public welfare official and the property owner. He found that each had developed ways of coping with floods but that the three, singly or in combination, did not lead to a situation of maximum use with minimum social cost. He linked this to the prevailing US national flood policy that was encouraging settlement of areas because, through disaster relief, it was reducing the cost of flood damage to the individual. His conclusion was that the present flood policy was encouraging a

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[1] The reference given here is to the second edition of the 1978 book of the same title.

dependence, amongst individuals and local governments, on the federal government, at the cost of the development of appropriate local adjustments and the most effective use of flood plains. He proposed that future research should concentrate on: the identification of 'successful' adjustments in America and elsewhere, the study of the factors affecting adjustments to floods and that this should be carried out within a broad interdisciplinary framework.

In the late 1950's White assessed flooding over the twenty years following the 1936 Flood Control Act. Analysing the scale and nature of flood plain occupation, he found that there had been a growth in flood plain development in all study areas, even at sites where the population had actually declined (White, 1960). He argued that the two main causes of this growth were highway construction and the flood-control programme. He identified nine adjustments that were commonly made: loss bearing, emergency evacuation and rescheduling, preventing flows, elevate land, controlling flows, change of structures, change in land use, insure and public relief. These might be made by an individual or organisation. He argued that, as in most resource-management situations, seven main considerations seem to affect the choice of differing adjustments.

- Estimating the resource and risk. Generally, White found that individuals and organisations had incomplete and inaccurate perceptions of flood hazards and a tendency to underestimate the probability of flooding
- Both public and private sector organisations tended not to undertake effective cost-benefit analysis
- At a local government and private sector level, there was little evidence of the harmonising of two or more possible land uses within flood protection measures. Federal, agencies on the other hand, did tend to harmonise flood protection measures and other uses
- Typically federal agencies assumed that there would be little change in demand as a result of the protection
- Private managers tended to over-estimate the protection offered by flood control measures and therefore a relatively minor piece of flood control work would lead to a relatively high level of flood plain encroachment

- Local government and private sector managers did not think in terms of regional water basin management
- Finally, and fundamentally, decision makers were restricted in some areas and encouraged to behave in certain ways in others. They were encouraged to develop floodplains by the federal agency who gave flood warnings, provided relief funds in the case of flooding and provided information on flood occurrence. White referred to this as social guides.

White (1945) suggested, in response to the problem of flood plain development keeping pace with flood protection measures, that decision makers should be given a broader range of choices and information, with public organisations regulating choice so that public safety was not infringed.

White and colleagues (Burton *et al.*, 1993) used systems models to illustrate the ecological interaction between people and the environment. Changes in one aspect of the system were seen to lead to a reaction in another part (figure 2.2). The mechanism underlying flood plain development was therefore an interaction between the hazard and society, with positive feedback in the form of a human response, often an adjustment (Burton *et al.*, 1993). The natural environment also provided natural resources that were exploited by the 'human use system'.

The response of the human use system would depend on both perception of the hazard and an awareness of potential opportunities to make *adjustments* (Burton *et al.*, 1993). Adjustments, that were made in the short term, were contrasted with adaptations that tended to be taken over a longer time period. *Biological adaptation* was linked to long term environmental conditions rather than short term environmental change. Thus long term exposure to malaria, it is argued, has lead to sickle-cell trait being common amongst Africans (Burton *et al.,* 1993). *Cultural adaptation*, in contrast to biological adaptation, can take place over a shorter time period leading to a relatively stable interaction between the environment and the people living within it. Cultural 'norms' were based on types of behaviour that were necessary to maintain existing modes of production and forms of living.

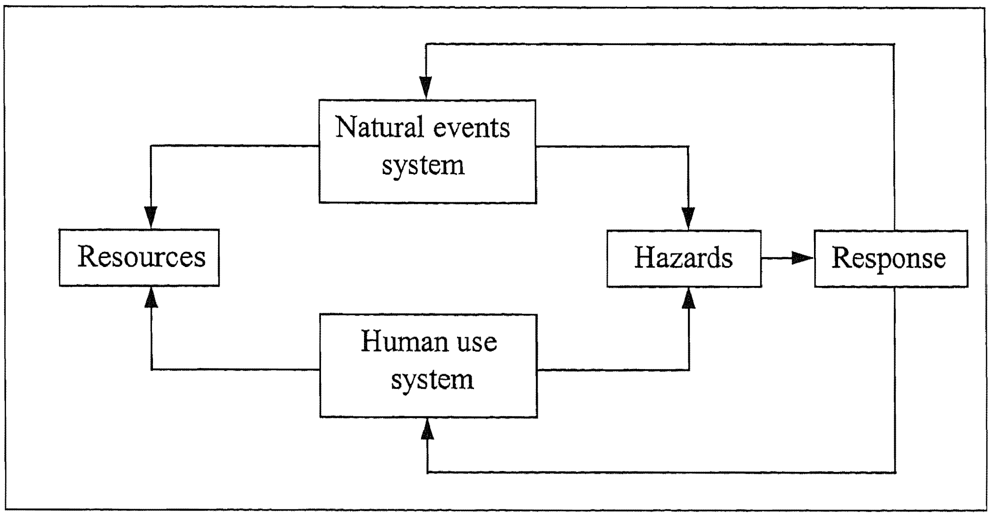

Figure 2.2: Resources and hazards from nature and man (after Burton *et al.* 1993, p. 32).

Adjustments are immediate, often short term, responses to specific environmental problems. Burton *et al.* (1993) separate them into *purposeful* and *incidental adjustments*. Incidental adjustments were not carried out with the aim of reducing the hazard but in effect did. Individuals were felt to have a range of choices; the most basic being the maintenance of their livelihood and choice of location. Burton *et al.* (1993) arranged adjustments along a time scale centred on the occurrence of an extreme event. Some adjustments could take place before an event others only after. They created a typology of *purposeful adjustments* which included: *loss acceptance*, *loss reduction* and *change*. Loss acceptance may be borne by the individual or, through social mechanisms, be shared out amongst a group. Insurance is an example of a social mechanism which transfers a large proportion of an individual's loss to a wider group. Loss reduction includes both the prevention of an event and also its injurious effects. Attempts to prevent an event might include cloud seeding or appeals to supernatural forces. Preventative adjustments, to limit injury and damage, might include warning systems, physical protection works, building codes and regulations or cropping practices. Change, as a form of adjustment, involves a fundamental shift in methods of production or location. In doing so the hazard for the individual is reduced or removed.

Burton *et al.* (1993) argued that adjustments to a hazard will be principally decided by individual decision making. They identified three models of individual decision making that could be applied to hazardous areas: *Expected Utility*, *Subjective Expected Utility* and *Bounded Rationality*. *Expected utility* is based on rational decision making and 'economic man'[2]. There are three main assumptions, first, that it is possible to have a concept such as 'gain', which is a composite of the advantages and disadvantages of different choices (Kaplan, 1991). Secondly, that people try to maximise gain and, thirdly, that in attempting to maximise gain, people have perfect knowledge. They need to have perfect knowledge to judge each potential choice in terms of two factors; value and probability. Value is the affective or emotional weight given to an outcome by an individual and the probability being the chance that an expected outcome would happen. Subjective expected utility recognises that an individual might subjectively rather than objectively value different elements within the process. Bounded rationality further refined the model, suggesting that decision makers would not necessarily take a course of action that would maximise gain but would use a *satisfier* principle to choose amongst a set of possible actions (Lloyd and Dicken, 1983). To choose what is good enough (ie. a satisfactory payoff) rather than what is best or of maximum gain (Simon, 1955). In effect, 'economic man' is replaced by 'administrative man'. Burton *et al.* (1993) suggested that decision making in the contexts of natural hazards involved balancing various elements. They give the example of a fisherman who needs to balance the chance of being caught at sea by a hurricane and the need to get a catch in order to stay out of debt with a local money lender. He will balance the probability of being caught in a storm with other more likely events. Because individuals never have perfect information on a decision making area and the bounds on decision making are frequently numerous, the bounded rational model of decision making was seen as the most appropriate for natural hazard decision making.

Kates (1971) produced a bounded rational model of adjustment behaviour. The simplified version of this model had four elements. The process of decision making was believed to start with:

> ...the individual (1) appraises the probability and magnitude of extreme events, (2) canvasses the range of possible alternative actions, (3) evaluating the consequences of selected actions, (4) chooses one or a combination of actions (Burton *et al.,* 1993, pp 101).

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[2] This author believes it is unhelpful and inaccurate to refer to the population as a whole using a masculine noun or pronoun. 'Economic man' and 'administrative man' is used here because this was the term used in the literature at the time.

Until an individual is aware of a hazard, he or she will not start on the process of decision making. Burton *et al.* (1993) argue that different people will have different thresholds at which they become aware of a hazard. At a second or loss threshold the individual will feel compelled to change resource use or technology. At a third or location threshold the individuals may decide that they have to migrate.

Perceptions of hazards are affected by a number of different factors. These include long-term or short-term horizons; for example how long a person is going to be at a certain location. Humans make errors when estimating or understanding probabilities. These are due to the use of *heuristics*, a procedure whose function is to reduce the possible number of outcomes or solutions to a problem and, therefore, make a problem more manageable. Tversky and Kahneman (1974) identified three important heuristics when considering probabilities and the biases that commonly result from their use. These are (1) *representativeness*, (2) *availability* and (3) *adjustment from an anchor*.

Ignoring *a priori* probability is a bias that often results when using a representative heuristic or stereotype. Being over receptive to the extent to which the description of a person's personality fits a stereotype of a particular profession, when assessing the type of work they probably do and ignoring *a priori* probability information is an example of this bias. In experiments subjects who are presented with both a description of a person and also information on the probability that the person will be from a particular profession are likely to favour the description over the probability information. In one case, subjects were asked to say whether a fictitious person was an accountant or not (Kahneman *et al.*, 1982). The person was described as 'wearing conservative clothing, being quiet and introvert'. The tendency was to say the person was an accountant despite being told that only 20% of the population are accountants. Another bias associated with representativeness is the 'gamblers fallacy' (Slovic *et al.*, 1974; Kahneman *et al.*, 1982). This is the belief that a random event is less likely to reoccur in the short term.

The second heuristic identified by Tversky and Kahneman (1974) is availability. This heuristic involves the calculations based on group, elements or aspects with which the individual has close contact. Thus, for example, basing a belief on the chances of being mugged on the number of your friends and acquaintances who have been mugged. Biases are introduced if there is a reason why this group, element or aspect is not representative of the phenomena of interest.

The third heuristic is adjustment from an anchor and involves the individual making an initial estimate which is refined as they come upon more information. This method may be biased if people insufficiently adjust their estimate. For example, research shows that people tend to overestimate *conjunctive* events and underestimate *disjunctive* events. A lack of hazard knowledge may be present and Burton *et al.* (1993) related this to urban and rural living. They argued that rural residents are generally 'closer' to the land and have a greater understanding of natural events. Awareness of a hazard may also be affected by the relative importance of the hazard in relation to other significant aspects of peoples' lives.

It is important for people to feel that there is something that they or a governing body can do to prevent damage from a hazard (Burton *et al.*, 1993). Those that do not feel they can do anything about a hazard typically have a personality characterised by the belief that control over events in their own life lies outside their control (Whyte, 1978). Whyte argues that this belief is more common in less developed countries where individuals have less choice. This suggests that the belief is not a facet of personality, but rather a reaction to actual physical and social conditions. This differentiation is not always clear in hazard research where the concept of *locus of control* (Rotter, 1966) has been applied. Locus of control is a personality trait which is related to perceived control across situations and is not necessarily related to actual levels of control. Studies, though, have found that underprivileged and minority groups tend to be external on the locus of control scale - believing they have little control over events affecting them (Shakleton and Fletcher, 1984). This raises the question, is a group, that does not have a high degree of control over aspects of their environment and believes this to be the case, the same as one that has control but does not believe it? It certainly seems clear that threat of a disaster affects people's perspectives profoundly.

> The constant reminder of the immediacy of death may in part account for the greater emphasis which is placed upon interpersonal relations in most poor societies as well as for the elaboration of beliefs and practises concerning the spiritual (Harrell-Bond, 1989, p. 202)

Burton et al. (1993) relates the adoption of adjustments to four main factors: past hazard experience, material wealth, personality traits and perceived social role. Burton *et al.* (1993) argued that the nature of a hazard at a specific location will lead to a response amongst the inhabitants that would be similar and, therefore, allow them to be classified as a whole. This was despite their own exploration of individual differences. They propose a fourfold classification of response based upon their three thresholds of hazard awareness. The first classification that they consider typical of zones of potential earthquakes and coast lines subject to occasional tropical storms is characterised by risk denial and the effect of the event is determined by the potential for the absorption of damage. The second classification, which includes events such as floods in Malawi, droughts in Nigeria and Hawaiian lava flows involves the inhabitants having crossed the threshold of awareness but believing that there was little they could do in response. Behaviour was classed as passive with the usual adaptive response being to evacuate or seek help (1993, Burton *et al.*). The third classification, which was most common amongst the sites studied, involved inhabitants having crossed the threshold of action. This type of situation typically takes place on flood plains where people actively try and influence the natural event. Action is based upon prediction and warnings but also on attempts to prevent losses. The fourth classification exits where a majority of inhabitants expect to move away from the area because of the pervasive nature and intensity of the hazard. This has happen in situations of drought, where large numbers of people have left an area.

2.4 THE CRITICAL BACKLASH

In the nineteen-seventies concern was growing with the nature of hazard research and management. The work of O'Keefe *et al.* (1976), Torry's (1979) review of 'Environment as hazard' and Hewitt's collection of essays *Interpretations of Calamity* (1983) and his own chapter in that text were some of the principal works in a critical backlash against disaster research and management as it was progressing. The critical backlash has been linked to the *radical* movement as it existed in geography and economics at that time (Chester, 1993). There are two main assumptions made in the arguments of the radical movement: first, that there is no such thing as value free science, all science and especially social science serves some political end (Peet, 1977). Secondly, that it is the function of conventional science to serve the established social system. It does this by providing within-the-system solutions and transferring blame away from the dominant institutions on to other groups within society. Radical science should:

> aim at exposing the 'false culture' for what it is - a device for the protection of the social and economic system against the rise of

> revolutionary consciousness amongst its own people (Peet, 1977, p. 240)

Workers within the radical movement were heavily influenced by neo-marxism and so, therefore, were their critiques of natural hazard research. Their approach centred on society and the inequalities of power within it. In contrast, other critics took a far more micro-level approach. Anthropologists, for example, looked at, in-depth, the nature of culture in areas affected by natural hazards. To this extent, the critics did not have a unified voice.

Hewitt (1983) described the work that was being carried out in the hazard field at that time as 'dominant research'. He saw it as characterised by the notion that disasters were the results of extremes of nature, that there was a direct causal link between the physical environment and its social impact, and that harm or damage was defined by the type, magnitude, frequency and other dimensions of a physical event. Although, social and economic factors were recognised as important, in much dominant research they tended to be seen as secondary factors. The dominant consensus, he felt, viewed disasters as primarily the result of natural events. Geophysical, climatological and biological events were seen as the 'triggers' for disasters (Blaikie *et al.,* 1994).

This particular conceptualisation had led to disaster mitigation being heavily biased towards: hazard monitoring, hazard control and emergency planning (Hewitt, 1983; Cannon, 1994). This type of approach was termed a 'technological fix'. The perceived need for these technological fixes stemmed from the apparent near random occurrence of natural hazard events. The removal of randomness, it was believed would result in the disappearance of the natural hazard (Hewitt, 1983). Therefore it was as important to study the threat of a disaster as the disaster event itself (Susman *et al.*, 1983). Hewitt (1983) questioned whether perfect prediction would actually reduce levels of risk. Research showed that improved prediction encouraged people to be more careless and political structures rarely create equity or social justice. Cannon (1994) expands this point by suggesting that any mitigation measures would, themselves, have social consequences:

> The technical interventions which are supposed to reduce hazard intensity or prepare people for them are themselves not socially neutral, and they must not be taken in isolation from the factors that create vulnerability, and should only be implemented with the full awareness of their impact on different sections of the people (Cannon, 1994, p. 14)

In effect, mitigation measures are designed for one hazard but by being introduced create another hazard. The process of mitigation may change the nature of the risk situation but will not necessarily reduce it.

The dominant approach had tended to emphasise individual decision making. Within the human ecological approach of Burton, Kates and White, individual decision making, albeit within bounded rationality, was seen as the prime factor in the environmental-human adjustment process. The human ecologists tended to use models of decision making derived mainly from economic theory and observations on decision making and attitude formation derived from experimental psychology. The individual decision maker from economic theory tended to be rational and knowledgeable. The decision making observations drawn from experimental psychology tended to be molecule in nature (ie. observed within an experimentally isolated situation within which extra or polluting factors had been deliberately removed or suppressed). The question raised by the critics was whether these were valid models from which behaviour in hazard environments could be predicted or understood. Much of the evidence used by the radicals in their assaults on the dominant approach came from field work in the less developed countries (LDC). In LDC's, it was argued, the need to acquire food, water, shelter and an income dominated decision making and behaviour (Mitchell, 1990). Choice, in this situation, was usually limited. The concept of constrained behaviour would be more appropriate than rational decision making. Measuring attitudes to a hazard or adjustments, researchers, within the dominant tradition, had a tendency to attribute the type of behaviour found in LDC to folk or 'primitive' traditions. A lack of knowledge, folk culture or superstitious beliefs were identified and seen as causal. The equally plausible explanation that these types of beliefs developed within a context of constrained behaviour was not explored. The use of a single methodology, typically a questionnaire interview, to analyse behaviour and attitudes may have biased the conclusions of many dominant research projects. The questionnaires used, in the International Geographical Union sponsored hazard research programme, for cross-cultural comparison have been described as culturally insensitive (Watts, 1983).

The alternative theories suggested by the critics tended to reflect the various epistemological backgrounds of the individual critics but with an emphasis on political-economy and neo-Marxist theories. The work of the critics did tend to have a number of common themes. They generally re-appraised the relationship between a hazard event and the population at risk. Hewitt (1983) identified three features: first, that the natural hazard was not explained nor dependent upon the geophysical event that may initiate a disaster. Secondly, that the perception of a natural hazard and behaviour that may affect the danger it poses, is more related to societal organisation and values than actual geophysical conditions. Thirdly, that natural disasters are not explained by behaviour peculiar to the disaster event but rather by the nature of society in a particular geographic location. Radical researchers argued that in order to understand disasters fully it would be necessary to see them as an:

> extreme situation implicit in the everyday condition of given populations (Susman *et al.,* 1983, p. 264).

Physical extremes should be viewed as just one aspect of the context within which an individual or group functions.

> In most places and segments of society where calamities are occurring, the natural events are about as certain as anything within a person's lifetime, or at least that of himself, his children and grandchildren. (Hewitt, 1983, p. 26).

The radicals argued that in order to understand why a disaster took place it was necessary to understand the context from which the disaster emerged. This should involve the study of socio-economic conditions in relation to the physical environment (Susman *et al.*, 1983).

Susman *et al.* (1983) analysed the process of under-development. They argued that under-development was not just a contemporary state but was part of an historical process, the 'process of under-development' (figure 2.3). This phenomenon centred around a world economic system with developed countries at its centre and less developed countries at the periphery. The consequences for the periphery, Susman *et al.* (1983) contend, has been overwhelmingly negative and the problems of under-development lie here rather than in factors such as environmental change. The problems that the relationship between the central economies and the periphery cause can be classified as external and internal. External factors generally relate to the economic situation created by companies from the centre within the peripheral countries. Internal factors are strongly related to the historic relationship between the central economies and the periphery which was often a colonial relationship. The changes brought about by colonial rule resulted in new modes of production. The local population of the colonial states were often enticed or forced off their land to become the labour force for foreign owned enterprises (eg. mines, plantations, urban manufacture etc.). The result was under-population in rural areas,\falling food production and, combined with a change from subsistence to cash cropping, the ability of the local population to produce enough food for themselves and cope with environmental stress was radically reduced. Susman *et al.* (1983) described a group that through the action of other classes and interest groups in society becomes marginal in it. They identified large groups especially in the less developed world who had become marginal and were underdeveloped. With marginality came increased vulnerability to physical events and disasters. Importantly, they argued that foreign aid merely alleviated the immediate suffering of the affected populations but did not remove the state of marginality that was the root cause of the disaster.

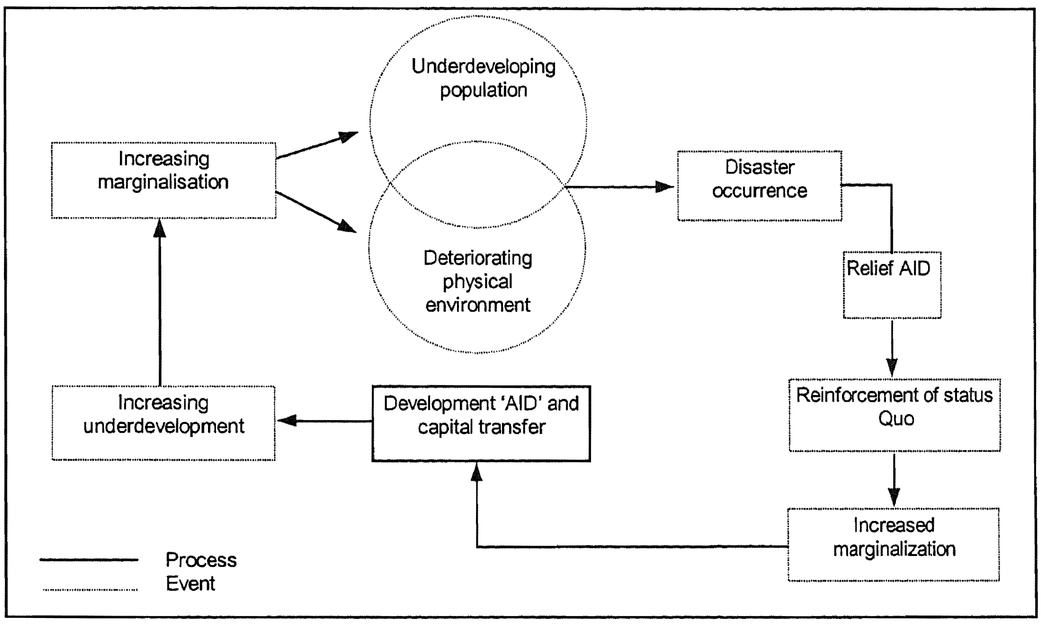

Figure 2.3: A model of marginalisation and its relationship with disasters (developed from: Susman *et al.*, 1983, p. 279).

Neo-Marxist structuralist analysis of society was used by many of the critics to explore the development of the socio-economic context from which disasters arose. Generally structuralism argues that all behaviour is the result of unseen mechanisms that reside in all structures (Johnston, 1985). Inequalities of opportunity and risk was the result of the principal systems of power operating within a society (Cannon, 1994). Palm (1990), however, identified two extremes within structuralism. First, determinists who believed that all behaviour was constrained by and predictable from the underlying structures in society. In this instance, decision making lay outside the domain of the individual. At the other end of the spectrum, probabilists who argued that at each stage of a process an individual has a choice but that certain choices are more likely or probable (Spate, 1957). Structure creates opportunities and constraints that would influence a majority or a significant group. The structuralist approach has been criticised on a number of different fronts. These criticisms are aimed not only at the theoretical basis of the work but also at the focus of the studies. One area of criticism is that which is applied to structural geography and sociology in general. A fundamental aspect of structuralism is its advocacy of supra-individual bodies with their own causal efficacy (Duncan and Ley, 1982). The contention is that individuals are merely the passive agents of greater bodies. Duncan and Ley (1982) refer to the holism apparent in structuralism as organicism. Organicism is then criticised for involving reification:

> which is a fallacy by which mental constructions or abstractions are seen as having substance and causal efficacy (Duncan and Ley, 1982, p. 36).

The accusation that, because many of the supra-individual entities that structuralism recognises are either all encompassing or are not able to predict specific outcomes and therefore, it is impossible to either prove or disprove their existence (Johnston, 1985).

The use of the concept of marginalisation has tended to emphasise the degenerating conditions of the people in less developed countries. Capitalism, loosely defined, has been seen as a cause of these degenerating conditions. It may have been in part the prejudice of some in the radical movement with regard to the effects of capitalism on countries in the less developed world that led them to be less than objective in analysing the issue and not recognising problems being experienced in socialist led countries. They, as a result, failed to see that capitalism was changing the nature of, rather than creating entirely new disasters (Cannon, 1994).

A considerable amount of the radicals' research was carried out in areas where recurring 'extremes' made it difficult to differentiate between disasters and 'normal life'; for example in famine hit areas of Africa (Blaikie *et al.,* 1994). These disasters were particularly suited to supporting a structuralist view point because of the limited opportunities and constraints that existed in these situations and the extent to which the physical hazard merged into 'normal life'. In many famine hit areas of less developed countries, the opportunities available to an individual were limited. Choice was therefore constrained and this may have given the impression that a particular situation determined behaviour, when in fact the process still involved choice, but amongst only a few alternatives. In a famine the interaction between people and the environment is more important in determining the transition from an extreme situation to a disaster, than in other natural hazard situations. Social processes are therefore more likely to have an influence on the process leading to a disaster.

2.5 CONCLUSION: AN INTEGRATIVE FRAMEWORK

In the late 1980's and 1990's there has been a growing consensus amongst researchers in the field of natural hazard research (Whyte, 1985; O'Riordan, 1986; Palm, 1990; Mitchell, 1990). There has been a retreat from the fairly polarised positions that were held in the 1970s and early 80s. In important works on natural hazards, successive workers have called for an integrative framework that brings together the macro or societal analysis of the structuralist radical movement and the micro behavioural perspective of the human ecologists. Any analysis of natural hazards today should approach the area from an integrative perspective. This type of approach is now developed.

CHAPTER THREE: VULNERABILITY IN VOLCANIC ENVIRONMENTS

3.1 INTRODUCTION

This chapter will outline the framework for analysis used in this thesis to explore the relationship between people and volcanic hazard. The framework allows the relationship to be broken down into the fundamental aspects of a person's vulnerability. These aspects are then explored within the context of an individual functioning in a specific milieu. The 'root causes' of vulnerability can then be identified.

3.2 THE CONCEPT OF VULNERABILITY

Vulnerability analysis attempts to integrate individual behaviour with broader social processes. Though many of the early advocates of this approach worked within the *radical* tradition and were therefore heavily influenced by structural Marxism, their most recent work is more *integrative*. Indeed, Blaikie *et al.* (1994) in their comprehensive review of the vulnerability approach, state their intention:

> to reintroduce the 'human factor' into disaster studies with greater precision, yet avoiding the dangers of an equally deterministic approach rooted in political economy alone (Blaikie *et al.,* 1994, p. 12)

Vulnerability may be defined as a combination of factors that determine the extent to which a person's life, livelihood or general well-being is threatened by an extreme event of nature (Blaikie *et al.*, 1994) and so define how susceptible they are to it (Anderson and Woodrow, 1989).

Vulnerability is not static but dynamic, related to both past and present socio-economic processes and individual decision making. Davis (1978) developed the *pressure and release model* (PAR) to illustrate the ways in which a disaster could be seen as a dynamic interaction between two opposing forces (figure 3.1). On one side are the pressures creating human vulnerability and on the other the physical hazards. The PAR model illustrates the chain of factors that lead to a situation of vulnerability. These factors are *root causes*, which lead to *dynamic pressures* and finally to *unsafe conditions*. The root causes are normally related to economic, demographic and political processes. Dynamic pressures channel the root causes into producing unsafe conditions. They may include: population growth; war; deforestation; foreign debt and possibly global environmental change. Unsafe conditions are the "specific forms in which the vulnerability of a population is expressed in time and space in conjunction with a hazard" (Blaikie *et al.*, 1994, p. 25). Structures are unsafe, only people are vulnerable. A building that is likely to collapse during a seismic event is in an unsafe condition but it is the inhabitants who would be vulnerable. This distinction is important, because vulnerability has often been defined narrowly: the UNDRO (1991) stated that vulnerability is solely a measure of the intrinsic susceptibility of built structures to potentially damaging natural phenomena. By defining risk purely in terms of buildings, the actual effect felt by individuals and communities is not assessed directly. It is the reliance of a community on structures and other elements and the effect of their collapse which determines the suffering caused by an extreme event of nature.

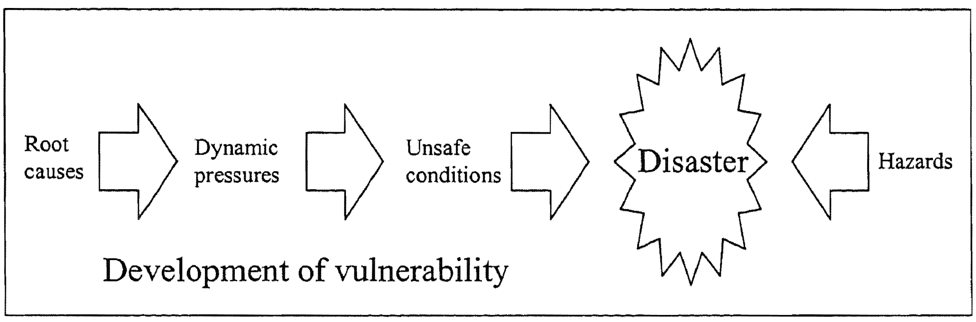

Figure 3.1: PAR pressure and release model (developed from Blaikie *et al.*, 1994, p. 23).

Hazardous events and post disaster aid work may play a role in the development of vulnerability. Chambers (1983) describes the process of positive feedback, when people are affected by a number of disasters closely spread in time, as the *ratchet effect*. Barakat and Ellis (1995), working in the context of wars, diagramatically represented this as a *downward spiral*; with each new event, the group affected becoming more vulnerable to the next event. This weakening process may result from the action of more than one type of event. Having to abandon a source of clean water because a village is threatened by pyroclastic flows, for example, may force people to drink contaminated water, a cholera outbreak would further increase their vulnerability by decreasing their ability to access material resources.

The term *capacity* has been used to refer to the physical and non-physical elements that allow people to cope (Anderson and Woodrow, 1989; Anderson, 1993)[3]. Davis (1995) has argued that elements that make an individual vulnerable may also provide capacities which allow them to cope with the situation. An old person might be physically weak, making them vulnerable, but they may also have experience of previous disasters and, therefore, a greater knowledge of what to do, so giving them a greater capacity.

It is often accepted implicitly by organisations providing aid in the aftermath of disasters that individuals loose this capacity to cope (Ellis, 1996). Though in many disasters physical assets may be lost, the non-physical elements that allow coping continue to be available even under very exacting conditions (Harrell-Bond, 1986). By ignoring these indigenous mechanisms of coping, organisations providing aid, lacking an empathy with local culture, have missed opportunities to provide an effective service and may have hindered the long term recovery of a region.

Vulnerability analysis, when applied to a disaster can provide a structure to post disaster-aid and development. Importantly it:

> ...can prevent two pitfalls of relief work. First, it calls into question any post-disaster attempts to "get things back to normal," because, by raising awareness of the factors that contributed to this disaster, it shows that "normalcy" involved vulnerabilities that, if not changed, may lead to future disasters. Second, it alerts relief workers to the potential for unwittingly contributing to future vulnerabilities by their interventions (Anderson and Woodrow, 1989, pp. 10-11).

It also shifts the emphasis away from expensive and often unsuccessful attempts to alter the hazard itself and concentrate on the elements that are making a population vulnerable to that hazard (Cannon, 1994).

3.3 CONCLUSION: A FRAMEWORK FOR VULNERABILITY ANALYSIS IN VOLCANIC ENVIRONMENTS

Blaikie *et al.* (1994) contend that vulnerability analysis is of limited use in areas of volcanic hazard. They argue that, 'volcanic eruptions endanger any person living within the high-risk zone, whether poor or rich, landowner or land-less farm

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[3] Physical elements, include stored food, emergency shelter or aid. Non-physical aspects could include: the support of family groups; skills and knowledge.

labourer, man or woman, old or young, member of ethnic minority or majority' (Blaikie *et al.,* 1994 p. 184). This environmentally determinist viewpoint ignores a number of not only important characteristics of volcanic activity but also human psychology and long-term consequences of the eruptive events. Fundamentally, people are living in an area that may be affected by a volcanic eruption and not somewhere else. Their reasons for being there are likely to be many and varied and may well reflect gender, class, economic and social differences. Many people affected by volcanic eruptions will not live within an area of total destruction. These may include, *inter alia*, coastal settlements at risk from tsunamis, areas affected by pyroclastic fall, towns influenced by seismic activity. The deleterious effects of volcanic products outside the area of intense activity can be severe. Volcanic ash and gases, for example, can have a significant affect on productive capacities. This may turn a life threatening event into an economic or resource crisis. After the Icelandic Laki fissure eruption of 1783, widespread starvation resulted from the devastation of the island's livestock. The eruption produced 500 million tons of noxious gas, as well as approximately 12 km^3 lava (Krafft, 1991). About 11,000 cattle, ~28,000 horses and ~200,000 sheep died as a result of fluorine poisoning and around 10,500 or a quarter of Iceland's population died in the famine that followed. Some individuals and groups are also more negatively affected by volcanic hazards than others. Psychological factors, such as knowledge or emotional attachment to place, can have a significant influence on behaviour. Differences in knowledge may, for example, affect health related behaviour during a pre-eruptive evacuation or during a crisis (eg. CO_2 seepage, fluoride in drinking water, and high levels of ash in the air). During eruptions different areas will be affected by different combinations of hazards and, therefore, where a person lives will affect the type of hazard faced. The ability to cope during a volcanic crisis and recover following it will be determined by factors such as access to resources, social networks, and physiological/ psychological stamina. These factors will also differentiate between individuals. Vulnerability is thus applicable to volcanic hazards.

The analysis of vulnerability in volcanic environments requires three ordered steps:

1) The identification of hazards and an understanding of their nature.

2) An assessment of the vulnerability of a population.

3) An exploration of how these conditions have come to exist.

This is then followed by two further steps, that transform the analysis from research into measures aimed at reducing vulnerability. This is probably the most difficult step (figure 3.2). The process should be repeated fairly frequently, for intervention will not remove vulnerability only change it. Intervention may have had unintended negative consequences and so informational feedback is needed to monitor the situation over time. Chapters four, five and six explore how, in the same order, steps 1-3 may be achieved.

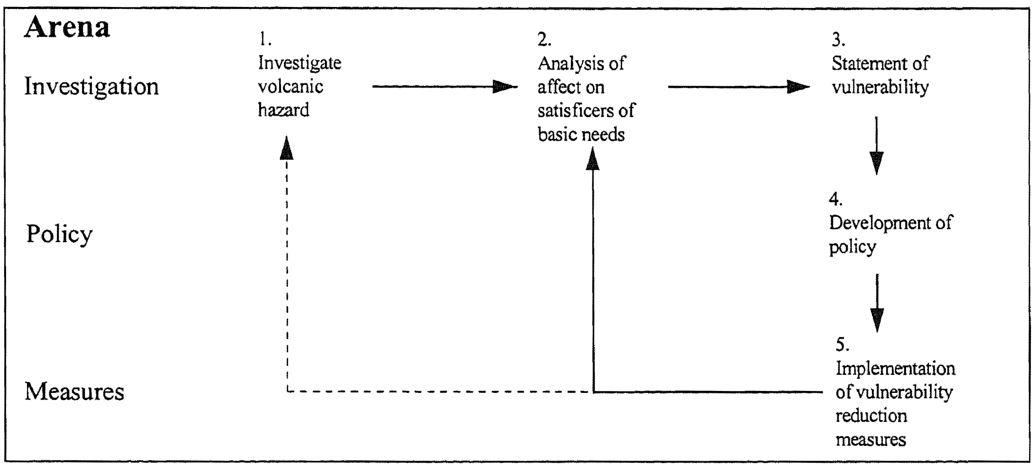

Figure 3.2: The process of vulnerability analysis and mitigation.

It should be emphasised that what is being discussed here is not the process whereby vulnerability is produced, this is discussed in chapter 6. This chapter discusses an approach with which to analyse vulnerability. Although an order to the research process is suggested, in some situations it may be necessary to move to steps 2 and 3 even if only rudimentary work has been carried out within step 1. This is because a delay within the process of vulnerability mitigation will itself be a cause of vulnerability. The process is conceived as cyclical and therefore greater understanding of volcanic hazard can be brought to the mitigation process over time. Indeed, it is possible that geological/ geophysical work may be invigorated by an engagement with political, social and economic spheres.

The analysis at steps 1-3 does not explicitly link the condition of vulnerability to the probability of an eruption in some measure of urgency or the need for change (eg. urgency = probability x vulnerability). The approach is designed to identify all potential disasters however unlikely or likely they are. The probability of an eruption should be considered, together with the vulnerability of people, at the stage of policy development (ie. stage 4) when the process of vulnerability analysis moves away from the research domain into the social world.

Decisions about what probability and size of a volcanic event is acceptable are fraught with problems. They are highly subjective and prone, as a social construct, to distortion by powerful groups. Structures of domination might therefore be affecting individuals both through their vulnerability to volcanic hazard and through the conceptualisation of urgency or need to act (eg. affecting women, minorities, the old etc.). It is therefore vital that it is decided upon in a consensual, visible and fair manner. This issue will be returned to in chapter ten of this thesis.

CHAPTER FOUR: VOLCANIC HAZARDS

4.1 INTRODUCTION

Although vulnerability analysis stands in opposition to what has been the view of the *dominant* movement in natural hazard research, that disasters are mainly determined by the characteristics of an extreme event of nature (Maskrey, 1989), the identification and detailed study of such events is clearly still a necessity. In the case of volcanic hazards this is particularly true because unlike other natural hazards, they are multi-faceted and are highly variable over time and space.

Volcanic hazards have been classified variously. UNDRO (1991) used a tripartite classification (figure 4.1). This classification seems incomplete as it ignores hazards such as tsunami, volcanogenic earthquakes and pyroclastic fall. The similarity between volcanic mud and lava flows is also questionable. While volcanic mud or lahars are fast moving, highly hazardous to people and are often generated through secondary processes (eg. high rain fall, the melting of an ice cap) and can occur during non-eruptive phases; lavas are usually slow moving, not a hazard to people and are a primary product of volcanic activity.

Main volcanic hazards
• Explosive eruptions (ash flow and pyroclastic flow) • Volcanic mud and lava flows • Volcanic gases

Figure 4.1: Volcanic hazards- UNDRO, 1991.

Chester (1993) produced a more comprehensive classification system defining 13 categories of volcanic hazard (figure 4.2). Included within his system are secondary societal affects such as: road accidents, civil unrest, epidemic disease and starvation. These secondary factors are the result of individuals interaction with a volcanic environment and are part of their own vulnerability to it and so these factors should be excluded from a typology of primary volcanic hazards.

Main volcanic hazards
• Lava flows • Domes and cryptodomes • Pyroclastic fall deposits • Lateral (directed) blasts • Volcanic gases • Pyroclastic flows • Pyroclastic surges • Hydrovolcanic (phreatic and phreatomagmatic) fall deposits • Lahars • Collapse • Ground deformation and volcanic earthquakes • Tsunamis • Other hazards (eg. starvation, epidemic disease, contamination of water supplies and land, transport accidents, breakdown in civil authority etc.)

Figure 4.2: Volcanic hazards - Chester, 1993.

Simplifying Chester's (1993) classification by categorising the products in terms of the similarity of their affect on human life and ignoring secondary factors that are a function of society, I suggest another scheme (figure 4.3).

Main volcanic Hazards
• Lava flows • Pyroclastic flows/ surges and lateral blasts • Pyroclastic fall and ballistics • Lahars • Slope failure (including caldera collapse) • Volcanic gases • Tsunamis • Volcanogenic earthquakes • Hydrothermal activity

Figure 4.3: Volcanic hazards.

4.2 TYPES OF VOLCANIC EVENT

The type of hazards that a particular volcano will generate, how often it does so and how wide an area it will affect depends on a number of factors. One of the most important determinants of eruptive style is magma type or composition. Magma composition is a continuum arbitrarily divided into three main types, defined by silica content (SiO_2): these are basaltic, andesitic/ trachytic and rhyolitic. Basaltic magmas are relatively silica-poor (45-52% SiO_2), are less viscous and gases are more able to exsolve and be released from the magma as it rises to the surface. The result is that only restricted fragmentation will take place and the eruption of the magma will not be particularly explosive in character with small eruptive columns and the main product being effusive lava flows (Chester, 1993). Rhyolitic magmas are silica rich (>62% SiO_2). The viscous nature of the magma does not allow the gases to escape readily. Retention of gases within the magma leads to explosive fragmentation on eruption. Andesitic/ trachytic magma is intermediate in composition containing about 54-62% SiO_2 and these magmas are also often gas-rich. Large explosive eruptions involving magmas ranging in composition from andesite to rhyolite typically generate eruption columns several km's high. The collapse of such columns leads to pyroclastic flows and surges. Lava can also be produced because gas retention occurs. Gas-rich rhyolitic magmas give rise to explosive eruptions. Gas-poor andesitic-rhyolitic magmas, however, erupts to form viscous lava domes. Gravitational collapse of these lava domes may generate pyroclastic flows (block and ash flows).

The interaction of water and magma is another important determinant of eruptive style. The explosive quenching of magma by water under the correct magma/ water ratio generates explosivity. The overall affect is to increase the fragmentation of the melt and therefore the explosivity of the eruption. The most explosive situation (explosive efficiency) is reached in basaltic magma when the ratio of water to magma is ~0.35, this situation is termed phreatomagmatic (Cas and Wright, 1987). Under these conditions eruptive columns, several km's high, can be expected, with associated pyroclastic fall, surge and flow.

Traditionally different types of volcanism have been placed in categories derived from observed eruptions at specific volcanoes. These include: Plininan, Sub-Plinian, Ultra-Plinian, Peléan, Hawaiian, Strombolian, Vulcanian, Surtseyan and Phreatoplinian (Chester, 1993). These types of volcanism are not always readily recognisable in an eruption and one eruption may show characteristics of more than one category.

Plinian eruptions are characterised by high eruptive columns and give rise to a wide dispersal of pyroclastic fall, the release of gases into the atmosphere and typically from pyroclastic flows related to eruptive column collapse (Chester, 1993; Scarth, 1994). The eruptions of Vesuvius AD 79, El Chichón 1992, Mount St Helens 1980 and Pinatubo 1991 are typical of this style of activity. Sub-Plinian, Plinian and Ultra-Plinian eruptions are distinguished by the height of their eruptive columns, with plinian eruptions having columns ~30 km high and Ultra-plinian eruptions ~60 km high. Pelēan eruptions are characterised by the formation of domes, pyroclastic flows associated with dome collapse and lateral blasts. The areas affected tend to be localised (<50 km^2), although there may be a high level of destruction in this area (Scarth, 1994). Hawaiian eruptions are typified by lava effusion from vents in a localised area and may also be associated with weak explosive activity. Strombolian eruptions only affect a very localised area. Magma is ejected up to about 1 km above the vent; cooling in the air, it falls to the ground as, lapilli, or spatter. There are two main categories of hydromagmatic activity Surtseyan and Phreatoplinian. Surtseyan activity is the equivalent of wet strombolian activity, although the effect of water on the eruptive process leads to greater explosivity and the production of a finer ash. Phreatoplinian eruptions have not been observed in historic times but are expected to more explosive forming higher columns than dry plinian eruptions.

The Volcanic Explosivity Index (VEI) is an attempt to classify eruptions in accordance with their scale (Simkin *et al.*, 1981). This index combines quantitative data with qualitative reports of observers in the assigning of a value, from 1 to 8, to an eruption. The measures used are summarised in figure 4.4.

Volcanic Explosivity Index
• Total volume of eruptive materials • Eruptive column height • Classic classification schemes (eg. Hawaiian, strombolian etc.) • Type of explosive activity (eg. lava flow, phreatic, pyroclastic flow etc.) • Descriptions of the explosivity of the eruption and other quantitative measures

Figure 4.4: The measures used in the VEI (Simkin *et al.*, 1981).

From this index Simkin *et al.* (1981) were able to compare and contrast various regions and volcanoes. They noted that there had never been an eruption with a VEI of 8 during the Holocene. Only one eruption, the 1815 eruption of Tambora (Indonesia), has been assigned a VEI of 7. Fifty-three eruptions, during the Holocene, on 38 volcanoes have been assigned a VEI of over 5 and 25% of these have been in New Zealand.

4.3 LAVA FLOWS

Lava flows have been categorised in a number of different ways, whether they are: erupted on land or subaqueously, compositional (basaltic through to silicic) or whether they are erupted from extensive fissures or from a central volcano. A lava flow may also be described in terms of its flow morphology: pahoehoe, aa or block type. A single flow can exhibit the characteristics of each of these main morphological types at different times and in different stages. Studies of the lavas on Etna, Sicily, have revealed that although pahoehoe flows can turn to aa, the reverse very rarely, if ever, happens (Kilburn, 1981; Rowland and Walker, 1987). It is possible however, for 'break-out' from aa flows to form pahoehoe lava as occurred at the front of the Etna 1992 lava. The flow itself may be simple (ie. a single flow unit) or compound (ie. made up of several flow fields) depending on the effusion rate and viscosity of the lava.

Lava flows are rarely a hazard to life. They are relatively slow moving and people are unlikely to be caught in their path. Between 1600 and 1982, Blong (1984) estimated that about 1070 deaths could be attributed to lava flows. This represented only 0.4% of all deaths attributable to volcanic processes in the same period. Even this figure may be too high. Over half of the deaths resulted from one eruption in 1631 on Vesuvius. These 700 deaths were estimated in the Volcano Reference File (VRF) by taking a conservative estimate of the total number of deaths and attributing 20% of them to lava flows. It now seems likely that these deaths were all actually the result of pyroclastic flows and surges (Rosi *et al.*, 1993). The deaths were thus wrongly attributed in the nineteenth century to lava flows.

Deaths, as a result of lava effusion, are only likely to happen if: there is a very rapid advance of a flow, a retreat has been cut off or if there is an explosion as a result of the flow coming in contact with water or ice (Blong, 1984). It is land, property and lines of communication that are principally at risk from lava flows. Agricultural land can be left barren for many centuries after it has been covered and buildings in its path bulldozed or set alight. Climate can affect the weathering of lava flows. In tropics the weathering of lava and its re-colonisation by plants will be far more rapid than in other climates.

Rapid moving lava flows have occurred, though they are rare. One such happened at Nyiragongo (Zaire) in 1977 (Fisher *et al.*, 1997). Between 1928 and 1977 the crater of the volcano had filled with lava. The height of the lava lake had varied over this period, then on January 10th 1977 a fissure opened on the flank of the volcano allowing the lava lake to rapidly drain. The escaping, highly fluid, lava travelled at speeds of up to 100 km an hour and travelled up to 20 km from the volcano. Seventy people had no time to escape and were killed and a further 800 hundred lost their homes. The lava flow moved rapidly because it had a very low viscosity (>40% silica), a large hydraulic head (1,800 metres and 1,300 metres) and a high temperature (~1000° C) (Fisher *et al.,* 1997). Other fast flows have been observed on Hawaii. In 1855, for example, a lava flow from Mauna Loa was reported to have reached a speed of 64 km per hour on a 10-25° slope.

The ability to predict how a lava flow will behave and especially how far it will flow, is important for civil defence planning. Decisions may have to be made about whether to evacuate a town that lies in the course of a flow or where to build diversionary barriers if attempts are to be made to manipulate the flow. Modelling the flow of lava is made difficult by its complex behaviour. Part of the difficulty lies in predicting how lava will react to varying conditions: how it will cool, degas, crystallise, react to local topography or respond to varying effusion rates (Pinkerton, 1987). Various models have been developed. Non-Newtonian flow models have demonstrated the importance of effusion rates and the duration of an eruption in determining the length of a lava flow. Silicic lavas (rhyolithic/ trachytic) tend to be viscous and travel slowly. Commonly they form lava domes which can pose a hazard when they collapse. Basaltic lavas are less viscous and have the potential to travel further at a greater velocity. The length of lava flows seems to be determined by two different factors depending on whether they are volume-limited or cooling-limited (Pinkerton, 1987). If a flow is cooling-limited, then effusion rate seems to be the most important factor in predicting flow length. If on the other hand the flow is volume-limited, then the erupted volume seems most important in determining length.

Lava diversions have been attempted in the twentieth century in Hawaii, Iceland and Sicily, using various combinations of dams, barriers, water and bombs (United Nations, 1977). Lava diversion had been tried before this. During the 1669 eruption of Mount Etna, fifty residents of the Catania, lead by Diego Pappalardo, attempted to divert the flow of the lava away from their city. In response to this the residents of Paterno, another town towards which the lava was being diverted, came and fought off the Cantanese (Chester *et al.*, 1985; Pinkerton, 1987; Scarth, 1994). After this episode, it became illegal to divert lava flows on Etna until 1983 (Chester *et al.*, 1985). There have been a number of attempts this century to divert or block a lava flows. In 1935 and 1942 bombs were used on a flow from Mauna Loa (Hawaii). In 1973 water was used on a flow from Heimaey that was threatening to overrun the town of Westmannaeyjar (Iceland). Jets of water were directed onto the flanks and front that were threatening the town and harbour in an attempt to discourage flow in that direction (United Nations, 1977; McPhee, 1989). In 1983 and 1991-3 earthen barriers were used on Mount Etna (Italy). There has been debate over how successful the interventions have been. During the 1983 eruption on Mt Etna, Sicily, a number of attempts were made to open up a new channel near the source of the flow and thereby starve the flow front of fresh lava (Pinkerton, 1987). The measures taken were successful but only indirectly. Explosives were use to blast a hole in the wall of the existing channel. The main flow of lava, however, was not diverted out of the hole but created its own breakout further down the main channel. This breakout has been attributed to debris from the blast blocking the channel. Some critics of this diversion attempt argued that the lava flow was never a threat to the towns towards which it was advancing and suggested that it would have cooled and stopped before reaching them (Pinkerton, 1987).

4.4 PYROCLASTIC FLOWS, SURGES AND LATERAL BLASTS

Pyroclastic deposits originate from explosive activity associated with the rapid expansion of volatiles during an eruption (Chester, 1993). This type of expansion is thought to happen as a result of rapid decompression of volatiles in the melt or when magma interacts with water. These two processes may both operate in a single event. Pyroclastic deposits have been classified either by the nature of their origin or by their sedimentary lithology (Fisher and Schmincke, 1984). As a result of the complications brought about by having these two methods, a simplified classification has been proposed (Sparks and Walker, 1973). This method categorises pyroclastic deposits as either fall, surge or flow. The hazard to humans associated with pyroclastic fall is quite different in nature to that posed by pyroclastic flows and surges. It is therefore dealt with in the next section (4.5).

Pyroclastic flows are clouds of hot gas and particles that, driven principally by gravity, move across a landscape as a density cloud (Chester, 1993). They are generated by the gravitational collapse of an eruptive column, lava domes or by explosive events in lava domes. They can vary from small scale flows, only a few km long, to large, often ignimbrite producing, flows which can travel over 100 km. An ignimbrite is a pyroclastic flow deposit where pumiceous juvenile material is the most important component of the deposit (Wilson, 1987). The energy of a flow is derived from explosive force, gravity and in the case of the collapse of eruptive columns kinetic energy relative to the height of the column.

Francis (1993) drawing upon the findings of the major workers in the field, characterised pyroclastic surges as: (1) low density compared to pyroclastic flow and therefore not so constrained by topography, (2) having a turbulent flow because of their high velocity and low density, and (3) having less momentum and therefore not travelling as far as flows because of their lower density. They are dilute, turbulent gas-particle mixtures which are subdivided into: base, ground and ash cloud surges. Base surges are low level, ground hugging, blasts that spread out radially from an explosive centre (Chester, 1993). Ground surges and ash-cloud surges are collectively known as hot surges, they are both made up of very hot gases and mainly juvenile particles. They are associated with pyroclastic flows. Ground surges are probably the result of the forward jetting of ash clouds ahead of a pyroclastic flow (Francis, 1993). Ash cloud surge is possibly the result of changes in the speed of a flow leading to a change from laminar to turbulent flow. This might happen as a flow reacted to the local relief. The ash cloud surge forms at the top of the pyroclastic flow and may itself detach from the parent pyroclastic flow.

Lateral blasts result from either the release of compressed magmatic gases or the explosion of pressurised hydrovolcanic systems (Chester, 1993). This may happen if pressure within a volcanic structure exceeds that of the outside or the structure is weakened by a physical process (eg. a landslide or earthquake). The 1980 lateral blast at Mount St Helens, resulted from a tectonic earthquake over a bulging area on the volcano (Foxworthy and Hill, 1982). This led to slope failure and the unroofing of the magma chamber. The blast was followed by pyroclastic flows and surges.

Pyroclastic flows, surges and lateral blasts have been the most common cause of volcanic related deaths in the last 400 years; 70% of deaths have been attributed to them (Blong, 1984). Pyroclastic flows, surge and blasts move at high speeds and it is generally impossible to escape from their path. A majority of people caught within them die as a result of the injuries incurred. Survival at the edge of a flow or surge and in a well protected location is possible (Baxter, 1990). Cypraris, a prisoner at the time of the 1902 pyroclastic flow that devastated the town of St Pierre on Martinique, was protected by the walls of his cell, although he was badly burnt and was probably the only survivor from the town itself (Tanguy, 1994). On the edge of the flow, on land and at sea, dozens of people recovered after having suffered various degrees of burns but in the town itself about 29,000 people perished. Flows tend to follow topographical depressions and so, in the case of small flows, high ground may offer some protection (Blong, 1984). Surges, though, are more mobile than flows and may ride up over aspects of the relief. A surge may also detach from the denser basal part of a flow if it turns sharply, for instance it may travel over a valley ridge while the main flow follows the valley. It has been argued that surges associated with flows cover a far wider area and caused a majority of deaths during the Mt Pelée (1902), Lamington (1951), El Chichòn (1982), Unzen (1991) and Montserrat (1997) eruptions (Wilson, 1987). It is possible that protective clothes and breathing mask may offer some protection for individuals in marginal intensity areas of the flow or surge (Baxter, 1990). In general, the only real method of protecting individuals from pyroclastic surges and flows is to evacuate them in advance.

4.5 PYROCLASTIC FALL AND BALLISTICS

Pyroclastic material ejected during explosive eruptions may be transported through the air by the eruptive plume and then falls back to the ground under the force of gravity. These fall deposits can be classified depending on the extent of their dispersal and fragmentation (Wright *et al.*, 1980). The dispersal and fragmentation can in turn be linked to different types of volcanism. Ultra-plinian eruptions, for example, produce very widely dispersed deposits while Surtseyan events produce only narrowly dispersed highly fragmented deposits (Chester, 1993).

The proportion of volcanic deaths attributable to pyroclastic fall is fairly low. Blong (1984) estimated that only about 4.6% of volcano-related deaths since AD 1600 could be attributed to it. From this 4.6% roof collapse, due to the accumulation of fall material, is the most common cause of death. Some of the deaths, during the AD 79 eruption of Vesuvius, in Pompeii have been attributed to ash asphyxiation (Blong, 1984). The evidence for this comes from the position of the body casts taken from the Pompeii. Recent work, though, suggests that the positions of these casts are more compatible with death in pyroclastic flow or surge (Baxter, 1990). During the 1991 eruption of Mt Pinatubo, over 10 cm of ash fell on many land areas and, combined with heavy rainfall, led to the roofs of numerous houses collapsing (Baxter, 1993). About 300 people were killed as a result of roof collapse. During the 1995 eruption of Ruapehu (New Zealand) inhabitants cleared ash from their roofs to avoid collapse. Unfortunately there were a number of injuries associated with people falling off their roofs.

Pyroclastic fall can lead to acute medical problems. The eyes and respiratory system of individuals can be affected by the fall material. Acute conjunctivitis, throat irritation, nasal irritation and infections of the upper respiratory tract have all been reported in areas affected by pyroclastic fall (Blong, 1984; Baxter, 1993). Chronic medical problems have also been linked to pyroclastic fall. These include chronic bronchitis, pneumoconiosis and silicosis. Pneumoconiosis and silicosis result from the inhalation of fine particles of toxic respirable materials which lodge in the lungs. Silicosis may result if the fall material contains crystalline silica (eg. quartz, cristobalite or tridymite). Cristobalite is especially significant because lava domes often contain large concentrations.

Pyroclastic fall may also contaminate water, damage vegetation and, if the water or vegetation is ingested, harm or kill people and animals. Thousands of grazing animals were killed during the 1947 and 1970 eruption of Hekla, in Iceland, when they ingested fluorine which had adhered to plants (United Nations, 1977). During and after the 1991 eruption of the Hudson volcano in Chile, sheep ate ash-covered plants causing diarrhoea and weakness (Inbar *et al.*, 1995). Fall deposits also caused sheep to collapse under the weight of the deposits on their coats. In heavily affected areas (10-30 cm of fall deposit) as many as 30-40% of the sheep died.

Volcanic ash poses a serious threat to air transport. Planes flying through a volcanic plume can lose power as the ash is sucked through the engine. This problem is increasing with the level of air transport and especially the growing volume of air traffic over the far east and north-west Pacific air routes. There are reports of damaged cause to over 60 aircraft most notably related to the eruptions of Galunggung (Indonesia) in 1982, Redoubt (Alaska) in 1989 and Pinatubo (Philippines) in 1991 (Steenblik, 1990; Casadevall, 1991). The Redoubt incident is estimated to have cost US$ 80 million in terms of damage to aircraft (Chester, in press). On September 17th 1996 an Air Canada plane had to make an emergency landing after flying through the Montserrat eruptive plume. Two million dollars worth of damage was done and the plane had to be shipped back to Canada (personal communication - Dr Paul Cole).

Hazards from pyroclastic fall can be reduced in a number of ways. The risk of roof collapse can be avoided by removing fall material at regular intervals and by not sheltering in structures that are known to have weak roofs. Removing fall material can in itself be hazardous, Baxter (1993) reports 8 deaths and 200 injuries from collapses of roofs that were being cleared of ash in the city of Leon after the 1992 eruption of Cerro Negro in Nicaragua. Masks can be used to protect the respiratory system from fall material and goggles can be used to protect the eyes (Blong, 1984).

Ballistic projectiles may be either blocks which are in a solid condition or bombs which are ejected in a molten state. Because of their size they tend to fall close to the eruptive centre, they rarely reach further than 5 km (Blong, 1984). The distance a projectile will travel depends on the velocity and initial angle of its trajectory, and is also governed by its density and diameter.

The hazard to humans from ballistic projectiles depends on their density and diameter. Small projectiles with high densities can cause serious injuries even at terminal velocity. Baxter, in discussions on hazards faced by people during the eruption of Montserrat, estimated that a 5 cm lithic (dense) clast could cause a skull fracture (personal communication with Dr Paul Cole). Projectiles can penetrate roofs or lead to their collapse. People caught in the open can be killed or injured by a projectile. A strike may immobilise a person making it difficult or impossible for them to escape or avoid further injury. This is what happened to Professor Stanley Williams during an unexpected volcanic explosion at Galeras volcano (Columbia) in 1993. He was hit a number of times, sustaining a fractured skull, jaw and breaks in both legs. These injuries made it impossible for him to escape and he was reduced to sheltering behind a boulder (Fisher *et al.,* 1997). Luckily he survived this incident. It is thus possible to shelter from projectiles or dodge them. The number and type of projectiles will determine whether such strategies will be successful. Ballistic projectiles tend to fall in a fairly localised area around a vent and therefore, often, only pose a hazard to people who, for different reasons, venture near the vent (eg. volcanologists, tourists etc.).

4.6 LAHARS

Lahars are water lubricated flows made up of any type of material from a volcanic edifice for example: trees, pyroclastic material, or large boulders (Scarth, 1994). The proportion of water to particles can vary quite considerably and this ratio will affect the nature of the flow of the material. When the proportion of particles to water is less than 9% the flow tends to be Newtonian, when this is exceeded the flow becomes progressively more plastic (Chester, 1993). Lahars flow down slope under the force of gravity, following topographic depressions such as river valleys. The threshold, or yield strength, at which a lahar becomes mobilised is a combination of: cohesion, mass, slope angle and moisture content (Chester, 1993).

The failure usually occurs when the moisture content increases because of: heavy rainfall, interaction with a water flow or through the release of stored water - the breaching of a lake or the melting of an ice cap.

Lahars are a serious hazard for people living in the vicinity of volcanoes. Although there have been lahars which have killed large numbers of people, it is more common for a relatively small number of deaths to result (Blong, 1984). Unlike pyroclastic surges and flows, lahar hazard is not related solely to periods of volcanic activity. The unconsolidated pyroclastic deposits may pose a lahar hazard long after volcanic activity has ceased. This is a particular problem in areas with tropical or monsoonal rainfall. After the 1991 eruption of Pinatubo, in the Philippines, areas surrounding the volcano are still threatened by lahars four years later (Rodolfo, 1995). In both Japan and Indonesia lahar warning systems have been established in vulnerable valleys.

Lahars, because they act under gravity, follow topographic depressions and, therefore, settlements in or near valleys are most at threat. High points in the relief can offer protection for people in these settlements, provided they can be given sufficient time to reach them. The lahar produced during a small eruption of Nevado del Ruiz (Colombia) caused a massive loss of life in the town of Armero. Nearly 25,000 people lost their lives when the eruption melted snow and ice releasing lahars down the Rio Lagunillas valley and onto the town of Armero (Fisher *et al.*, 1997).

4.7 SLOPE FAILURE

Slope failure can result from either volcanic activity or instabilities in volcanic structures. Landslides may result from the collapse of part of the volcano during an eruptive event. The lateral blast on Mount St Helens in 1980 transferred 3 km^3 of material over an area of 600 km^2 (Lipman and Mullineaux, 1981). Landslides may be triggered by volcanogenic earthquakes. Before the 1914 eruption of Sakura-jima in Japan, a volcanogenic earthquake triggered landslides that is reported to have killed 12 people (Blong, 1984).

Volcanic structures themselves can be structurally weak and subject to rock-falls, gravity collapse, rock slides as well as large scale landslides. Large scale landslides have taken place on Etna in Sicily and Piton de la Fournaise in Réunion. Both volcanoes are buttressed except for a seaward facing side where the sliding takes place (Scarth, 1994). Landslides on volcanoes situated close to the sea can create tsunamis that may threaten distant coastal areas.

4.8 VOLCANIC GASES

Gases are released from volcanoes both during and after periods of activity. Volcanic gases usually have a high concentration of water vapour; they may also often contain HF, HCl, H_2S, SO_3, SO_4, CO, CO_2, traces of N, A and other inert gases (United Nations, 1977). The compositions of the gas output varies widely between volcanoes and periods of activity on a volcano. Change in the output of gases may be an important indicator of how a volcano is likely to behave (Francis, 1993).

Volcanic gases can cause a number of problems. Winds and local air currents may transport the volcanic gases over inhabited or cultivated areas and combine with local rainfall or pyroclastic fall. This may result in acid rain: damaging buildings, killing crops and injuring people. CO_2 and SO_2 can both cause asphyxia when they reach certain concentrations within the air. CO_2 is particularly hazardous because it is heavier than air, flows downhill and therefore tends to build up in low lying areas. These pools are very difficult to detect because of the colourless and odourless nature of CO_2. 1,700 people were killed in the north-west Province of Cameroon when an aerosol of water and CO_2, with trace H_2S, was released from Lake Nyos and flowed into villages below the lake (Freeth and Kay, 1987). Exposure to SO_2 leads to asphyxia because of throat inflammation and closure.

Attempts have been made to block outlets of volcanic gases. Explosives were successfully used in 1927 to trigger landslides into a fissure on the Masaya-Nindiri volcano, Nicaragua, and the emission of gas was stopped for 19 years (United Nations, 1977). Spraying plants with an alkali slurry has also been attempted, but this method, though successful, is expensive because of the need to reapply the spray after rainfall.

4.9 TSUNAMI

Volcanic tsunamis may be the result of volcanogenic earthquakes, the impact of pyroclastic flows on the sea, submarine explosions, caldera collapse, landslides, lahars flowing into the sea, atmospheric shock waves or lava avalanching into the sea (Latter, 1981). The nature of the tsunami is determined by the process that initiated it, the relief of the sea bed, the distance travelled and conditions on the shoreline/ coast it hits (Blong, 1984).

The most notorious volcanogenic tsunamis of historical times were those produced during the 1883 Krakatau eruption (Blong, 1984). Waves as high as 30-40 metres inundated most of the coastline along the Sunda Straits. As many as 36,000 people are estimated to have died (United Nations, 1977). Tsunami have been a major cause of volcanic related deaths in historic times. Most of them stem from a few very devastating events (figure 4.5).

Historical Tsunami in which over 50 people have died.	Deaths
Krakatau, 1883	~33,000
Tambora, 1815	~4,600
Unzen, 1792	4,300
Oshima-o-shima, 1741	1,475
Komagatake, 1640	700

Figure 4.5: Tsunami deaths (Derived from Blong, 1984 p. 117)

Research has shown that tsunami are a hazard to coastal areas more than 100 km away from a volcano (Blong, 1984). Warnings and evacuations are possible, provided that the volcano is a sufficient distance away from the endangered coastline. People living on a coastline near a volcano may only have had a very short time period between any warning and a tsunami's arrival.

4.10 VOLCANOGENIC EARTHQUAKES

Volcanogenic earthquakes occur because of magma movement, ground fracturing, gas explosions and caldera/ dome collapse (Schick, 1981; Blong, 1984). There has been some debate over how destructive volcanogenic earthquakes are; they tend to be mild harmonic tremors with a shallow focus and therefore generate violent surface shaking near the focus but with a rapid falling away of intensity with distance (Swiss Reassurance, 1993).

It is difficult to distinguish between tectonic and volcanogenic earthquakes. For example a tectonic earthquakes may create fractures through which magma can rise (Blong, 1984). After careful scrutiny of historical records, Blong (1984) estimates that out of a possible 37,582 deaths, probably only 79 are attributable to volcanogenic earthquakes. It should be noted that many volcanoes are situated in areas with a tectonic earthquake hazard. On Mt Etna, Sicily, it has been suggested that the some flank eruptions may be due to fracturing caused by tensile forces associated with the East-West extension of Eastern Sicily (Sharp *et al.*, 1981). Tectonic earthquakes precede these eruptions though it is not always easy to distinguish between tectonic and volcanogenic seismic activity.

As with tectonic earthquakes, the behaviour of people and the design of buildings are the two most important safety factors. Buildings designed to withstand violent shaking without collapse will decrease the chance of being injured or killed during a volcanogenic earthquake. The siting of settlements away from unstable slopes will decrease the danger of a volcanogenic earthquake triggered landslide overwhelming a town. It is also important that potential evacuation routes are not threatened by landslip or other blockage because volcanogenic earthquakes are often a precursor of an eruption. Unlike tectonic earthquakes, there will probably be a need to leave an area that has suffered a volcanogenic earthquake because of the threat of other volcanic hazards.

4.11 HYDROTHERMAL AND OTHER VOLCANIC HAZARDS

Volcanic activity produces a number of other hazards for humans. These include shock waves, floods generated by changes in the relief, volcanic induced lightning and hydrothermal activity. These hazards only rarely cause injury or damage to property and should therefore be seen as minor hazards.

Shock waves occur because of the sudden release of gases in an eruption and the resulting increase in local air pressure (Blong, 1984). Shock waves have been detected up to 800 km away from a volcano. In some cases shock waves may have been mistaken for volcanogenic earthquakes. In the 1630 eruption of Furnas, in the Azores, there were reports that earth tremors caused a church bell to ring in a town 30 km away from the volcano (Cole *et al.,* 1995). It is possible that this was the result of shock waves rather than volcanogenic earthquakes. During the 1958 eruption of Asama, in Japan, there were reports of people being injured by flying glass from windows broken by the shock waves (Blong, 1984). In general it seems likely that few people have actually been injured or buildings damaged by shock waves.

Volcanic lightning results from the build up of static electricity due to friction between the gases and ashes being ejected by the volcano (Francis, 1976). It is difficult to estimate the number of people who have been killed by volcanic lightning because few autopsies of eruption victims have been carried out (Baxter, 1990). People struck by lightning may have been mistaken for victims of pyroclastic flows or surges (Blong, 1984).

Hydrothermal activity occurs when water is able to drain into the ground, is heated by shallow magma and returns to the surface under hydrostatic pressure

(Scarth, 1994). The resulting features include hot springs, fumaroles, geysers and mud-pots. If there is a slow circulation of water, chemical reactions between the water and the surrounding rock can take place. The result is waters with differing mineral and gas contents. Hydrothermal activity presents only a minor hazards to humans. Injury and death because of scalding and burns is only likely if a person comes close to the feature or is caught in a minor hydrothermal explosion.

4.12 CONCLUSION

It was emphasised at the beginning of this chapter that an initial examination of the potential volcanic processes at a site was a necessary first step in establishing the level of vulnerability. A single volcanic centre can produce a great variety of different hazards that will affect areas at different distances. To be able to understand the interaction between a community and a volcanic threat it is necessary to identify precisely what that threat is. It is also necessary to revisit hazard work occasionally because change within the volcano or during an eruption may have altered the threat. The internal plumbing and external structure of the volcano, for example, may have altered over time, producing new sets of threat of differing intensities. Understanding of volcanic processes also changes with time, so that new hazards, not before apparent, may be identified at a site if it is revisited at regular intervals.

The next chapter will propose a method for operationalising the concept of vulnerability with regard to volcanic hazards.

CHAPTER FIVE: VULNERABILITY OPERATIONALISED

5.1 INTRODUCTION

Vulnerability is identified through the study of past events and the simulation of future disasters. Blaikie *et al.* (1994) argue that vulnerability, in respect to natural hazard, is:

> a measure of a person or group's exposure to the effects of a natural hazard, including the degree to which they can recover from the impact of that event (p. 57).

By defining vulnerability in terms of an individual or group's ability to recover, the researcher is faced with a number of problems. Can, for example, a group who existed in a state of poverty before a hazard event be said to have 'recovered' if they return to their same state of poverty? Similarly, should a wealthy individual who loses more but is still better off than another individual who recovers all their resources, be defined as more vulnerable than the other? This problem can be avoided if vulnerability is conceived in terms of universal needs. *An individual would be vulnerable if a hazard event could deprive them of basic human needs and/ or the means by which they would be satisfied in the future. In a society where these needs are not being satisfied even before a hazard event, vulnerability could be seen as the effect of a hazard event on the long term chances of an individual being in a situation where they are satisfied.*

There is considerable difficulty in defining objectively what the basic needs are. It has been argued that universal needs can never be identified because needs are defined within an individual culture or by an individual group. A culture or group *constructs* its own identity. Mental illness is, for example, defined by a system that is culturally bound. A person may be seen as schizophrenic, possessed by demons or a visionary within different cultures. From a relativist position it can be argued needs vary between places and over time. This, though, is not always true, an individual cannot always distinguish what they want from what they really need. What a person wants and what they need are conceptually separate. Wants must always be understood and be something that is desired, while needs may not be either understood or desired.

> you can need what you want, and want or not want what you need. What you cannot consistently do is **not** need what is required in order to avoid serious harm - whatever you may want. (Doyal and Gough, 1991, p. 42 - emphasis added).

The conceptual problem therefore lies in separating universal needs from subjective wants. Doyal and Gough (1991) solve this problem by identifying what it is necessary for an individual to have to avoid serious harm. They define serious harm as:

> [being] fundamentally disabled in the pursuit of one's vision of the good (Doyal and Gough, 1991 p. 50).

All personal goals must be realised in a social context, thus being disabled in pursuit of one's vision of the good can be said to be an inability to *participate* in the form of life that they find themselves. Basic needs are, therefore, the pre-requisites for *social participation* (Townsend, 1987). If there are pre-conditions to social participation which everyone faces, then universal needs can be said to exists (Percy-Smith and Sanderson, 1992). The importance of social participation is illustrated in definitions of poverty; poverty is:

> ...not only about shortage of money. It is about rights and relationships; about how people are treated and how they regard themselves; about powerlessness, exclusion, and loss of dignity (Archbishop of Canterbury's Commission, 1985, p. 197)

The need for social participation has been recognised by many social commentators (Alcock, 1997). Adam Smith wrote:

> By necessaries, I understand not only the commodities which are indispensably necessary for the support of life but whatever the custom of the country renders it indecent for creditable people, even of the lowest order, to be without. A linen shirt, for example, is strictly speaking not a necessity of life .....But in the present time ....a credible day labourer would be ashamed to appear in public without a linen shirt (Smith, 1776, p. 691- from Alcock, 1997, p. 69)

Townsend (1979) argues that this aspect of poverty is relativist because it is linked to cultures which vary through time and between groups and defines the search for a level below which poverty can be said to exist as:

> ...to endeavour to define the style of living which is generally shared or approved in each society, and find whether there is...a point on the scale of the diminish, families find it particularly difficult to share in

> the customs, activities and diets comprising their society's style of living (Townsend 1979, p. 114).

But while poverty may be relative in terms of the *commodities* needed to achieve a similar level of *functioning* (eg. different types of food can all allow good health), it is not relativist in terms of the need for a particular *characteristic* of a commodity (ie. the satisfaction of hunger) to allow human functioning (Sen, 1992). The commodities needed for social participation in a European country would be very different and more expensive than those required in an isolated rural community in Africa but the characteristics of the commodities that would allow social participation would be the same.

The basic needs that facilitate social participation are an optimum level of *physical health* and *autonomy of agency* - the ability to make informed choices about what needs to done and how it should be carried out (Doyal and Gough, 1991). Physical health and autonomy are inter-linked, it is necessary to have both to be 'healthy' (Boorse, 1975). Within western medical ethics, for example, it is deemed acceptable to end someone's life, by not feeding them, if they are in a permanent vegetative state, because they are not and will not be able to lead an *autonomous* life (Doyal and Gough, 1991). An optimum level of physical health and autonomy will allow the individual to:

> ...choose activities in which they will take part within their culture, possess the cognitive, emotional and social capacities to do so and have access to the means by which these capacities can be acquired (Doyal and Gough, 1991, p. 160).

and also:

> ...formulate the aims and beliefs necessary to question their form of life, to participate in a political process directed towards this end and/ or join another culture altogether (Doyal and Gough, 1991, p. 160).

An individual's physical health involves both an absence of ill-health and also a reasonable life-expectancy. Autonomy requires an absence of mental illness, cognitive deprivation and the existence of social opportunities - especially economic activity.

There are many ways in which physical health and autonomy can be maintained. Hunger, for example, can be satisfied with many different types of food but the nutritional component of food in general - a characteristic of the commodity food -

is a universal satisfier because it is necessary for the maintenance of physical health and autonomy.

> In so far as the underlying reasoning of the basic-needs approach relates to giving people the *means* of achieving basic functioning, the problem of interpersonal variations in 'transforming' commodities into functionings ....can be avoided by looking at the functioning space rather than at the commodity space. (Sen, 1992, p. 109).

It is therefore necessary to identify universal characteristics of commodities that enhance physical health and autonomy (ie. basic functioning) (Percy-Smith and Sanderson, 1992). Doyal and Gough (1991) reviewed the literature on basic needs and identified 11 Satisfiers that conformed to their definition of being both universal and positively contributing to physical health and autonomy. A minimum level of these should be present, in an individual's situation, for promoting an optimum level of basic needs satisfaction. This thesis will use a slightly modified version of this list of basic human needs. While acknowledging that some individuals and cultures do not seem to conform to this list of basic needs, it is argued that these are the exception to a fairly consistent world-wide pattern that confirms their universality (figure 5.1).

Basic need Satisfier
• Nutritional food and water
• Adequate shelter
• A non-hazardous environment
• Appropriate health care
• Security in childhood
• The possibility of primary relationships
• Physical security
• Economic security
• Appropriate education
• Safe birth control and child-bearing

Figure 5.1: A list of the Satisfiers of basic needs developed from Doyal and Gough (1991).

Satisfiers need to be carefully defined. *Nutritional food and water*, represent the availability of a minimum amount of nutrients and water for nourishing an individual (Doyal and Gough, 1991). *Adequate shelter* involves: sufficient protection from the climate, a non-disease transmitting environment and non-crowded conditions (crowded being the subjective measure of insufficient privacy). A non-hazard environment is the absence of harmful conditions rather than the absence of risk. Harmful conditions may include: toxic chemicals, bacteria, viruses, intense heat, toxic gases, crushing forces, deprivation of sleep or excessive physical work. *Appropriate health care* is the availability of primary health care and associated therapeutic medicines (eg. antibiotics, drugs, painkillers etc.). *Security in childhood* represents a minimum level of security, stimulation, recognition and responsibility to allow a child to become healthy and autonomous (Doyal and Gough, 1991). The *possibility of primary relationships* is the opportunity, if chosen, to be within: a group of friends, a relationship, a family or community. Imposed isolation seems to lead to depression, mental breakdown and anti-social behaviour. *Economic security* is a situation where there are sufficient resources to satisfy basic needs and to allow an individual to participate, at least at a minimum level, in their chosen lifestyle (Townsend, 1987). *Physical security* is the absence of the threat of violence against the individual by other individuals or groups in society. *Basic education* is the provision of sufficient information and cognitive skills to allow an individual to participate successfully in their culture. The educational provision must allow them to accrue sufficient resources to satisfy basic needs. Across cultures the basic education process is fairly consistent providing skills in: maths, literacy, social skills, physical processes and vocations (Doyal and Gough, 1991). *Safe birth control and child-bearing* is a basic need because, although it principally affects one half the population and not the other, it has a significant affect on a major part of a woman's life and childbirth is an important determinant of a woman's health and autonomy.

To return to the earlier proposed definition of vulnerability that:

> An individual would be vulnerable if a hazard event could deprive them of basic human needs and/ or the means by which they would be satisfied in the future. In a society where these needs are not being satisfied, even before a hazard event, vulnerability could be seen as the effect of a hazard event on the long term chances of an individual being in a situation where they are satisfied (p. 45)

Vulnerability can thus be said to be the extent to which the interaction of a natural hazard event within a social situation will lead to a depression of Satisfiers (through the process leading to the achievement of Satisfiers) and health and autonomy to a level where social participation is disabled. *The appropriate measure of vulnerability is an individual's susceptibility.*

The literature on vulnerability suggests two main ways in which an individual can be susceptible. The first of these is hazard to health (Blaikie *et al.*, 1994; Cannon, 1994). This relates to the presence of life or health threatening situations and is dependent on *location* and the potential for *self-protection*. The second is the susceptibility of *livelihood* to damage. Livelihood is the physical, social and cultural elements that allow an individual or social group to generate resources (Chambers, 1983; Blaikie *et al.,* 1994; Cannon, 1994). These two are closely related in that poor access to livelihood can lead to conditions that negatively affect health and similarly poor health can negatively affect livelihood (Cannon, 1994). They depend not only on individual or household conditions but also on organisations within a society which can provide protection and support (eg. Civil defence, local government, health clinics, national government, army etc.). For example, the evacuation of all residents of a flood plain by the civil defence negates the susceptibility of a old person who would find escaping flood waters very difficult. If the civil defence had been able to protect a local factory the livelihood susceptibility of a family who relied on it for employment would be reduced. Susceptibility of livelihood, self-protection and organisational response only partially captures how some, and ignores how other, Satisfiers of basic needs, health and autonomy might be depressed by a hazard event. It is proposed in this thesis that other important susceptibilities are: location of activities and home, physiological/ psychological resilience and the reaction of family, communities, social organisations and society in general (figure 5.2).

Susceptibilities to volcanic hazards

- Location of activities and home
- Self protection ability
- Physiological/ psychological resilience
- Livelihood and resource resilience
- Emergency organisation response
- Reaction of family, communities, social organisations and society in

Figure 5.2: The main ways in which an individual is susceptible to the effect of volcanic activity.

Taking these susceptibilities forward in figure 5.3 they can be seen to relate to the *societal preconditions* for [3], the individual/ family units affect on [2] and to basic needs [1] themselves (figure 5.3). Though the affect of a eruption on societal pre-conditions [3] for the satisfaction of basic needs may be instantaneous with the event itself, the actual affect on an individual may be felt sometime after. An individual may be directly affected at the time of the eruption through a direct impact on their basic needs [1]. Thus it is possible for someone spatially distant from a volcano, to be unaffected by the immediate impact but still be vulnerable because the facilitation of their basic needs would be affected. A volcanic event 'ripples' through a society. The greater the linkage between communities; the further away these ripples will be felt. Importantly, it is possible that the 'societal ripples' from a volcanic event will not necessarily have a 'negative' affect. This is true for both people who have and have not been directly affected by the initial volcanic event.

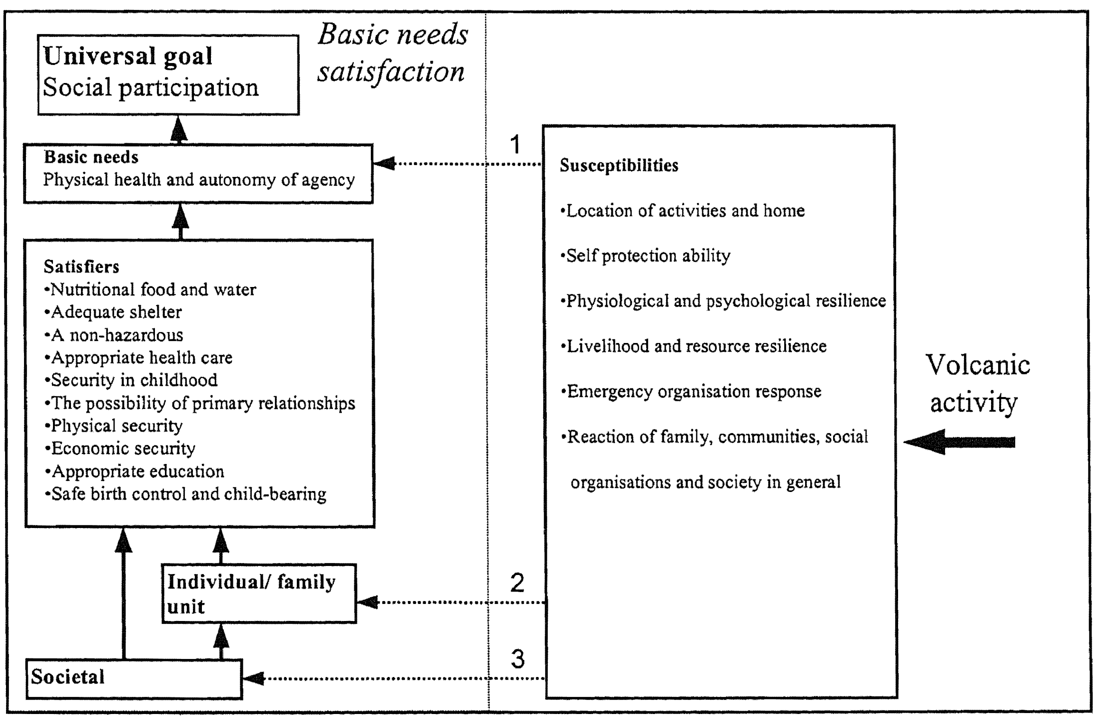

Figure 5.3: Vulnerability to volcanic hazard - this diagram illustrates how susceptibilities mediate the impact of volcanic activity on the process whereby an individual's basic needs are met. (the left hand side is modified from Doyal and Gough, 1991, p. 170).

Aspects of susceptibility can be additive or subtractive. For example, an old man would be vulnerable to seismic activity because, if the town where he lived was to be destroyed, he might be injured since he could not reach shelter fast enough, be short of food due to the deaths of members of his extended family upon which he depended and suffer a loss of primary relationships because of the destruction of the community in which he functioned. For him susceptibility is additive, he is in a situation of extreme vulnerability. Hewitt (1997) described this as a '*vulnerability syndrome*'. Susceptibility may also be subtractive. A young woman working in a hazardous location might have a very clear understanding of the hazard of that location and know how to respond to a hazard warning. Susceptibility in reference to a non-hazardous physical environment, because of location, is reduced by the opportunity for self-protection.

5.2. LOCATION DECISION MAKING

The *location* of a person's work, home and recreational activity is a fundamental aspect of vulnerability. If a person never entered an area affected by hazards they would not be vulnerable. Location will modulate the affect of volcanic hazard on all the Satisfiers of basic needs and also an individual's health and autonomy.

Location is of particular significance in a volcanic environment because different volcanic hazards will affect different areas around a volcano. Some areas may be affected by all volcanic hazards, others by fewer. Topography provides an important control of hazard, valleys close to the volcano are, for example, often more likely to be affected by lahars, pyroclastic flows/ surges and lava flows than hill tops and ridges. Prevailing wind directions will determine the probability of different sectors of the volcano and the surrounding region being subjected to pyroclastic fall.

Individuals move between different locations at different times. Typically a person will have home, work and leisure locations. The more time they spend in an area of high hazard and the type of activity they are involved in that location will affect the probability that they will be affected by volcanic activity. The reasons for locating home and livelihood in an environment and the 'day-to day' movement about it are embedded in the social and economic context of the individual. It is within this context that individual decision making takes place and defines the level of susceptibility to harm they face.

5.3 SELF-PROTECTION

Self-protection is the ability of an individual to avoid health damaging environmental situations. This ability depends on a synthesis of psychological, physiological and external factors. Psychological factors include: hazard knowledge, risk behaviour and crisis decision making. The actual ability of people to respond to their own knowledge and perception of risk may depend on physiological factors. Physical agility, strength and stamina, for example, may be important in determining whether escape is possible and ultimately successful. External factors will also be important in deciding whether certain behaviours are possible; access to a car, for example, might allow evacuation from an area of extreme hazard. If there is heavy pyroclastic fall cars may be made inoperable. More generally both an individual's *ability* and *willingness* to act on an understanding of a hazard may be influence by their own particular circumstances.

Self-protection in volcanic situations can be subdivided into four aspects:

- Knowledge and awareness of a hazard
- Safety behaviour
- Warnings and evacuations
- Survival behaviour

These aspects will now be examined.

5.3.1 Knowledge and awareness of a hazard

Volcanic environments can be hazardous during non-eruptive periods. Gas seepage fluoride in water and hydrothermal activity can be a hazard to health and are typical features of some volcanic environments. Self-protection behaviour is different in this situation than would be the case during eruptions. CO_2 seepage, for example, is difficult to detect and the gas tends to accumulate in hollows. Self-protection in these situations depends on a knowledge of the hazard. The safety behaviour associated with this knowledge - to look for dead animals on the ground or to use candles to test for high CO_2 levels - will be a constant feature of a person's day to day life; they may be an inconvenience and some people will ignore them. Awareness of a hazard does not guarantee safe behaviour but with an absence of awareness, safety behaviour will never be initiated.

5.3.2 Safety behaviour

Adams (1995, 1997) has demonstrated that in situations where individuals have control over a discernible level of risk, they will modulate it to achieve a preferred level. A rock climber will often increase the technical difficulty of a climb as his or her climbing skills increase to maintain a constant level of risk (Ross, 1974). A car driver who is forced by law to wear a seat-belt, when they did not wear one before, is likely to drive in a more hazardous manner therefore maintaining a similar level of risk as before (Adams, 1995; Heino *et al., 1996*). This theory is known as *risk compensation* or *risk homeostatic theory* and postulates that: risk taking propensity will be balanced against a perception of likely risk; that risk taking propensity will be related to how an individual values the rewards of risk taking and risk perception by one's own and others' experience of accidents.

Self-protective behaviour towards non-eruptive volcanic hazards can be equated with other home, work and environmental hazards. A person must be aware of a hazard before they will alter their behaviour towards it. Individuals do not seem to attempt to reduce the risk they face from a perceptible risk to either zero - which is never possible - or to a 'standard' level. They achieve a level that is acceptable to themselves. This level is often related to social groups to which they belong (this discussion is expanded on in the next section). Safety cultures (ie. safety attitudes within a socially or spatially linked group) within a workforce, for example, have been found to correlate highly with number of accidents in factories (Zohar, 1980; Donald and Canter, 1993).

Safety rules are guides to behaviour provided by organisations. They may be provided by a national or governmental body and their imposition required of other organisations. They are usually provided when an organisation believes individuals may have an inaccurate knowledge of a risk, and are therefore unwittingly taking risks, or to encourage safer behaviour amongst those, who for various reasons, are behaving in a more risky way than deem 'sensible'. Because safety rules are imposed on a proportion of people (ie. those that are not behaving in a 'sensible' manner), there is usually a conflict between the authority imposing the rules and those for whom it is imposed.

5.3.3 Warnings and evacuations

Self-protective behaviour during eruptions is usually associated with escape. The areas affected by volcanic hazards are often devastated. A high proportion of people caught in these areas will be killed or seriously injured. In areas affected by pyroclastic fall there may not be the need to evacuate but particular types of behaviour will reduce the chance of injury and death from particle inhalation or building collapse. Unlike behaviour associated with safety rules which are often a feature of everyday life, evacuation behaviour is usually highly irregular. People may have experienced practises but are unlikely to have been involved in an actual eruption. Safety rules (eg. leave a building when you hear the siren) may be ignored but for different reasons. These might be: disbelief, lack of knowledge, or conflicting information. Janis and Mann (1977) identified four mediating conditions that need to be met if vigilance and coping are to be effective:

> 1) awareness of serious risks if no protective measures are taken; 2) awareness of serious risks if any of the salient protective actions is [sic] taken; 3) moderate or high degree of hope that a search for information and advice will lead to a better (i.e., less risky) solution; and 4) belief that there is sufficient time to search and deliberate before any serious threat may materialise. (Janis and Mann, 1977, p. 35)

In the absence of these conditions the individual is likely to respectively show: unconflicted inertia (continuing with activity unaffected by the warning), unconflicted change (taking known or rehearsed protective measures whether they are effective or not), defence avoidance (believing that there are no alternative sources of useful information) and hypervigilance (taking inappropriate action because there is no time for effective decision making).

One of the typical reactions to a warning of an impending hazard is disbelief (ie. unconflicted inertia) (Drabek, 1969; Drabek, 1986). This process is exacerbated if the disaster is unexpected and the level of disaster preparedness low (Perry *et al.*, 1982). Disbelief results in warnings being ignored until the individual receives further confirmatory information or evidence as to a situations seriousness (Quarantelli, 1980; Canter, 1990). This is what Janis and Mann (1977) termed unconflicted inertia.

An individual or group's socio-economic context may affect their willingness to evacuate. During the 1941-52 eruption of Parícutin, Mexico, the first to permanently leave were people who had relatives in other villages, possessed skills that would allow them to gain employment or had flexible assets that could be moved (Nolan, 1979). These individuals and groups tended to be from the wealthier section of society, though some of the affluent did not leave because their wealth was tied up in land and property. The other group that tended to leave were people who, though poor, were ambitious and had been thinking about migrating before the eruption started.

Evacuation may be delayed if individuals do not know that other individuals or groups are escaping. In the 1973 Summerland fire, on the Isle of Man, parents tried to collect their children rather than evacuate the building and this delayed their escape and caused blockages (Sime, 1983). Johnson *et al.* (1994) found that increased threat led to a higher social response. This relationship of social response increasing with threat continued until a threshold at which point social behaviour decreased. This threshold seems to be the point where the required behaviour was not solely about escape but rather survival. There has also been a commonly observed inverse relationship between age and propensity to evacuate (Mileti, *et al.*, 1975). This has been attributed to decreasing contact with both the community and with sources of warning rather than an inherent unwillingness to escape (Perry, 1985). Once the severity of a potential event is realised there seems to little differentiation between the old and the young and their propensity to evacuate.

Perry *et al.* (1980) formulated a model of evacuation compliance based on the assumptions that the speed of the onset of the disaster would still allow a warning message to be communicated and sufficient time for the warning to be received. This theory defines evacuation decision making in terms of: the representation of concepts, warning confirmation/ credibility, perceived risk and ability to act. The model made two assumptions about the decision making process. First, that people will try and verify information and, second, when in danger people will try and protect themselves. He identified six variables, that reflected the emergent norm approach to decision making. These variables were:

- warning confirmation
- warning source credibility
- warning content
- perceived risk
- family context in which warning received
- possession of an adaptive plan.

In four different flood situations (ie. four different towns) all the variables were important in predicting compliance except family context (there was no variation in family context, it was therefore ignored) and plans. Compliance was most strongly related to perceived risk.

There are a number of common 'myths' about behaviour during evacuations (Wenger *et al.*, 1975). These myths are to do with panic, looting and flight behaviour. Although looting rarely occurs during an evacuation, people commonly believe that their property is at risk (Mileti, Drabek, and Haas, 1975). An official, who told people that there was not a police presence on the streets because looting would not take place, would risk significant non-compliance with an evacuation order. The assumption that during a disaster people do not think or act rationally but panic, has been the basis for disaster planning in many countries (Sime, 1990). Fire alarms in many shops, informing staff before the public, were deliberately designed so to restrict information because of the fear of panic. Delays in useful information are likely to lead to people not escaping a disaster. Generally, the only people who 'fly' a disaster are those who are only in the area transiently, for example tourists (Wenger *et al.*, 1975). The greater problem is encouraging people to leave.

Analysing the major (ie. life threatening) volcanic eruptions between 1980 and 1995 it is clear that many large scale evacuations have been successfully carried out (figure 5.4). Where a large number of deaths have occurred despite an evacuation, these have been the result of secondary volcanic events - lahar, roof collapse and disease in the case of Pinatubo (Baxter, 1993) - or people returning to the area of hazard - El Chichón (Scarth, 1994). It also notable that during the two events that have cause the greatest number of volcanic related deaths - Nevado del Ruiz (1985) and Lake Nyos (1986), there were no evacuations. Evacuations clearly play a central role in reducing the number of volcanic related deaths. The success of an evacuation does not just depend on the reaction of the evacuees but also the effectiveness of the organisations charged with monitoring the situation, this will be dealt with in section 5.6.

Year	Volcano	Evacuees	Fatalities	Year	Volcano	Evacuees	Fatalities
1980	Gamalama (Indonesia)	40,000	0	1987	Anak Ranakah (Indonesia)	4,200	0
	Uluwan (Papua New Guinea)	2,000	0	1988	Gamalama (Indonesia)	3,500	0
1981	Paluweh (Indonesia)	1,850	0		Banda Api (Indonesia)	10,000	4
	Semeru (Indonesia)	0	373		Makian (Indonesia)	15,000	0
	Mayon (Philippines)	0	200	1989	Lonquimay (Chile)	2,000	0
	Gamkonora (Indonesia)	3,500	0		Galeras (Colombia)	2,000	0
1982	El Chichón (Mexico)	10,000	1,879		Lonquimay (Chile)	4,600	0
	Galunggung (Indonesia)	75,000	68	1990	Kelut (Indonesia)	60,000	32
1983	Una una (Indonesia)	7,000	0		Sabancaya (Peru)	4,000	0
	Gamalama (Indonesia)	5,000	0	1991	Pinatubo (Philippines)	250,000	800
	Miyake-Jiima (Japan)	1,400	0		Pacaya (Guatemala)	1,500	0
1984	Merapi (Indonesia)	1,000	0		Lokun-Empong (Indonesia)	10,000	1
	Karengatang (Indonesia)	20,000	0	1992	Cerro-Negro (Nicaragua)	28,000	2
	Mayon (Philippines)	73,000	0	1993	Mayon (Philippines)	57,000	75
1985	Sangeang Api (Indonesia)	1,250	0	1994	Rabaul (Papua New Guinea)	50,000	5
	Nevado del Ruiz (Colombia)	0	23,080		Merapi (Indonesia)	6,000	41
1986	Nevado del Ruiz (Colombia)	15,000	0		Popocatapetl (Mexico)	75,000	0
	Lake Nyos (Cameroon)	0	1,700	1995	Fogo (Cape Verde islands)	1,050	0
	Toshima (Japan)	12,200	0		Soufriere Hills (Montserrat)	5,000	0

Figure 5.4: Major eruptions (explosive) (ie. >1000 people evacuate or over 200 people killed) between 1980 and 1995 (from Oppenheimer, 1996, p. 78).

5.3.4 Survival behaviour

Despite media and popular conceptions, *panic* - uncontrollable self-destructive behaviour - is not a common feature of disasters (Sime, 1990). Leach (1994) estimated that less than 10% of individuals during a disaster demonstrate behaviour patterns that can be described as panic. A large proportion of people (~70%), though, are passive. They require instructions, guidance, leadership and to be provided with a clear course of action before exhibiting survival behaviour. The final group of people exhibit creative behaviour. They actively seek out a method for escape, become leaders and generally act optimally within the confining parameters of the disaster situation.

For people still in the area affected by destructive eruptive forces the chances of survival will be low but certain behavioural patterns may increase it. Incoming volcanic bombs can be dodged if they are visible and the their numbers are not too great. Scarth (1994) reports a case of British scientist caught by an eruption dodging bombs on the beach they had landed on for over an hour. A sudden explosion from the Bocca Nuova Crater of Etna, Sicily, on 12th September, 1979, left 9 dead and 20 injured out of a group of approximately 150 tourists in the area affected by the explosion (Chester *et al.,* 1985). Mountain guides reported that they tried to stop the tourists running away but they were ignored. They felt that it was better to try and dodge the bombs rather than turn their backs on the eruption although some of the guides were also killed (Personal communication - Professor John Guest).

People have survived being in pyroclastic flows and surges. During the May 18th 1980 eruption of Mt St Helens, nine people survived despite being in the channellised zone of pyroclastic flows and surges (Baxter, 1990). Four may have protected themselves by falling into a hole and another by rolling under a tree. When the steamship Roraima was caught in the 1902 pyroclastic surge from Mount Pelée, Martinique, nine crew members survived. Four were in cabins with closed doors, two were in the engine room and three were protected by the bodies of other crew members.

5.4 PHYSIOLOGICAL AND PSYCHOLOGICAL RESILIENCE OF THE INDIVIDUAL

However effective self-protection is, an eruption is likely to impose physiological stresses on individuals. Having to act rapidly, keep going without rest, water or food, suffering minor injuries and being in an inhospitable environment (eg. suffering cold, heat, ashy air etc.) are some of the potential stresses likely to be experienced. The old, young, pregnant and ill will be particularly susceptible to this. Those that are particularly susceptible to this physiological stress will need to be better protected than others both during and after an event.

The stress of being involved in an eruption and the experience of its consequences may also affect mental well-being. The long term effect of a highly stressful event has been termed post traumatic stress disorder. In the case of a volcanic eruption the stress of the actual event itself may be combined, in the longer term, with other traumas such as the loss of family and friends, destruction of familiar environments, loss of economic security and more generally a derailment of normal life. The effect on mental well being can be severe (Raphael, 1986). In a study of natural disasters in the USA between 1982 and 1989 (all events declared by the federal government to be natural disasters were studied), it was found that in the years after floods, hurricanes and earthquakes, suicide rates increased (data on suicides before and after the event were collected) (Krug *et al.*, 1998). In the first year after an earthquake the suicide rate within counties affected by the event increased by 62.9%. The effect of a disaster on children is not particularly well understood. They probably have a very different experience to the adults around them (Raphael, 1986). Their experience is probably related to the child's inability to comprehend the nature of death. The experience may particularly focus on the absence of parents or the terror of seeing 'all-powerful' parents rendered helpless and scared. The psychological resilience of the individual will be important in determining their susceptibility to a volcanic eruption

5.5 LIVELIHOOD AND RESOURCES RESILIENCE

Livelihood is the:

> ...command an individual, family, or other social group has over an income and/ or bundles of resources that can be used or exchanged to satisfy its needs (Blaikie *et al.,* 1994, p. 9).

The susceptibility of livelihood, will affect a number of the Satisfiers of basic needs. If the eruption has destroyed a family's house, the extent to which their livelihood will allow them to rebuild it will define whether their need for shelter is satisfied. Similarly, they might not be able to purchase health care, food or other Satisfiers of basic needs.

The nature of an individual's or group's livelihood will vary greatly within and between cultures. There will be differences in the size of economic resources, the nature of revenue generating mechanisms and the type of loss reduction mechanisms that can be used. These factors will differentiate the susceptibility of people within an area affected by the same volcanic processes.

An eruption will have varying effects on different aspects of a livelihood. Animals may die if their grazing land is covered in pyroclastic fall but they could be moved away from a lava flow. If a factory was destroyed in a pyroclastic flow, a worker might be able to find new work fairly easily because of the transferable nature of their skills. Aid money flowing into an area, after a disaster, might create new opportunities allowing a person to reconstruct their livelihood and even prosper.

The ability of an individual, family or community to adapt their livelihood to a new environment, can be important in situations where volcanic activity has meant relocation or where the activity has led to significant environmental change. Being able to make use of farm land with extensive fall deposits or partly covered in lava, might determine the difference between the success or failure of a person's livelihood in the post-eruption environment.

5.6 EMERGENCY ORGANISATION RESPONSE

The response of organisations charged with the protection and governance of a community, will affect the extent to which individuals within that community will be able to avoid damage to physical health and autonomy. Organisations can act to minimise the amount of harm inflicted by a volcanic eruption and aid recovery after it. They can reduce the extent to which people are exposed to a hazardous environment by having procedures in place that will enable successful evacuation prior to an eruption. By providing an emergency field centre, they can ensure that appropriate healthcare is available.

Political infighting, lack of scientific knowledge, fears about economic costs and scientific disagreement have been associated with inappropriate emergency response. The results have sometimes been disastrous. The town of St Pierre, Martinique, was not evacuated during the 1902 activity at Mount Pelée, because the threat of pyroclastic flows was not really understood by the scientific community and there was, as a result, an unwarranted sense of security in which it was seen as unnecessary to order an evacuation of the town (Tanguy, 1994). There has been a suggestion in the literature that the governor Louis-Guillaume Mouttet was keen to detain the population in the town until after an important election and had requested thirty soldiers to come to the town in order to halt the flight. It seems likely that these troops were actually requested to maintain order and stop the looting of houses of people who had already left the town. During the November 1985 eruption of Nevado del Ruiz, Colombia, a series of devastating lahars were generated when the snow cap and glaciers of the volcano melted during a period of sub-plinian volcanic activity (Sigurdsson and Carey, 1986). About 23,000 people lost their lives when the lahars swept through a number of towns near the volcano. There had been no evacuation carried out despite scientists from INGEOMINAS (Instituto Nacional de Investigaciones Geologico-Mineras) and the Universidad de Caldas issuing a hazard map that accurately delineated the area that was to be affected by the lahars and there being sufficient time to respond to warnings of lahars after the onset of the eruption.

The response of emergency organisation is also important in the post-eruption reconstruction process. The success or failure of recovery will depend on organisations, individuals, families and local communities to varying extents. In situations where the destruction of local infrastructure and economy has been extensive, external organisations will often play an important role in the reconstruction process.

5.7 REACTION OF FAMILY, COMMUNITIES, SOCIAL ORGANISATIONS AND SOCIETY IN GENERAL

Significant reverberations will be felt by the individual with the impact of a volcanic event upon their families, communities and society in general. These will affect them economically, socially and psychologically.

A family is defined in this context as members of a group that support or would be supported economically and socially by other members of that group and who are linked by kinship. Community denotes individuals who are spatially, socially or economically closely linked. The resilience of a family and community can be defined as the probability of their existence as structures after a volcanic event. This will be fundamental in determining whether an individual has the possibility of primary relationships but will also affect all the other Satisfiers of basic needs. The resilience of community and family will be determined by the extent to which the community can be re-establish at its original site or other location after the eruption or whether it will fragment during the recovery period.

The post-eruptive state of the social system, within which the vulnerable individual exists, will be important in determining indirectly and directly the presence of many of the Satisfiers of basic needs. The social system will be responsible for actively aiding recovery and also providing a social and physical environment in which recovery can take place. The potential affect of natural hazards on social systems and institutions such as the nation state or the world economy is difficult to assess because of the number of variables and unknowns. If Tokyo was destroyed in a seismic event, an event that is predicted, the affect on the Japanese and world economy would be severe (Chester, in press). The destabilising affect on the Japanese social system and social institutions would probably hinder their ability to aid in the post-disaster period. The susceptibility of infrastructure to damage will be important in defining how society will be affected by an eruption. If an economically important town or city is in an area that will be affected by volcanic products, people even some distance from the volcano may still be affected by it.

5.8 CONCLUSION

In this chapter a framework for analysing how people are vulnerable to volcanic hazard was outlined. At the core of this framework lies the concept of universal human needs. A person can be said to be vulnerable if a volcanic event would hinder the achievement of basic needs and, ultimately, impede social participation. Although basic needs are in essence universal they may actually take different forms between societies. This is because they are what is needed to achieve social participation and this varies between societies. The extent to which volcanic events will impede the achievement of basic needs will depend on an individual's susceptibility. Susceptibility to volcanic hazard being a fusion of individual and societal conditions. The next chapter explores why these conditions are produced and reproduced.

CHAPTER SIX: A THEORY OF VULNERABILITY CHANGE

6.1 INTRODUCTION

Once vulnerability has been identified it is important to investigate its roots and development. A number of models have been devised to do this. The *pressure and release* and *access model* (Blaikie *et al.*, 1994) and the process of *marginalisation* (Susman, *et al.*, 1983) have already been discussed (chapter 2). The debate between those that believe in individual behaviour and those that favour structural determinist explanation of disasters has also been outlined in chapter 2. The conclusion reached in that chapter was that neither of them, on their own, offered a satisfactory approach to understanding hazards and disasters. Instead an integrative approach was required.

In this thesis it is argued that changes in vulnerability result from elements both inside and outside the sphere of individual action. This chapter discusses first the factors that lie within the sphere of individual action and then goes on to discuss factors outside it. When using the term individual action a freedom of agency is implied but it is a state that exists within a complex web of circumstances. The circumstances represent a world that:

> ..is contingent and probabilistic, and interactions between people and environment in given places and times are neither random nor law-given, but instead are the result of a combination of historical circumstances that confine but do not determine behaviour (Palm, 1990, p. 78)

and in a situation in which people:

> ...make history, but they do not make it just as they please; they do not make it under circumstances chosen by themselves, but under circumstances directly encountered, given and transmitted from the past [and by geography] (Marx, 1869/1963, p. 15 - in: Ritzer, 1996, p. 528)

Although this chapter separates changes in vulnerability that are outside the sphere of individual action from those that may be due to it, this is an artificial distinction drawn to aid explanation. Actually the same aspects of society that lead to changes independent of individual action may also be implicated in changes that take place through individual action. During a civil war, for example, a local market may cease to function as traders and customers decide not to participate. At the same time farmers may supply food to those fighting to avoid raids on their land. This leaves the farmer vulnerable to future droughts because of low material resources both in terms of food stocks and other goods purchased through the sale of cash crops. The civil war is the cause of vulnerability both because of an individual's action and factors independent of that individual action.

This chapter will try to bring together findings from a variety of different research fields and propose a model of vulnerability change in volcanic environments. The validity of this model will be explored in two case studies of societies situated within areas of volcanic hazard (chapters 8 & 9).

6.2 INDIVIDUAL ACTION

Individual action or agency both produces and reproduces society. Individual action does not take place independently of society and it is therefore important to develop an integrated model of the two in order to understand why individuals behave in a way that increases or decreases their own vulnerability and the extent to which aspects of society are implicated in this process.

The literature on the psychology and sociology of risk is dominated by research into the perception of risk and more recently its communication. Risk behaviour and its relationship with risk perception has not been studied to nearly the same degree. When it has been the focus of research the approach has tended to be reductionist, analysing specific perception-behaviour relationships in isolation and focused on certain types of risks (ie. transport and industrial accidents, health behaviour and economic decision making). Frequently the study of risk behaviour has been limited to accident statistics with little attempt made to explore the motivations behind the behaviour at anything more than a very superficial level. The goal for these studies being a quantification of how 'risky' an activity, location or lifestyle is. Risk reduction measures have, as a result, often been flawed and their effects been unanticipated (Adams, 1995). In this section it is argued that when volcanic risk behaviour is scrutinised within context, the counterintuitive conclusion is reached that in the dialogue between risk perception and risk behaviour in volcanic environments, it is behaviour that is dominant.

6.2.1 Risk perception

Differences in how individuals conceptualise risks have been explored by psychologists, sociologists and anthropologists. Thus a number of different methodologies and theoretical frameworks have been developed, generally reflecting the preoccupation's of the different subject areas.

Risk perception has been explored psychometrically, using adjectival scales and multivariate analysis. This approach has revealed a number of dimensions that seem to structure individual perception. Three dimensions, for example, were identified by Slovic *et al.* (1980), these were: *'familiarity'*, *'dread'* and *'exposure'*. These results have been replicated a number of times. Familiarity relates to scales such as observability, knowledge and familiarity of consequences. Dread relates to scales such as dread, catastrophic, fatal and hard to prevent and exposure to the number of people exposed to the risk. One major criticism of the psychometric approach to risk perception is that, although there are usually a large number of semantic differential scales available to rate the various hazards, they were provided for the subject by the testers. The semantic differential scales used do not necessarily reflect the actual constructs used by the subjects when thinking about the various hazards. These constructs may be related to the context within which the judgement is made. The building of a nuclear power station, for example, might be judged by one resident, of a nearby town, in terms of dread, while another might base her judgement on whether they were likely to gain employment. This also highlights another criticism of the psychometric approach, that it does not capture the contextual, and therefore individual, aspects of the experience of risk. The responses of participants are analysed together despite the fact that they are likely to have had difference experiences of accidents, hazards and risk. When they did break their sample down into groups, in a different study, (between League of Women Voters, College Students, Active Club Members and Risk Experts), there was no suggestion made that members of a group had a distinctly similar experience of risk, indeed with the variety of risks they were being asked to rate, this would be extremely unlikely.

When social context has been explored, research shows that hazards and individuals can be differentiated in terms of the way they are perceived and the way they perceive. Natural hazards, amongst a Norwegian sample for example, were seen as voluntarily taken and therefore the responsibility of the individual; while 'man-made' hazards were seen to be the responsibility of government and authority (Brun, 1992). Similarly, Slovic *et al.* (1980) found that engineers tended to frame the risks involved with nuclear power in terms of probabilities while the public focused upon the consequences. Individual differences in risk perception seems to be related to an individual's social situation, cultural background and general belief systems. Individual differences seem to affect what aspects of the risk phenomena an individual sees as salient, the frame of reference used in social discourse about risk and what risks are see as important. Wynne (1992) found that during the 1977 Windscale Public Inquiry at the core of the debate, between the proponents and opponents of expansion, lay the issue of 'trust in institutions'. Each group framed the issue according to their own perspective and the public debate became polarised and degenerated.

Cultural theorists have developed the idea of differences in risk perception between members of various social groups. They argue that:

> Whatever objective dangers may exit in the world, social organizations will emphasize those that reinforce the moral, political, or religious order that holds the group together (Rayner, 1992, p. 87).

From an individual perspective:

> Viewing individuals as the active organizers of their own perceptions, *cultural theorists* have proposed that individuals choose what to fear (and how to fear it), in order to support their way of life. (Dake and Wildavsky, 1993, p. 43).

Risk selection is said to be based on *cultural biases* or deeply held beliefs and worldviews whose value lie in the defence of particular patterns of social relations. The patterns of social relations in cultural theory are summarised under four, sometimes five, archetypes. These are differentiated depending on the extent to which they involve membership of bounded groups ('*group*') or the extent to which interactions are governed by rules or are negotiated ad hoc ('*grid*') (Pigeon *et al.*, 1992). The main four cultural biases are: *egalitarians* (high group, low grid), *individualists* (low group, low grid), *hierarchists* (high group, high grid) and *fatalists* (low group, high grid). The fifth cultural bias, that is sometimes added, is the *autonomist*, which represents a disengagement, detachment and independence (Adams, 1995). Cultural theory has been less extensively researched than other areas of risk perception (Pigeon *et al.*, 1992). When quantitative analysis of the theory has been attempted, the scales used to represent the various biases have correlated with each other (Dake, 1991). This suggests that either the scales used to measure the different cosmologies do not effectively capture their essence or individuals do not conform to particular cosmologies across all situations. In one study of 300 San Francisco Bay residents, hierarchists and individualists scales were positively correlated with each other (r=0.54) and to the societal risk taking scale. This suggests that there may really be only two main, generalised, positions on societal risk. Those that are averse to societal risk taking (egalitarians - catastrophists) and those that favour it (hierarchists and individualists - cornucopians) (Pigeon *et al.*, 1992). Renn and Swanton (1984) reported that people who scored highly on scales measuring environmental consciousness, have a desire for more participation, and those that have a non-fatalistic view of life were more against nuclear power than those who were low on these scales. The reverse was found for those that had scored highly on scales measuring confidence in science and technology and a conservative view of life. In contrast, some critics have argued that the typology is not really subtle or flexible enough to be able to classify different social groups, they point to the fact that deep green ecological groups and the Sierra Club have both been put, as environmental organisations, into the egalitarian classification (Rayner, 1992). When risk taking is clearly in the domain of social groups rather than relatively isolated individual decision making, it seems likely that the nature of social groups will have an influence on the framing of and behaviour towards the risk of its members. Decision making surrounding the expansion of a nuclear plant, for example, will usually take place within the context of a forum, with various social groups struggling to have their own interests satisfied. In contrast, the decision to drive a car fast is relatively isolated from the discourse of a particular social group; though aspects of social group membership, such as feelings towards the law, the police or peer pressure, may affect decision making. A related issue is the extent to which cultural biases are stable across different situations. Some theorists argue that individuals will seek to homogenise their experience across different social situations; a person from a hierarchist family, will seek a hierarchist job and join hierarchist organisation (Rayner, 1992). This has been described as the *stability hypothesis*. The *mobility hypothesis*, in contrast, argues that individuals will change the nature of their argument as they move between contexts. If the mobility hypothesis is favoured over the stability hypothesis then it suggests that the cultural biases are associated with a specific social context, and the dialogue is taking place within that context, rather than it being an individual trait. This, it is argued, overcomes the criticism that cultural theory is determinist (Rayner, 1992).

While accepting that the evidence supporting the three to five cosmologies proposed by cultural theorists is inconclusive at present, there seems to be sufficient evidence to support the concept that membership of social organisations and groups will affect what risks individuals identify for attention and how they are integrated into existing patterns of belief (Green *et al.*, 1990). Membership of social organisation and groups is often described as a role. Roles are transitory and an individual is likely to have various, the risks chosen for attention and the way they frame risk and will, therefore, change over time and between situations. Scientists or engineers working in the risk area, for example, spend some time being 'members of the public', in this role their assessment might not be from a 'professional' position (ie. Probable Risk Analysis). It may also be true that people who strongly favour a particular form of social organisation are likely to seek environmental and social roles within that form. Adams (1997) argues that the effect of cultural biases on perceptions of risk will be felt especially strongly when 'objective assessment' of risk is very difficult or impossible. He describes risks where no probability calculation is possible as 'virtual risk'. Because the incubation period of new variant Creutzfeldt-Jakob Disease (CJD) in humans is unknown, it is impossible to calculate the risk associated with, for example, eating beef. In these circumstances, people are especially likely to impose meaning on to the uncertainty.

A psychological model of risk communication is proposed in *risk amplification* theory. It explores why certain risks become more a focus for concern than others (Pigeon *et al.*, 1992). Based on the assumption that most of the information people receive on risk is through communication rather than direct experience, it explores how various psychological, social and cultural factors lead to the perception of risk being either attenuated or intensified (Kasperson, 1992). The key elements of risk amplification theory are, that information on risk is seen as a *signal* and that when it passes through particular *stations* (eg. groups of scientists, newspaper or pressure group) it undergoes predictable transformations. Different aspects of the risk are either attenuated or intensified and therefore groups and individuals have differential interpretations of hazard events (Pigeon *et al.*, 1992). Although this proposal has been criticised by cultural theorists (Rayner, 1992), it does present a mechanism by which meaning might be transferred.

In summary the literature on risk perception demonstrates that individuals perceive various hazards in different ways and may, indeed, perceive the same risk in various ways over time and between places. This differentiation seems to stem from interplay between individual differences (eg. experience, culture and psychological traits) and the social context within which it is experienced. The individual's relationship with risk is reflexive and social. The information they receive on and their experience of risk both being affected by but also transforming their own representation of it. Importantly, therefore, risk perception needs to be studied within context. Many studies have artificially separated the perception of risk from a perception of the general context within which it exists. It will be argued in the next section that the level of threat, from volcanic activity, is typically mediated by decision making and behaviour unrelated to representations of volcanic activity.

6.2.2 Risk taking

If defining risk as the probability of a consequence that would induce anxiety in a majority of people, it is important to recognise that risk is not necessarily a negative experience. Risk taking is a constant feature of everyday life. It is a central component of economic and social decision making, in, for example, the type of financial investments made, crop grown or partner chosen. Relatively high levels of risk are also actively sought by various people at different times. This is very apparent in the type of leisure activities individuals choose to participate in (eg. parachuting, rock climbing, hang-gliding or bungee jumping). Adams (1995) analysed behavioural data - accident statistics - and demonstrated that imposed safety measures - seat belt legislation - did not have an effect on the general trends in car road accidents. He argued that individuals '*balance*' perceived risk and reward, so that a fall in perceived risk inherent in a situation leads to an increase in risky behaviour. Seat belt legislation, as a result, seems to have led to some displacement of risk on to other road users (eg. cyclists, pedestrians) as drivers who prefer relatively higher levels of risk have *compensated* for the increased feeling of safety by driving more dangerously.

Two types of risk takers have been identified, those that are *risk averse* and those that are *risk seekers* (Lopes, 1987). Risk or sensation seekers are more likely to take part in risky sports and take up relative dangerous occupations. Risk seekers might be risk-averse in some situations and vice versa. To build on the Lopes (1987) argument, when considering behaviour that directly determines a level of risk, some individuals are more likely to choose higher risk than others across different situations. The experience of risk and the feelings of excitement, control and stimulation that go with it, has a positive emotional effect for an individual in situations where they have made a deliberate choice to experience it. Csikszentmihalyi (1977) found that rock climbers enjoyed the intense feeling of control or *flow* they experienced as they climbed. Differences in risk preferences are not necessarily a chronic fact of human behaviour but are also a function of situational factors. A situational variable in the context of risk can be termed an aspirational level. Three sources of aspirational levels, functioning in a given situation, are: the direct assessment of what is reasonable or safe to hope for, the other alternatives in a given choice set and the effect of outside influence (Lopes, 1987). Similarly, Wilde (1982) argues, within the risk homeostatic theory, that risk behaviour is determined by the interplay of *target risk* and *risk perception*. In regard to driving, perceived risk is related to past experience of risk and target risk is determined by (1) background factors (eg. age, sex, driving experience etc.), (2) trip specific factors (eg. blood alcohol levels, fatigue etc.) and (3) Momentary factors (eg. traffic hold up etc.). Social environment may have a strong influence on risk behaviour. Thompson (1980), with reference to Himalayan mountaineering, notes that although the Sherpas of Nepal carry out high altitude portering as their job, they have the same attitude to the risks and challenges involved in climbing as the mountaineers. They also see the Hunt expedition route up Everest, via the South Col, as the 'yak route' because it is technically relatively easy.

Levenson (1990) identified two types of risk taking that could differentiate rock climbers, drug addicts and heroes (policemen and firemen who had been commended for bravery). Drug addicts tended to score highly on an *anti-social* function, characterised by depression, emotionality, psychopathology and have lower scores on moral reasoning. Rock climbers scored highly on an *anti-structural* function, characterised by sensation seeking and moral reasoning. The heroes were not characterised by either discriminant function which suggested their risk taking was not motivated by thrill seeking.

It is important, therefore, to differentiate between individuals deliberately putting themselves at higher risk than others because they have chosen to do so and those who are in a higher risk situation because: they are not aware of a threat, they perceive it is an acceptable by-product of an activity, they have constricted choices or they have been put at risk by something outside their control. This is not the same as Starr's (1969) distinction between voluntary and involuntary risks. It is possible to be voluntarily involved in an activity that is high risk in some regard but not to be involved in it because of the risk. This is more likely to occur when risky tasks are part of a more general activity, such as a job, that is attractive in non-thrill satisfying ways. For example, a woman might move to a town near a volcano because her future husband lives there. She is moving because she is getting married not because she wants to experience a higher level of risk. In this case it will be an unexpected or acceptable consequence of a particular type of behaviour. Experience of risk taking, therefore, can be placed into one of four categories. If an activity or action is deliberately chosen or taken because of the high level of risk, the experience might be termed *elected* risk taking. An activity that has a high level of risk, which is a consequence rather than the reason an individual has for being involved in the activity, but which does not worry them, might be termed *acceptable* risk taking. If they were unaware of the risk it might be termed *unconscious* risk taking and if it was unwanted it might be described as *unacceptable.* Though constrained by various factors, a person will always attempt to change a situation of unacceptable risk taking. Whether risk taking is acceptable or unacceptable depends on the individual's representation of risk and so one way to change a situation of unacceptable risk is to think about it in a different way. It is argued, therefore, that risk perception may determine elected risk taking but the reverse is true of unacceptable risk taking. Unacceptable risk taking will lead to the development of risk perceptions that will, in turn, transform it into acceptable risk taking. This process will now be explored.

6.2.3 Decision making and levels of risk

The extent to which the perception of a risk will affect action is dependent on its role within decision making. As has been discussed above, research shows that people have differing propensities to take risks (Lopes, 1987; Levenson, 1990; Hillman, 1993; Adams, 1995). When an individual has direct control over an aspect of their environment that can be modulated to achieve different levels of risk, they will act in such a way as to generate a perceived level of risk that they are comfortable with. This can be represented as an instrumentality where "*" equals a reward, goal or payoff (figure 6.1). This has been described above as *elected risk.*

A ——► B*

Figure 6.1: Simple instrumentality.

Action "A" leads to a risk payoff "B*". In the case of driving, action "A" might be increasing speed by pressing on the accelerator, while payoff "B*" is the thrill or stimulus or 'flow' felt by the driver with the increased speed. Whether action "A" leads to an actual increase in risk will depend on the accuracy of an individual's cognition of the risk situation.

This simple *link* can be contrasted with the decision making process associated with a goal that may involve action with high risk but which is not its aim. This is the most usual situation associated with an increase in risk in the context of volcanic hazards. To take, for example, changing location, which is frequently a cause of increasing volcanic risk. If again the decision making process is represented instrumentally.

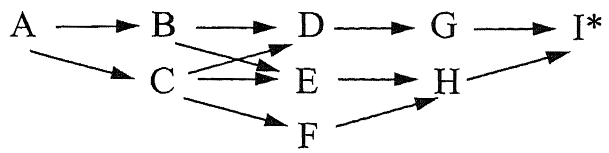

Figure 6.2: Complex instrumentality.

The decision making process in this case is represented as a *map* rather than a *link* (Kaplan, 1991) (figure 6.2). Not only is there a series of intervening sequences before the goal is achieved but also there are a number of alternative paths or contingencies. Because in most location decision making situations there are a very large number of possible links and sequences, an individual cannot assess each possible path separately. Traditional decision making theory proposes that a person would weigh up alternatives and optimise a potential solution. Even when modified, for example with Simon's (1955) *satisfier* concept, rational choice theory still assumes an analytical process of weighting alternatives. In contrast to this, Kaplan (1991) proposed that the whole *'problem space'* is assessed. The *clarity* of this cognitive structure is important and is defined by its *match* and its *strength* or interconnectedness. Its match is the extent to which expectations correspond to perceived reality. Some situations are structured in such a way, that a good match is possible despite the individual being unfamiliar with it. Its strength or interconnectedness represents the familiarity an individual has with it or whether they know all its features. Strength will be low if elements of the structure are ambiguous because of unknown or difficult to predict occurrences. Cognitive structures with low clarity will be affectively unpleasant. There is a tendency to avoid low clarity decisions. When approaching decision making, individuals will seek out clarity. This is recognised by politicians whose messages often offer a simple clarity - for example withdrawing from the European Union is a case of reclaiming nationality rather than a rejection, upon analysis, of the legal, economic and social processes of the Union. An increase in risk, in the case of volcanic hazard, will be a function of one or more of the sequences within the decision making structure. If the cognitive structure is simplified to increase its clarity, it is very likely that this aspect, if it is known, will be lost. An increase in risk will, therefore, be an unexpected consequence of behaviour.

Location decision making generally involves a large number of possible elements and sequences, the cognitive structure is often low in strength (ie. unfamiliar and with ambiguous aspects) and a poor match to past and present experience. A lack of clarity means that individuals actively seek information and advice that will allow them to increase the clarity of the cognitive structure (Kaplan, 1991). International and metropolitan migrants often move initially to areas which are linked to their home. A contact can offer information such as 'A' being the best city to move to initially. This would offer a much simpler cognitive structure than one that involved assessment of a large number of locations. McHugh (1984) found that amongst a sample of metropolitan settlers, 95% had at least one contact in the chosen location, 75% had two.

> ..prospective migrants tend to restrict their "search" to locations they are familiar with...place ties represent the basis for this familiarity (McHugh, 1984, p. 317).

Destinations will often have a simplified, even iconic, image: the Northwest passage, the Wild West - 'go west young man' - and London with its streets paved with gold (Downs and Stea, 1977). When the clarity of a migration decision structure is increased by the acceptance of an image of a destination, it is likely that any awareness of the risk-increasing aspect of the decision making process will be lost in the simplification.

Individuals relocating themselves will often have a poor knowledge of the area into which they are moving. It is possible that in the case of volcanic hazard, they will be unaware of the hazard or at least uncertain about it. In this situation it is likely that the presence of people living in an area of hazard will reassure a potential migrant as to its safety. As has been discussed above, migrants typically move to areas where they have contacts. In this situation they are relying, to some extent, on the contacts knowledge of a geographical area; its problems and its advantages over other places. If the contact believes that the danger posed by volcanic hazard is not sufficient to be worried about, then this attitude is likely to be absorbed by the migrant.

Individuals, in some circumstances, may have or perceive they have limited choices. They may be aware of a hazard, be worried by it but, within the context of deciding amongst other risks or taking certain opportunities, decide that they must accept it. This is a constant feature of human existence, individuals balancing, through action, the multitude of risks they face (Adams, 1995). Social context will play an important role in defining this balancing process. As has been discussed in the context of risk perception: membership of social groups, collectivities and cultures will influence how risk is constructed. For someone living in an area affected by natural hazards, other dangers, may seem far more likely and be perceived as far more threatening than that from volcanoes or other natural hazards (Hewitt, 1983). Whyte (1985) found that on five eastern Caribbean islands, the main concern of the residents was social and economic conditions - the level of inflation and lack of jobs were particularly consistent worries - rather than the natural hazards the islands were prone to. These included earthquakes, major volcanic eruptions and hurricanes:

> Even individual and governmental decisions that directly affect the vulnerability of the population to natural hazards, such as house construction style and land use zoning, are determined primarily by other considerations, such as traditional land tenure systems and the desire for increased tourism (Whyte, 1985, p. 405).

Volcanic risk taking is likely to be either unconscious, unacceptable or acceptable. It is unlikely that it is elected because it will generally result from a broader context of action. Awareness of a hazard in this situation is likely to be low. The sheer scale of a volcanic event, especially if it is irregularly occurring, compared to the familiarity of other problems, makes it difficult to comprehend. Awareness may be increased by a number of factors including: environmental cues or communication. If individuals are aware of the hazard, are not comfortable with it and realise that they have either brought the hazard upon themselves - unacceptable risk taking - or at least have not done anything about it, they may experience tension or unpleasant arousal. This state has been described as *cognitive dissonance* (Festinger, 1957). The theory of cognitive dissonance predicts:

> a negative drive state occurring when an individual holds two cognitions which are psychologically inconsistent (Festinger, 1957, p. 13).

Festinger's original theory has undergone some modification. Aronson (1968) suggests that dissonance occurs when one cognition violates the expectancy of another. Similarly, recent research has changed the emphasis of the process slightly.

> Such unpleasant feelings appear to be particularly associated with beliefs in one's own responsibility for a bad behavioural decision

> leading, actually or potentially, to adverse consequences that one should have been able to foresee (Eiser and van der Pligt, 1988 p. 40).

The theory predicts that an individual will attempt various methods of cognitive restructuring in order to remove the feelings of tension or unpleasant arousal. This cognitive restructuring may take on a number of forms. It may include changing one of the existing cognitions or adding another. If, for example, the dissonance results from the knowledge that 'I live in town A' (cognition X) and the belief that 'Town A is in a volcanically hazardous zone' (cognition Y), then dissonance may be reduced by changing cognition Y 'Town A is not really very hazardous'. Similarly, an extra cognition may be added, 'Life in town A is very good, there are dangers in all other places'.

The reduction of dissonance typically involves the search for information in support of previous decisions (Frey and Wickland, 1978). Prasad (1950), studying rumours after the 1938 earthquake in the Indian province of Bihar, concluded that they are formed of:

> whatever may be 'congruent' with the patterns of the attitude are selectively constructed or adapted from the environment, particularly the cultural heritage of the people....It 'draws' such materials from the external socio-cultural surroundings as are congruent with patterns [of belief] (Prasad, 1950, pp. 143-144).

This information, in the case of volcanic hazards, might be about: improvements in the scientific monitoring of volcanic hazard, a neighbour's confidence that an eruption is very unlikely or the belief that God will protect them. Decision making heuristics, as discussed in chapter two, may support a cognition of lower risk. The 'gamblers fallacy' is an often cited example of a 'systematic error' that an individual may use in response to environmental uncertainty (Palm, 1990). It involves the belief that random events are actually cyclical so that a recurrence is less likely immediately after the previous event (Slovic *et al.*, 1974). The belief that fate or a deity controls the future may also reduce the dissonance felt by the individual. This is different from Rotter's (1966) identification of a dichotomy between those who attribute aspects of their life to their own behaviour and those who attribute it to chance (internal verses external control - I-E scale). Schmidt and Gifford (1989) argue that perceived control over the environment may be different to perceived control over social contexts, the main constituent of Rotter's I-E scale. They found only low correlation between the three scales that made up their Environmental Appraisal Inventory and Rotter's I-E scale. Their scales measured the extent to which a person perceived control to be a possible response to a hazard while Rotter's locus of control focuses on how outcomes occur. Whyte (1978) argues that people with little actual control over aspects of their life will, over time, come to believe that they have little control over their own fate. This situation has been described as learned helplessness (Seligman, 1983). A final strategy would be to avoid the feelings of tension or unpleasant arousal associated with dissonance by suppressing the whole discordant cognitive structure. This might be achieved by avoiding situations where awareness might be raised or ignoring information that supported the reality of the 'at threat' situation. This is referred to as an avoidant (or distracting) coping style (Evans, 1991). In a community this could mean that the subject is avoided during conversation.

Dissonance can also be reduced through action or an instrumental response. Behaviour intended to reduce hazard is referred to as adaptive, adjustive or mitigative. Workers within the human ecological tradition of hazard research, explored the various adaptive, adjustive and mitigative strategies used by individuals, groups and organisations. The problem with this research is the emphasis it placed on action in relation to hazard. By focusing on this relationship to the exclusion of other aspects, the human ecologists failed to produce a plausible theory of why adjustment did not take place. The emphasis on isolated decision making rather than action within a complex milieu, meant that non-adjustment was blamed on 'inaccurate' risk perception. While risk perception is often consistent with non-adjustment, it is possible that non-adjustment to a hazard is the cause rather than result of the perception of that hazard.

When adjustment takes place, it does so under conditions of uncertainty and bounded knowledge. This may lead to unforeseen outcomes. Adjustment usually takes place within a social context where others may affect the outcome of the individual's action. The results of the collective nature of action in a social environment may be a sub-optimal (everyone gets something but not as much as they wanted) or counterfinal (everyone gets the opposite to what they were expecting) situation (Bogard, 1988). Adjustment to a hazard leads to new social and environmental conditions rather than necessarily a safer environment. If the new conditions are perceived to be worse than before, adjustive behaviour can be modified in the future (positive feedback) but this new information will only lesson rather than remove the uncertainty surrounding future action. When hazard events are infrequent (as is common with volcanic events) then there will be no opportunity for this learning process to take place. The uncertainty surrounding the consequences of adjustive behaviour may make it unattractive even if an individual perceives the need to act and has the ability to do so.

Awareness of a hazard and decisions about whether to adjust to it are not taken by individuals acting alone. An individual will usually be a member of a series of social groups (eg. families, kinship, communities) and organisations (eg. firms, collectives, estates, government bodies). Within some groups, individuals may have varying influence over their own vulnerability. A child's vulnerability will typically be strongly influenced by the actions of parents or extended family but in some situations as the only literate members of the group they may have access to information and influence the actions of that group. The importance of hearth groups and family units are recognised by both Palm (1990) in her integrative approach to earthquake hazards and Blaikie *et al.* (1994) in their *Access to Livelihood* model.

Today, with the amount of stored knowledge, the ease of communication and the existence of organisations across time and space, it is very unlikely that in a situation where vulnerability exists there will be no awareness of risk. In a folk society, where a community would be isolated from others and rely on an oral tradition rather than written records, it is more likely that this might be the case. But even within the oral traditions of folk societies there is evidence of the storage of information about volcanic risk (Shanklin, 1989). Thus perception of risk will usually be a factor in defining vulnerability but its affect and nature will be highly variable between people and across time and space. As has been discussed above, individuals often rely on information from others to clarify the decision making process and reduce cognitive dissonance. In this manner a feedback system is likely to exist in a vulnerable community, where the feelings of unacceptable risk taking are surfacing and being reduced by information from others.

The perceptions of risk held by people in communities facing volcanic risk are a function of their *participation in a social world* rather than them being the result of an individual *confronting a social world.* People who share a world must have a common representational system so that they can communicate but at the same time people who share a world will have different relationships with it and therefore will have varying representations of it (Canter and Monteiro, 1993). These have been described as *Social representations*. They are:

> systems of values, ideas and practises with a twofold function; first, to establish an order which will enable individuals to orient themselves

> in their material and social worlds and to master it [sic]; secondly to enable communication to take place among the members of a community by providing them with a code for social exchange and a code for naming and classifying unambiguously the various aspects of their world and their individual and group history (Moscovici, 1973, p. 13: in Duveen and Lloyd, 1990, p. 1)

and

> as well as being always the representation of *someone or some collective*...The interdependence between social representations and the collectivities for which they function means that social life is always considered as a construction, rather than being taken as a given (Duveen and Lloyd, 1990, p. 3)

People with varying degrees of common experience will therefore have social representations that are similar, some that overlap and some that differ with others. This then creates conditions for communication or misunderstanding and conflict in society. People are likely to have different roles in a community and therefore different representations of it. It is environmental role that is important in the construction of social representations of volcanic hazard (ie. whether a person is a member of the civil defence).

Representations of volcanic hazard do not exist in isolation but are one aspect of a complex transactional relationship between the individual and his or her environment. *Place attachment,* an individual's feeling towards personally important environments, and their need for *ontological security*, power the need to reduce the feeling of unacceptable risk taking. A feeling of place attachment will also encourage the psychological reduction of the feeling of unacceptable risk taking, rather than actually attempting to reduce the risk itself. These factors are now explored.

6.2.4 The transactional relationship between people and the environment

A person's relationship with the physical environment can be described as transactional. Behaviour is not simply determined by milieu nor is it due solely to intra-individual phenomena (ie. the self - psychological traits, goals, experience) but rather a synthesis of a person within a social and physical environment. In other words, two intra-dependent aspects of the same phenomena or unit (Altman, 1973; Altman and Rogoff, 1987). These holistic units which have various psychological, temporal and contextual facets (Altman and Rogoff, 1987).

Barker's school of ecological psychology identified 'behavioural settings' as appropriate units for analysis. A behavioural setting is:

> a bounded, self-regulated and ordered system composed of replaceable human and non-human components that interact in a synchronised fashion to carry out an ordered sequence of events called the setting programme (Wicker, 1984, p12)

Canter (1991) is critical of the concept of a behavioural setting in two regards. Although behavioural settings are defined by their own physical boundaries, there is little development of how people actually use space. Similarly the boundaries of a behavioural setting are defined by the researcher, account is not taken of whether the boundaries are actually psychologically significant. Canter (1977) urges the identification of units of significant experience. He suggests that the unit of study should be psychological *places.* A place is the result of an interaction between its physical attributes, conceptions of it and activities happening within it (figure 6.3).

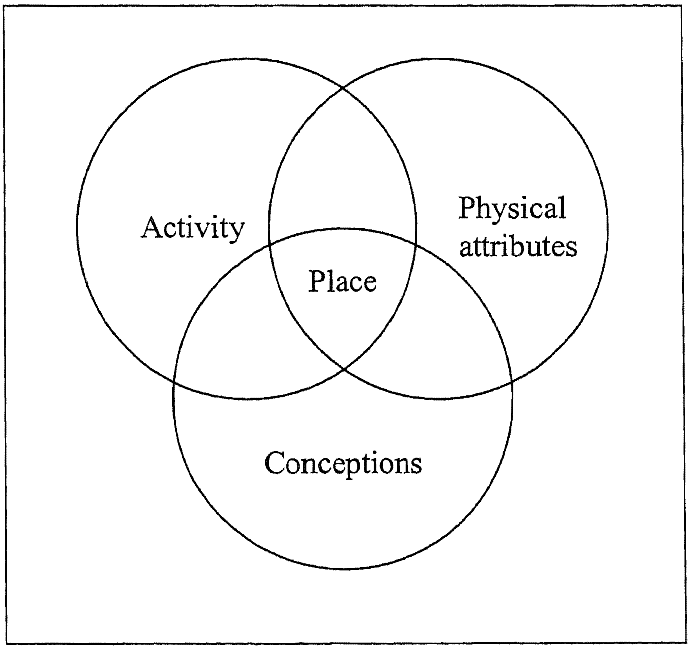

Figure 6.3: Theory of place (Source: Canter, 1977: p. 158).

> It must be emphasised, though, that places are part of the experience. They cannot be specified independently of the people who are experiencing them. The central postulate is that people always situate their actions in a specified place and that the nature of the place, so specified, is an important ingredient in the understanding of human actions and experience (Canter, 1983, p.667)

The unit of study is holistic, the person acting within a particular context or place; this has been described as a dynamically organised system (Ittelson *et al.,* 1974).

Human activity, orientated towards goals, is seen as the organising agent. Individuals must be able to predict the nature of the social interaction within an environment in order to achieve goal objectives. Wicker (1987) states, in developing Barker's ecological psychology, that individuals have strong and rich representations of *setting programmes*. Setting programmes are the understood and expected interrelationships between individuals within a physical setting. Canter (1985) has described the socially formed expectations of roles and types of interrelationships within a specific environment as '*place rules*'. He argues that place rules define forms and patterns of place use (Canter, 1991). An understanding and ability to reproduce rules enables a person to 'competently' go about their daily lives. Thus place rules and, more generally, social rules are routinized or reproduced behaviour. They are not, however, 'mindlessly' carried out but rather require constant monitoring of social context. Giddens (1984) has suggested that the motivation behind reproduced behaviour is the sustaining of a sense of ontological security or a the feeling that the immediate world is predictable. Place rules are often robust. During the 1987 Kings Cross fire, for instance, people caught in the fire continued behaving in ways typical of that environment until they received instructions from figures in authority or there was overwhelming evidence about the catastrophic nature of the situation (Donald and Canter, 1990). Changes in the physical environment may allow the emergence of different place rules and therefore initiate different types of behaviour. Canter (1975) explored the seating pattern of individuals within lecture theatres. He found that the positioning of the lecturer, the distance from the front row, and the layout of the seats, a series of rows or one semicircle, influenced the seating pattern that was taken by the students.

Environmental *roles* are the differing purposes people have for being in places (Canter, 1991). Environmental roles are generally defined by an individual's position in collectivities, social groups and organisations. Access to, and rules within, places are influenced by membership of and position in different social groups or organisations. Peoples entrance to and expected behaviour in a police station, shop or home, would be affected by their membership of different organisations - the police or retailer - and social groups - a family or suspect criminal. Space can play an important role in ordering and stratifying a social group. Variation in purposes and goals, associated with a particular place, will lead to differing actions within and cognitions' of it. Individuals while influencing the nature of situated activity and the meaning of place, also draw their own self identity from them. More generally a group's culture develops, over time, within this context of interactions in specific places.

When living within a particular environment for some time an individual may develop a strong bond with it. Fried and Gleicher (1961) found that residents of the Boston slums, especially those with a large number of relations in the area, generally felt very positively about their neighbourhood. This was despite the fact that the slum might be classified as high-risk (in terms of threat to property and self). Some residents even denied the existence of any threats. They conclude that behind this satisfaction lay two major components:

> On the one hand, the residential area is the region in which a vast and interlocking set of social networks are localized. And, on the other, the physical area has considerable meaning as an extension of home, in which various parts are delineated and structured on the basis of a sense of belonging (Fried and Gleicher, 1961, p. 315)

When a hazard is one aspect of a significant or important environment, then the individual's relationship with other aspects of the environment may dominate the environment-person transaction. The psychological attachment an individual feels towards a place has been recognised by many researchers who have termed it topophilia (Tuan, 1974), insidedness (Rowles, 1980), rootedness (Buttimer, 1980) and place attachment (Low and Altman, 1992). All these theories recognise an interplay between emotion, cognition (knowledge and belief) and practice (behaviour and action) in a particular environment (Low and Altman, 1992). Place attachment generally reflects stability and long term bonds between people, their homes and their communities (Fried, 1963; Rivlin, 1987).

The effect of attachment to place, within a situation of potential *cognitive dissonance,* is dual. First, it invigorates the feelings of tension or unpleasant arousal. Volcanic activity, in an area a person feels psychologically attached to, threatens not only themselves but is also a fundamental aspect of a person's existence. Secondly, it affects the possible strategies for reducing dissonance. The most effective way of reducing volcanic hazard is to relocate. This would not be favoured because of the attachment felt to the present location. When this has been partially forced on attached communities the perceived costs may lead to a reversal of the relocation. This happened after the evacuation of the 264 inhabitants of Tristan da Cunha in 1961 following a volcanic eruption on the remote island. After 18 months in Britain the islanders elected to return to their island (Blair, 1964). Place attachment has an important effect on cognitive dissonance and risk reduction behaviour. Place attachment increases the feeling of discomfort associated with the inconsistency, while at the same time acting against a particular strategy for reducing that inconsistency, namely relocation. Combined with the affective bond that seems to develop between the individual and the environment as part of the process, place attachment encourages the seeking of and belief in information that supports a 'less risk' situation. It is people's existence within a particular community and environment combined with the underlying need to suppress cognitive dissonance which leads to specific representations of risk. It is principally their behaviour, in reference to other aspects of their social life, that has led to the level of risk they are experiencing.

Place rules and roles, the meaning of space and routine environmental activities are clearly the manifestation of a social context that exists temporally and spatially outside the immediate experience of individuals as are the reasons why they enter into various places at various times. To understand these various aspects of place, it is necessary to explore the wider social context, though as will be emphasised in section 6.2.5, it is within situated activity that the wider social context is constituted. This social dimension will be further explored in the next section.

6.2 5 Society and the individual

In the previous sections it has been argued that individuals are responding to aspects, other than volcanic threat, when they behave in a way that increases their vulnerability. It has been proposed that this is because the individual is actively engaging in a social world that allures and cajoles them into vulnerability increasing behaviour. They are at certain times and in certain places provided with opportunities to increase vulnerability while being constrained in their ability to reduce it. Simultaneously society is providing them with representations that enable them to discount any discomfort they feel. The intentions of an individual should, also be seen as separate from their action for they act under unacknowledged conditions and their actions have unintended consequences (Giddens, 1979). In this section the way in which society is implicated in the generation of vulnerability is explored.

When examining the wider social context it is important to heed the warning given by Duncan and Ley (1982) that:

> macro-scale structures....do not have autonomy or an existence that is not ultimately reducible to cumulative human actions and interaction (Duncan and Ley, 1982, p. 32)

In other words it is wrong to presuppose an independently existing social structure which determines behaviour, instead it is necessary to develop a theory of how human agency relates to a relatively regular and predictable society. Giddens (1979) proposed the concept of structuration to explain this relationship.

> The concept of structuration involves that of the *duality of structure,* which relates to the *fundamentally recursive character of social life, and expresses the mutual dependence of structure and agency* (Giddens, 1979, p. 69).

Structure is produced and reproduced in the social practises which are organised by it. Social practise has an essentially recursive nature. Individuals do not create social practises but rather recreate them and in doing so produce situations that allow these practises to take place (Giddens, 1984). An individual, for example, does not invent a language when communicating with another, rather he or she draws upon what is already known and in doing so reproduces language. Giddens describes the fairly enduring aspects of social life or frequently reproduced structure as *Institutions*. *Social systems* are reproduced relations or practices patterned across time and space, they are typically regular, organised and fairly enduring. Social systems are therefore the result of different clusterings of social institutions.

Structure does not determine behaviour but rather it is both constraining and enabling (Giddens 1976, 1979, 1984). Giddens (1984) argues there are two aspects to structure: *rules* and *resources*. *Rules* are accepted social practises. They may include formally recognised codes (eg. national laws, religious taboos or accepted manners) or they may, simply, be known ways of behaving. Resources allow people to get things done, they are therefore *transformative*, and like rules only come into being through action. They are of two types. First, *allocative resources* which are material objects and, secondly, *authoritative* resources that complement allocative and result from some individuals being able to dominate others (Layder, 1994). Allocative resources include: material features (eg. wood, concrete, gas, electricity), means of material production (eg. machines) and produced goods (Giddens, 1984). Authoritative resources include: organisation of social time-space, the organisation of groups of people acting together and organisation of life chances (eg. literacy). Like rules, authoritative resources only exist when they are being used or are in the memory of knowledgeable actors. The combination of resources and rules generate the power that enables an individual to transform their social and material conditions and also to dominate others or create constraints in the context within which they act. Archer (1982) has criticised Giddens for suggesting that material resources only have an existence through human action. She argues that natural hazards are examples of aspects of the environment that affect action independently of human intervention. In answering her criticisms, the physical environment can be said to provide an absolute boundary to human action. The effect of gravity, the need for oxygen in air to enable breathing and the impossibility of moving through a solid are all examples of the physical boundaries present in the environment. The physical environment only rarely completely constrains behaviour; technology is a good example of people's ability to overcome the constraints in the physical environment. The physical environment also enables action, thus while a river may stop a non-swimmer travelling to the other side, stepping stones further upstream will allow this action. Giddens (1984), in response to these criticisms clarifies his position by defining three types of constraint: material, negatively applied sanctions and structure. Material constraints derive from the characteristics of the material world and the qualities of the human body as discussed above. Negatively applied sanctions stem from the action of others. Constraints rarely involve compulsion. If it does, the compulsion usually lasts for only a short period, if for example someone is held to the ground. Typically some form of choice is always present. A person with a gun to their head will only obey the instructions given if they value their own life. In many circumstances sanctions may be applied in a non lethal or violent manner, in which case compliance may depend more on conscience or other moral imperatives. Structural constraint derives from the social context of action. It functions through the motivation of individuals. People seem to need a predictable social environment and therefore rationalise the social world through the development of routines (rules) that enable them, and people in general, to negotiate it successfully. Structure constrains only in as much as it is driven by individual wants and motivations and to the extent it provides the means by which action is initiated. People who do not follow the rules expected within a particular situation, may well have sanctions applied against them.

Structuralist Marxist explanations of disasters have tended to emphasise constraint as the principal cause of vulnerability. Marginal or powerless groups become vulnerable because they have limited choices of where to live, farm or find employment and also do not have access to resources which could be used to recover (O'Keefe *et al.*, 1976; Susman *et al.*, 1983; Blaikie and Brookfield, 1987).

Their behaviour is determined by their position in society. The concept of marginality seems to have a great deal of explanatory power in certain disaster situations, especially those suffered in less economically developed countries (LDC). By concentrating on disasters that have taken place in situations where individuals are constrained in their behaviour or rather have few opportunities, structuralists have concluded that disasters always result from constraint. Disaster, however, still take place in situations where individuals have greater choice, though there is probably less interaction between hazard events and people. In situations where individuals have greater choice, behaviour is not so predictable and models that do not include individual motivation and decision making will have little explanatory power. One of the proposals being investigated in this thesis is that vulnerability will develop in situations where individuals have choices and are not economically, politically and socially marginal. It may be the opportunities offered at a location or in a community that entices an individual to behave in a way that increases his or her vulnerability. The transactional relationship that then forms between the individual and community in place, leads to a particular way of coping with the threat they are under. These methods of coping, as described in previous sections, allow vulnerability to exist despite the individual having opportunities to remove it.

Giddens (1979) tentatively suggests that ontological security is the main driving force behind the reproduction of society. Individuals seem to require ontological security or a confidence that the social world is as it appears to be. The desire for ontological security will tend to vary between people but generally all need to be able to predict the behavioural patterns of others. In the terms used above, in the context of behaviour in different environments, an understanding of place rules are not only necessary for the achievement of goals but also for comfortable living. If an individual's behaviour continuously resulted in them not achieving goals, incurring aggression from others within a place or being harmed by the physical environment, the affect on them is likely to be extremely damaging. Social systems, as a result, tend to have a resilience to change. Not only do peoples need for ontological security act against change but also structure as institutions and social systems stretch out across time and space and therefore change in one locale or time may be ineffective against the weight of practise elsewhere (Giddens, 1984). Social institutions and systems do change but this change tends to be fairly independent of an individual or group. The industrial revolution, for example, brought about enormous changes in the lives of individuals who had been working on the land and who then moved to cities but this change was a result of the character of the social system at that time rather than action of any one individual or group. The action of individuals is, of course, an intrinsic part of the process but individuals, except for fleeting moments or in extreme situations, are reproducing rather than creating the process of change. In communities located in areas of volcanic hazard, the character of the social system within which the community functions will make certain types of social life more likely than others. It is this character that will determine the extent and depth of vulnerability within a community. The character of a social system is unlikely to lead to a reduction in vulnerability in a specific location because social systems themselves stretch across space and between social groups and therefore reflect interests that are distant to and, therefore, disinterested in the vulnerable community. Even if a powerful group, within a social system, decides to try and reduce vulnerability it is likely to find the task extremely difficult because of its own limited understanding of vulnerability or difficulties arising from acting against the character of the existing social system.

Social systems are reproduced relationships between individuals/ collectives, they are typically regular, organised and fairly enduring (Giddens, 1984). They are governed by *structuration, which* is the set of conditions, which govern the continuity, or transformation of structure and therefore the reproduction of social systems. Structuration consists of three modalities that are drawn upon by actors when they interact with others, in doing so they reproduce parallel aspects of structure. Two of them relate to rules (*interpretative scheme* and *norm*), the other to *resources* (*facilities*). When they communicate, they draw upon an interpretative scheme (*rule)*, typifications or classifications in the stocks of knowledge an individual has. In doing so they reproduce *signification* or the meaning of given phenomena. When they accept the *power* of others or exert power over others they draw upon the *facilities* offered by resources and thus reproduce *domination* and *subordination.* When they *sanction,* accept or reject others behaviour, they draw on *norms* (*rules*) and reproduce *legitimisation.* The modalities of structuration are only analytically separable. Within the context of interaction each modality is present, although different emphasises are placed on them. Thus within a typical conversation a common vocabulary, with meaning attached to verbal utterances, (interpretative schemes) will be drawn upon, that different power relationships will guide and be expressed within the interaction (facility) and a knowledge of grammar, flow of speech, level of volume and other rules of communication (*norm*) will be used. In different situations individuals will place different emphasis on the different modalities of structuration in doing so they will create different types of institutional orders. Giddens (1984) identified four main types: symbolic orders or modes of discourse, political institutions, economic institutions and legal institutions (figure 6.4). These, in their different forms, represent practises that have the greatest time-space extension. The existence of political, economic and legal institutional orders do not necessarily mean that the society in question has a state apparatus, economy or legal system. Political institutions, ordering authority relations, for example, exist in all societies.

S-D-L	Symbolic orders/modes of discourse
D(auth)-S-L	Political institutions
D(alloc)-S-L	Economic institutions
L-D-S	Legal institutions
S = signification, D = domination, L = legitimisation.	

Figure 6.4: Classification of institutional orders (Giddens, 1984, p. 33).

The character of social systems and the nature of social structure and institutions is never free of space and time (Thrift, 1983). People learn about their social roles and come to understand social structure and institutions within specific places and at particular times (Johnston, 1991). They are likely, therefore, to develop a located identity and social practises. The effect of broad societal change will often be felt by the individual through their located existence. Spatially, as well as, socially separate individuals will therefore experience change differently. Broad change within a social system (eg. the industrial revolution) will affect all parts of the system but will realise itself in different ways in different places because of the various character of places. Place will therefore be important in the reproduction of individual volcanic vulnerability. Importantly the character of a place, being typically affected infrequently by volcanic events, will reflect economic, social, political and culture conditions rather than volcanic hazard. An individual's style of living and therefore vulnerability will, in turn, be shaped by these conditions rather than volcanic hazard.

The interdependence implicit in systems is measured by the extent of its *integration* - regularised ties, interchanges or reciprocity of practises. Integration does not mean cohesion or consensus, though these may be present to some extent within it. Giddens (1979) identifies two aspects of integration: social integration and systems integration, though he strongly emphasises that social integration is fundamental to systems integration:

> The duality of structure relates the smallest item of day-to-day behaviour to attributes of far more inclusive social systems (Giddens, 1979, p. 77)

Social integration relates to face-to-face interaction and systems integration to interaction across time and space (Giddens, 1979). Social and system integration would be indistinguishable but for the affect of unintended consequences of action which go beyond the duality of structure because they are unintended. Within a highly integrated society, the action of an individual will often have consequences well beyond that intended by the individual. By breaking sharply on a road, for example, a motorist may cause a traffic jam some time after and some distant away on the same road. The effects of the unintended consequences of action, in terms of systems integration, can be illustrated by three different types of systems: homeostatic causal loops, self-regulation through feed-back and reflexive self-regulation. Homeostatic causal loops reach back to the actor without anyone attempting to control or filter it. If the system is monitored and some kind of control feedback to the actor is present, then the system is self-regulated through feedback. If the system is monitored and, as a result, a decision is made to try and intervene in the operation of the system then it becomes reflexively self-regulated. Giddens (1984) proposes that in *tribal* or oral societies social and system integration are fused, whereas in *class-divided* and *class society* (capitalism) they are differentiated. Thus reflexive self-regulation is one of the principal features of modern society where it is typically carried out by social organisations and movements. This has important implications for the development of vulnerability. Mitigation will not simply be a response or reaction to a potential hazard but rather be a set of actions that reshape or reorganise the social parameters of a hazard (Bogard, 1988). The effect of the probability of volcanic activity on society depends on the way it is conceptualised by individuals across time and space and within different positions and roles within the various social systems that make it up. Without a sense that being or living in an area that may potentially be affected by volcanic activity is a problem, a society will develop in an area of volcanic activity independent of volcanic risk. It is unlikely that no one, at any time, will feel that some change is require or action should be taken but it is equally unlikely that there will ever be a consensus in peoples views across time and space or between various social groups. Because a situation of vulnerability exists as a result of a great variety of different pressures and forces emanating from various aspects of a social system, it is unlikely that even a fairly large or powerful group will be able to substantially change a situation of continuing or increasing vulnerability. It is more likely that changes in vulnerability will be separate from volcanic hazard *per se* and probably distant from the community itself. This will be discussed in the next section.

The roots of vulnerability lie in the nature of society at a specific location and the social system that it exists within. More specifically it is fundamentally rooted in situated (in time and space) social practices. Importantly, it is likely that vulnerability will be maintained unless the social system itself changes. This is because the same opportunities will continue to exist and are likely to be exploited and constraints will still be experienced. Vulnerability will therefore be reproduced.

6.3 FACTORS INDEPENDENT OF INDIVIDUAL ACTION

Changes in vulnerability, that are due to factors independent of the individual, take place either because of variations in the physical or social environment. Changes in the physical environment might include an alteration in the behaviour of the volcano, for example a change in its internal plumbing making effusive rather than explosive activity more likely, while changes in the social environment might include an economic depression affecting the material resources of the inhabitants of a volcanic area. Changes in the physical environment are likely to take place over a longer period of time than social changes. While fluctuations in an economy may involve a cycle of 4 or 5 years or a war start and end in 10 years, changes in the behaviour of a volcano typically occur over a longer time scale. Human manipulation of the physical environment, for example the management of a river basin, may bring about rapid change but this should be seen as the result of social rather than physical forces. It is therefore possible to generalise and argue that changes in vulnerability, due to factors independent of the individual, are likely to be social in origin.

Socially and spatially distant individuals, organisations or groups, that cause a change in vulnerability that is independent of a vulnerable individual's action, may be aware or unaware of their responsibility for this change. In complex modern societies, with high levels of systems integration within and across national boundaries, it is increasingly likely that those involved in the processes through which a state of vulnerability is maintained or changed will be unaware that this is happening. In modern societies, social organisations (eg. government departments, NGO's etc.) and social movements (eg. local resident groups, environmental organisations etc.) attempt to intervene in social systems in order to reduce vulnerability. Reflexive self-regulation is often complicated by: differing objectives, political interests, economic propriety, inaccurate information and the shear complexity of modern society. It has already been noted in chapter two that social organisations often hold particular conceptualisation of hazards and disasters - it is expected that individuals associated with the organisation will hold similar beliefs. The dominant view allows social organisations to implement policies to mitigate hazards while at the same time not affecting the social relationships that are central to its own functioning. These mitigation measures have often failed to actually reduce vulnerability, sometimes even increasing it.

The processes that cause changes in vulnerability and are independent of a vulnerable individual's action, will be related primarily to situations distant and unrelated to the condition of volcanic threat. These processes, within the different contexts of vulnerability to volcanic activity, will be many and varied. As is common with many other 'natural' hazards, factors affecting the economic prosperity of a region will be significant. Typically individuals and groups with greater access to resources (both authoritative and allocative) will be less vulnerable than those with low access although this will not always be the case. Other factors will be far more context specific. Though certain groups may attempt, through reflexive self-regulation, to reduce vulnerability, it is possible that any attempts will be hindered by other factors or the measures themselves may be misconceived.

6.4 CONCLUSION: A THEORY OF VULNERABILITY CHANGE

One of the main objectives of this thesis was to construct a theory of vulnerability of change. A theory is now outlined.

From the literature it is possible to tentatively suggest a theory of vulnerability change in volcanic environments. Part of the theory, as it applies to the individual, is illustrated in figure 6.5. This figure shows the main proposed relationships. The arrows represent suggested directions of influence rather than proven causal pathways. It is meant as an illustrative tool rather than a fully specified model. The figure depicts the individual's interaction with a *social and physical environment* in the present and at a specific point in space and how vulnerability is modulated by this interaction. The socio-physical environment is represented as independent inputs into the individual's 'system'. This is an artificial distinction because at the same time as the individuals are acting in response to a social environment, they are also part of that social environment. The constraints and opportunities that the individual finds in the socio-physical environment is a result of a transaction of the external and the individual. It is presented as such to illustrate the main proposed relationships at the micro/ individual level.

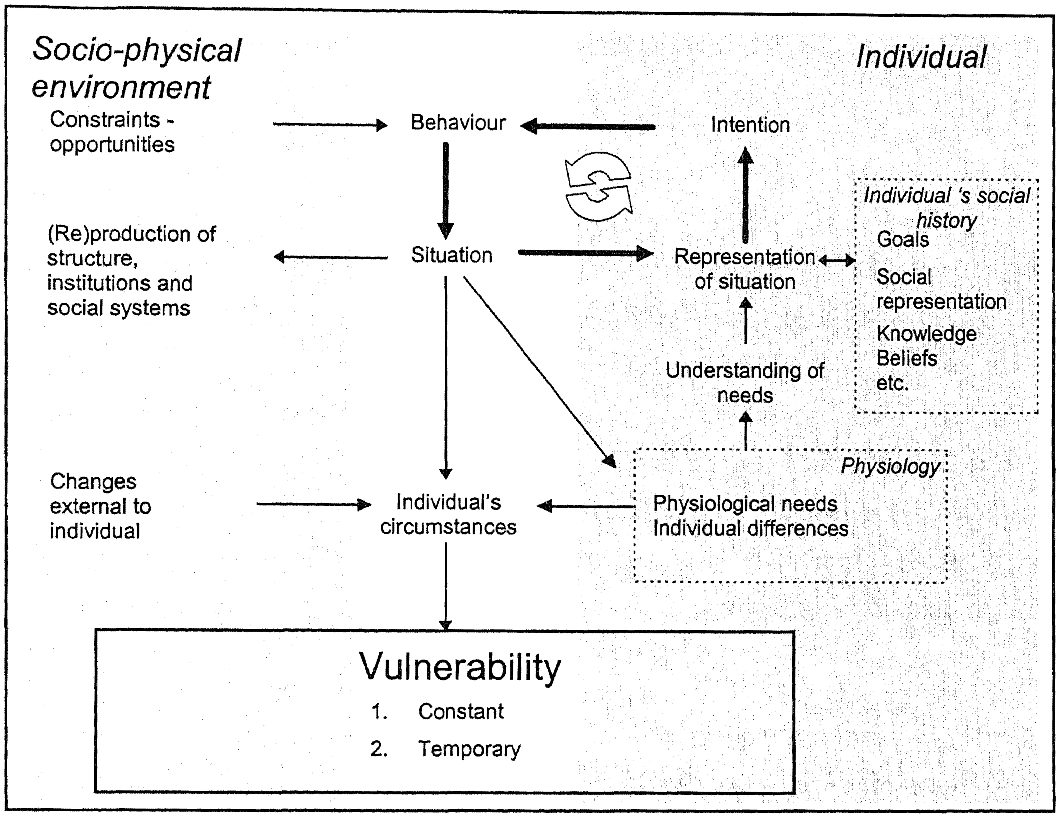

Figure 6.5: Vulnerability change at the micro-level.

At the core of micro-level vulnerability change is a continuous process where the individual, through observation of their own *situation* and knowledge of their *circumstances*, strives to achieve *goals* within a social and physical environment that offers both *constraints* and *opportunities*. This process drives the individual forward in time-space modifying, at the same time, their circumstances (ie. long-term condition) which in turn defines their vulnerability. Society is the cumulative product of the many individuals involved in this process.

The figure divides the *individual* and the *socio-physical* environment. This, as has been stated above, is an artificial distinction. The shaded areas represent parts that are more clearly related to one or the other. The individual's behaviour and the situation they find themselves in are related to both the cognitive processes of the individual and the social and physical environment and hence are situated between the two. The individual is subdivided into two. These are aspects that are related more to either an individual's own social history or to fundamental individual differences. An individual's own social history is the remembered total of their own experiences. These experiences have almost inevitably been social and are often strongly related to the contexts within which the individual has moved. The physiology of an individual interacts with cognitive processes, an individual's understanding of their own needs, to affect a certain type of representation and so wants, intentions and behaviour.

The physical and social environment is both the context for an individual's behaviour and is constituted by this behaviour. It should be noted that the influence of the individual on the socio-physical environment would typically be weak unless the individual or situation is particularly strong. The diagram does not illustrate environmental stimulus-response behaviour. While not arguing that certain behaviour is an automatic response to an external stimulus, it is maintained that the response is not significant in terms of the general processes described. Any significant behaviour, which changes vulnerability, will involve cognition. Aspects of a situation can have a direct effect on an individual's physiology, for example they may be injured or infected with a virus.

An important contention within the theory is that the environment is actively constructed by the individual. As it is the individual's *representation of a situation* that leads to the formation of particular intentions and therefore behaviour, the elements that affect this process of construction can be as important as the actual physical and social elements found within a situation, in determining behaviour. This is especially true when an individual has a wide range of opportunities and a low level of constraint.

The individual can attempt to ignore or work against constraints or try to create new opportunities. This is moderated against by the action of social sanction, societal norms, accidents and other negative affects, that through learning and, therefore, experience, lead to an increasing probability of compliant forms of behaviour. Being compliant, it is important to note, does not imply determined behaviour, rather it means a person follows particular social rules when exploiting a particular opportunity within a situation. An individual may have many opportunities in the same situation. An accurate representation of constraints and opportunities, as well as compliant behaviour, is usually vital for a successful social life. Those that lack either may be ostracised by others and excluded from society (eg. mentally ill - hospitals, the criminal - prison etc.).

A situation is a manifestation of a great number of different elements and, as has been demonstrated above, there is a tendency for the individual's representation of the situation to be different from others because it reflects a personal social history. The aspects of a situation that affect an individual's circumstances and therefore vulnerability, may be difficult to assess even if intensely scrutinised. To the individual concerned with 'everyday' life it may be seem unimportant and indistinct. This is not to say that the individual is not effective in negotiating their social and physical environment, as seemed to be suggested by the workers within the ecological tradition, but rather that the individual's approach to the complexity and uncertainty of social life may necessarily involve simplification, heuristics, scripts and other types of cognitive shortcuts. These approaches may be highly refined and efficient within the general contexts within which the individual operates. They are also formulated within a social context and, consequently are reflective of particular worldviews. The potential or threat of a volcanic eruption will typically have a weak influence on the process.

An individual's vulnerability is defined by their circumstances. The salience of indicators of vulnerability present in their circumstances will vary over time. It may be increased by actual events such as an accident or report of an accident (eg. a news item or information from friends). Salience falls with the absence of actual events and the affect of other elements. These other elements may include: social representations, individual differences and knowledge. Social representations of a hazard may mean an individual interprets the cues to their vulnerability in a particular way. If they are members of a particular social group they may interpret it in a way that is peculiar to that group. This might, for example, involve a spiritual interpretation if they were members of a religion. Individual differences can lead to cues to vulnerability, with a similar level of clarity and salience, being evaluated very differently. While one person may positively enjoy the feeling of exposure to stress another may experience it negatively. As evaluation, or the extent to which a situation conforms with goals, is an important part of the way a situation is being conceptualised by an individual, their overall representation will be different. Variation in knowledge, gained through experience, may also lead to different representations. Different areas of knowledge will lead to particular types of interpretation of cues and general information. Social representations will also lead to the interpretation of information in different ways. A person who exists in a particular social or cultural group will share, to differing extents, similar social representations of the world. People who are members of a group which is closely linked to a hazard will therefore share representations of that hazard.

At the macro-level: structure, institutions and social systems describe patterns of individual behaviour. These notions of societal functioning are only probabilistic at the micro-level. They do not determine behaviour even in situations of extreme social control, rather they make patterns of behaviour likely. They do this because they represent constraints and opportunities. While a specific individual will not necessarily comply with particular constraints or utilise opportunities, it is likely that as they enter into particular social and environmental roles that they will. When opportunities and constraints and resulting patterns of social practise spatially overlap with volcanic hazard then vulnerability is likely to exist. The extent and nature of the vulnerability will depend on the type of modes of living that emanate out of the particular situation of constraint and opportunity. An individual's vulnerability may change independently of their own actions. This may be due to variation within society or the physical environment. The change can also be socially and spatially distant from the individual.

Within the theory, vulnerability of the individual is a result of their circumstances. Vulnerability is either temporary (eg. going to work in a specific location) or constant (eg. levels of savings). A fundamental aspect of personal circumstances is the difficulty an individual has in changing them. They are a product of a lifetime or possibly a number of generations of action and therefore change may be difficult or undesirable. They are also the result of action within the context of various constraints and opportunity. An individual's ability to change them may therefore be limited.

With the theory presented it is possible to hypothesise that the threat (ie. probability of a damaging eruption) to a resident population, posed by a volcano, is unlikely to lead to vulnerability reducing behaviour. It is more likely that vulnerability reducing behaviour will be undertaken if an actual damaging volcanic eruption is experienced but that this will be limited by the constraints experienced by an individual and the draw of opportunities. The argument can be outlined as: [1] The threat from volcanoes is experienced by most of those who are vulnerable as an indirect aspect of the situations and circumstances they find themselves in. This does not apply to tourists, scientists or other visitors whose principal reason for being in an area is the volcano. [2] They are therefore unlikely to have chosen their particular circumstances because they enjoy the feeling of being at risk. They are instead in a situation where they would want to reduce their vulnerability but they may be unaware of it or its reduction will involve personal 'costs' or might be impossible. This is especially true because volcanic vulnerability is strongly associated with location. [3] The conflict between the knowledge that they are at risk and their understanding that any action to reduce this risk is unlikely to be resolved through action. This is because the likely costs to an individual of appropriate action are often very unattractive and the cognitive reduction of worry or motivation compared to action is relatively easy. It is also encouraged through the social experience or specifically through the social representations of the volcano that exist in communities. In general it is suggested that an individual's representation of the volcano and eruptive activity *allow* rather than *direct* behaviour. This is not to say that individual activity will not lead to a change in their vulnerability, only that this activity is not likely to have been directed by such a desire. [4] In communities based in areas of volcanic hazard it is suggested that individuals reacting to and influencing aspects of social structure, systems and institutions - unrelated or indirectly related to volcanic hazard - will be the main force behind vulnerability change. [5] Often it will only be those socially and spatially distant from the volcanic area who will attempt to change volcanic vulnerability directly. Their affect on vulnerability will be determined by the power and ability they have to change and influence individual's representations, more generally social representations and the social system present in a particular place. If conditions of vulnerability are being generated in an area of volcanic activity, it is probable that only very determined efforts will affect a reduction in its vulnerability. [6] It is important to note that although the threat inherent in a volcanic environment may not affect vulnerability, the volcanic environment itself may have a significant affect on it. This is in part due to the typically infrequent occurrence of hazardous activity within a volcanic environment but more fundamentally it is due to the psychological and social processes described above.

This theory will now be used with the framework for analysis outlined in chapter 3, 4 and 5 to address the issue of vulnerability in two case study areas.

PART TWO

CHAPTER SEVEN: METHODOLOGY

7.1 INTRODUCTION

Case study methodology is used in this thesis to carry out vulnerability analysis. With this methodology a variety of different actual research techniques may be used. Decisions on what methods to use arise when considering the individual case study and therefore methodologies may vary between case studies. Broadly a case study approach typically involves (Robson, 1995): a *strategy* rather than a method, a broad definition of *research* that includes concepts such as evaluation, *empiricism* in the sense that it provides a realistic representation of what is going on, a particular *situation* or case and focuses on a phenomenon as it exists within that particular context and the use of multiple methods. Vulnerability analysis is a strategy; it attempts to investigate the constituent parts of a disaster and in so doing provide a realistic explanation of their genesis and character. It should also be a critique of existing methods of disaster and hazard mitigation. It necessarily focuses on a particular situation and requires multiple methods to tackle the diverse areas that need to be investigated.

This chapter outlines the case study approach used in this thesis to apply vulnerability analysis to particular volcanic contexts.

7.2 CASE STUDY

Robson, (1995, p. 150) argues that to carry out a case study effectively it is necessary to have:

- a conceptual framework
- a set of research questions
- a sampling strategy
- and, to decide upon methods and instruments for data collection.

The conceptual framework and research questions have been outlined in chapters three, four and five. In the context of this framework and these research questions, it was decided to carry out two case studies. The first centred on Mount Etna in Sicily (Italy), and the second, Furnas volcano, San Miguel island, Azores

(Portugal). These two volcanoes exhibit fundamentally different styles of eruptive activity. Mount Etna is continuously active at the summit craters and has frequent flank eruptions (every 3-7 years) (Chester *et al.,* 1985) while Furnas has less frequent activity (~300-600 years) (Guest *et al.,* 1996). They are also fundamentally different in terms of their eruptive behaviour. The volcanic activity on Mt Etna, though there is typically localised minor explosive activity (strombolian) around vents and fissures, is normally effusive with eruption of lava flows. In contrast, the volcanic activity associated with Furnas volcano is explosive, sub-plinian and, sometimes, plinian in character. These two broad types of volcanic activity: regular effusive activity and infrequent explosive eruptions have very different implications for a potentially affected population. Lava flows are rarely a direct hazard to human life, they are relatively slow moving and as a result there is usually time for people to remove themselves from danger. They often destroy all structures along their course and cover land and crops, making it sterile for hundreds of years. In contrast, the explosive activity at Furnas volcano threatens both lives and livelihoods though in contrast to lava flows, land covered by tephra can often recover agriculturally in 2-3 years (Blong, 1984).

The types of activity present in the two selected case studies, allows a broad comparison to be made between the development of vulnerability under two extremes of volcanism. Both case studies areas are similar in certain social, physical and economic aspects, they both: have what might be termed Southern European economies, are situated within the European Union, with some form of autonomy within a larger nation state, are islands, with the Catholic faith predominating and a history of out-migration in recent years. It is recognised that any generalisations from these two situations of volcanism would have to be made with caution because of the many differences that exist between the two.

7.3 SAMPLING STRATEGY

The sampling strategy initially involved in a case study is different from classic probability sampling. The case study sampling strategy is necessary because implicit in the approach lies the notion that everything that could be studied is being studied. In the case of vulnerability analysis the case study is of a society, of possibly thousands or millions of people, both at present and through history. Under such circumstances it is clearly not possible to study everything and it is necessary therefore to choose or sample particular aspects that give a reliable and valid approximation about what is actually happening.

As outlined in chapter six, vulnerability analysis artificially divides or brackets society, exploring vulnerability at one level in the context of an individual functioning in a particular social context and at the other as society or cumulative human action and interaction. Analysis should therefore take place at both these levels.

7.3.1 The micro - individual level

It was decided a town should be selected in each of the case study areas and interviews carried out in each. Other information would also be collected on the towns, to allow the information on attitudes and decision making to be understood in context. Towns would be selected that had a relatively, for the area, high probability of being affected by volcanic activity. Within each of the towns a systematic sample of households would be drawn and interviews conducted within each household.

Further information was collected at the level of the individual from secondary sources of data. These included written accounts, newspaper reports, photographs and film footage.

7.3.2 The macro - Societal level

Information and data were gathered on communities that might be affected by the products of activity at one of the case study volcanoes. The widespread dispersal of pyroclastic fall and the potential global affect of resulting climatic change, meant that a limit had to be placed on the spatial extent of the study. The effect of volcanic ash in the atmosphere was therefore not included when identifying the area of study. For this aspect of the study, it was necessary to draw upon secondary data and information sources. These types of information and data were naturally limited by availability and therefore no attempt was made to sample it. Instead attempts were made to collect as many data as possible.

7.3.3 Volcanic hazard

Information on volcanic hazards was principally collected through published papers and research reports, though one piece of primary data collection was carried out with Dr David Chester involving a survey of roads out of the town of Furnas. This survey mapped potential points at which the roads might become impassable because of: landslips, bridge collapse, road slippage and fallen vegetation; especially resulting from seismicity preceding eruption.

7.4 SECONDARY DATA

Secondary sources of data and information were collected from the case study areas and from international sources. The sources of information included:

- Population census - all census information available for the case study areas.
- Economic and social data - data provided by banks, local government and government agencies.
- Newspapers - local newspapers with reports on periods of volcanic activity and the also the English-language press.
- Government reports and transcripts - concerning civil defence issues and environmental planning.
- Research reports and published work - concerning the sociology, cultural, economics, history and hazards of the case study areas.

7.4.1 The reliability of secondary sources of data

Efforts were made whenever possible to check the reliability of secondary sources of data. It was assumed that government published work was reliable. The reliability of other sources of information was tested through 'triangulation', where, if possible, at least two pieces of information are required to validate a finding.

7.4.2 Analysis of secondary sources of data

The type of analysis employed depended upon (1) the requirements of the research and (2) the data available. The data available for San Miguel was sparse (ie. only available for large geographic areas and on a limited number of topics) as was the data for Sicily before 1950. For San Miguel, census information was only available for large spatial units up until the 1980's and statistical analysis was therefore only appropriate for the Sicilian census data after 1950's. The Sicilian census data, after 1950, held quite detailed information, down to a fine scale (a comuni[4]). This allowed an analysis of population, economic and social change in the Etna area.

7.4.3 Statistical analysis of census data

The Italian census data (after 1950) allowed a fairly detailed analysis of in and out migration to be carried out for the four decades up to the present. The analysis attempted to identify factors that best predicted whether a comuni had a population that was being increased or reduced by in and out migration.

Migration was measured using an index proposed by King and Strachan (1980). This index relates net loss and gain in population, due to migration, to the average population in the comuni during the period in question. The net loss and gain in population was derived from inter-census differences in populations once births and deaths had been accounted for. Migratory information is also available through the anagraphical movements which are published annually for each comuni. These record cancellations and registrations of residence in a particular comuni. These figures, however, have been found to be quite inaccurate (King and Strachan, 1980). Many people do not cancel their registration when they are absent from their homes. This is especially true of migrants working abroad who wish to safeguard national pensions and welfare benefits. Also comuni are slow to register cancellations.

Other socio-economic variables, that might explain in or out migration, were derived from the census with aim of modelling migration using Ordinary Least Squares regression (OLS). In this instance the dependent variable would be the migratory index and the independent variables would be derived from the social, economic and environmental data on the comuni in question. The proposed analysis would attempt to identify independent variables that best predicted the migratory index. Before any analysis was carried out the data set was checked for missing data, outliers and normality of distributions. The appropriate remedial actions would be taken if this was found not to be the case (ie. data cleaning or transformations).

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[4] A comuni is the smallest unit at which the Italian census is published. They vary greatly in size, both in terms of population and land. There main unifying characteristic is that they contain a single town or city.

One particular method, available with many statistical packages, of generating a parsimonious OLS model (ie. a model with as few independent variables explaining as much of the variance in the dependent variable as possible), is stepwise estimation. This method introduces and removes particular independent variables depending on the amount of variances that they explain. This method runs the danger of overfitting the data in situations where there is a high ratio of independent variables to cases (Hair *et al.*, 1984). With less than 50 comuni in the Etna area, there was clearly a danger of overfitting in this case. It was decided, therefore, to introduce all independent variables and remove only those that achieved a low level of significance. Using this method, variables that might be important in explaining variance, given a particular combination of independent variables, might be removed early on because at that time there was a different combination independent variables. This danger might be reduced if there was not a large number of independent variables to begin with.

Because a number of the independent variables were fairly highly correlated with each other it was decided to reduce the number of variables by using Principle Component Analysis (PCA). This technique examines the relationships underlying a large number of variables and assesses whether they can be reduced to a smaller number of components. The independent variables that the analysis was applied to were socio-economic, thus the aim of the PCA was to identify the dimensions that differentiate groups of comuni. After an initial PCA solution was achieved, components that had a latent root of 1 or over were then taken and rotated orthogonally using Varimax method (Kline, 1994). This method attempts to achieve a parsimonious solution where a small number of uncorrelated components explain a large proportion of the variance. The components were then identified by looking at their variable factor loadings. A reduction in the number of independent variables using this method would also reduce the problem of multicollinearity (ie. the correlation amongst a set of independent variables).

Principle component scores and other important variables were then entered into the OLS regression. After each model had been produced the various assumptions that OLS regression makes about data were then checked. These included: linearity, homoscedasticity, normality and the independence of the residuals. The last assumption, the independence of residuals or non-autocorrelation, is of particular importance in cases where the variables being modelled have a spatial component because autocorrelation is commonly found in such data sets (Cliff and Ord, 1973). In order for the measures of statistical significance to be accurate there should not be any spatial auto-correlation. The data was therefore checked using Moran's I at different spatial lags. No spatial auto-correlation was found amongst the residuals of the various regression models.

7.5 INTERVIEWS

Interviews were carried out in two towns in Sicily and two in San Miguel. One set of interviews at each location were not probability samples, one in Sicily was a convenience sample and the one in San Miguel was a snowball sample. These two, non-probability samples, were not intended to be representative of a population of interest but were rather to allow a historical event to be reconstructed. In the case of Sicily this was a destructive volcanic eruption and in the Azores an earthquake. Interviews were also carried out with people who were significant in the context of the research being carried out. These included scientists, civil defence workers and politicians.

Interviews were used in preference to other techniques because they offered the chance to explore people's beliefs and attitudes in some depth while being fairly easy to organise. They were also flexible enough to respond to unexpected elements that would be highly likely in a culture unfamiliar to the researcher and one that had not been researched before.

Interviews were carried out both in Sicily and San Miguel with the assistance of a translator who though local was not from the town in which the interviews were carried out. It was hoped that this would encourage the participation of potential respondents. The translator not only knew local dialects but also had an understanding of the local culture. This aided interpretation of the responses. The interviews were taped and carried out with a person's answers being roughly translated into English. This allowed the interviewer to respond and prompt in a non-leading manner. After the interviews had been completed the translator and researcher reviewed the tapes. A verbatim translation was, at this stage, transcribed into English while at the same time the responses were discussed and interpreted.

7.5.1 Interviews in Sicily

The interviews that were carried out in Sicily included a semi-structured telephone interview with residents of Trecastagni (figure 8.1) and face-to-face interviews with people who had lived through the destruction of the town of Mascali in 1928. Pilot work on the interview schedule was also carried out through face-to-face interviews in Trecastagni and Zafferana. Interviews were also held with a number of volcanologists working at the Istituto Internazionale di Vulcanologia (University of Catania). Trecastagni was chosen because it has a relatively high risk of invasion by lava. By also studying the case of Mascali, a town that was destroyed by a lava flow in 1928 it was possible to examine how Sicilians responded to a destructive volcanic eruption. The 1928 eruption was the last time a lava flow had destroyed the greater part of a town on Etna.

The work carried out on the attitudes and beliefs of people living near Etna had an essentially flexible character. A semi-structured interview schedule, for telephone interviewing, was drawn up from theoretical considerations and as a result of face-to-face pilot interviewing in Trecastagni and Zafferana. The flexible approach taken in the development of measuring instruments and questions did not mean that the approach was not rigorous. Whenever appropriate the principles of good research were applied (eg. random sampling, questioning that did not lead the respondent etc.).

A systematic sample of residents of Trecastagni was achieved by drawing a random number and using it as a starting position in the phone directory. The phone number was divided by 400 and this number was used to 'jump' from the random start point. All the phoning was carried out between 7.00-9.00 p.m. to try and avoid bias towards non-workers, though this was hampered to some extent by the late working hours of some Italian businesses. When the phone was answered the person was asked whether they would mind taking part in a sociological study of their town and then whether this was the house they lived in and that they were over 18. The survey produced a demographic profile that fairly closely approximated that of the population of interest (residents of Trecastagni). It was believed that the systematic sample fairly accurately approximated to a random sample, though it was recognised that the sample was biased in that the deaf, ex-directory and those without phones would be excluded. By comparing the number of telephone numbers in the directory it was found that these were not short of the total number of households in the town. It was therefore assumed that the number of excluded individuals was not great. The response rate for the survey was 52%. It was not believed that non-response would be related to any particular question on the interview schedule and therefore non-response bias was unlikely to be a problem. The target of 200 respondents was achieved. The level of precision, at the 95% confidence level, when extrapolating the findings to the population as a whole, is shown in figure 7.1.

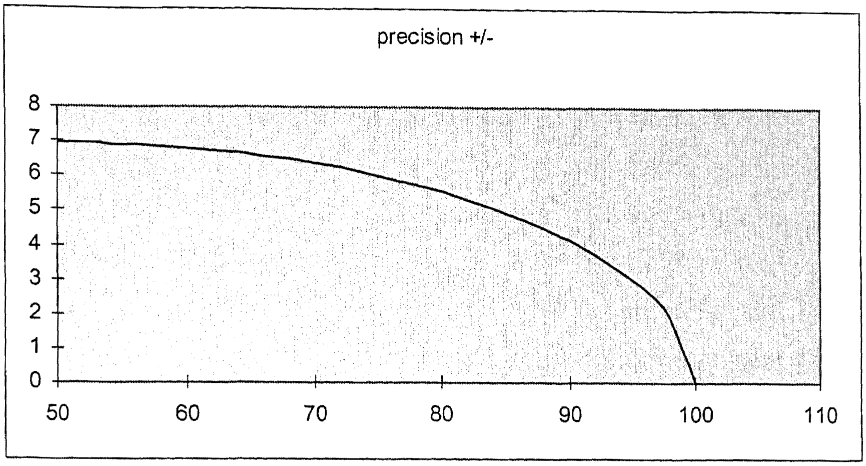

Figure 7.1: The level of precision achieved with a sample of 200 for different proportions, at the 95% confidence level.

The interviews were semi-structured, with both closed and open questions. Because the interviews were being carried out in the absence of the author, a more structured format was needed. This structure was informed by the earlier work carried out in Zafferana and Mascali and other previous work on risk and hazard. The questions covered 5 main areas: (1) length of residence and reasons for moving to the town, (2) attitudes to the town generally, (3) perceptions of the volcanic hazard and other natural hazards, (4) disaster preparation and (5) attitudes to various hazard mitigation measures (see appendix A). It took about 30 minutes to complete.

Interviews in Mascali were hindered by the fact that the people who had to be spoken to would all be around 80 years old. Respondents were gained by a mixture of local knowledge of Sicilian customs and snowball sampling. It is common for old men to sit in the piazza of their town in the early morning. The researcher therefore went to the piazza at that time in the morning and interviewed those there and also asked about friends who might be willing to be interviewed at a different time. These individuals were then interviewed at a convenient time.

7.5.2 Interviews in San Miguel

The volcanic character of Furnas volcano is fundamentally different from that of Etna. Importantly in the context of this discussion, there has been no eruption since 1630. In depth semi-structured interviews were carried out with 50 residents of the town of Furnas. A systematic sample was achieved by dividing the number houses in the town (derived from the census) by 70, to give 70 potential interviewees, and then using that to 'skip' between houses starting from a randomly assigned starting point. This approach, it was believed effectively approximated a random sample. If there was nobody present in the house, then the house to the left was approached. If the person answering the door was over 18 they were asked if they would mind taking part in a sociological survey about the town. The interviews lasted between half an hour to one hour. Fifty responses were achieved with a response rate of over 95%. The sample approximated the demographic profile of the population, though older residents were slightly over represented. This was probably the result of interviewing throughout the day and early evening, so that more interviewing was actually carried out during the day time. Because the interview period was outside the holiday period, temporary second home owners were not represented in the sample. The 50 responses achieved gave levels of precision for various proportions as shown in figure 7.2, when extrapolating the findings to the population as a whole. A smaller sample was used in the Azores in order to complete more in-depth interviews. The relative stability of the population meant that there was little opportunity to compare the perceptions of those that had moved to the village to those that had lived there all their lives instead it was decided it would be more useful to explore the nature of these perceptions in greater depth.

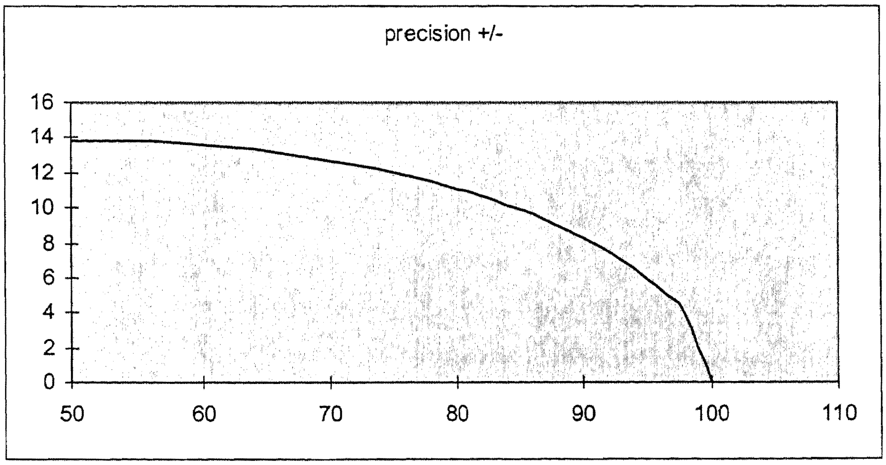

Figure 7.2: The level of precision achieved with a sample of 50 for different proportions, at the 95% confidence level.

The questions, as with those carried out in Sicily, covered 5 main areas: (1) length of residence and reasons for moving to the town, (2) attitudes to the town generally, (3) perceptions of the volcanic hazard and other natural hazards, (4) disaster preparation and (5) attitudes to various hazard mitigation measures.

Interviews were also carried out in the town of Riberia Quente. The aim was to try to reconstruct the events around an earthquake that occurred in the 1952. A sample of people was achieved through a snowball sample where, if a person had remembered the event, they were spoken to and then asked if they knew anyone else who knew about the event and where they lived. Through this method 15 people were identified and spoken to.

7.6 OBSERVATION

During the periods spent in the study area field notes were kept and recording observations made. This information was useful in confirming or throwing doubt on information gained from other sources. Photographs were also used to record information.

7.7 CONCLUSION

This chapter has outlined the case study approach used to investigate vulnerability into volcanic hazard within two European regions. In the following chapters the findings from the case studies will be outlined and explored. In the discussion chapter of this thesis the approach described in this chapter will be assessed and possible improvements suggested.

CHAPTER EIGHT: CASE STUDY OF THE ETNA REGION OF SICILY

8.1 INTRODUCTION

8.1.1 Structure of the chapter

In this chapter the vulnerability of people living in the Etna region of Sicily (Italy) will be explored. After a brief introduction to the geography of the region the volcanology of Etna will be discussed and the hazard it presents to the population of the region outlined. The vulnerability of those that live close to the volcano will then be analysed using the framework presented in chapter 5 with reference to past volcanic eruptions and other 'natural' disasters. Although it is an individual's vulnerability to volcanic hazard that is being studied, other disasters provide useful insights into the reaction of people and organisations to extreme conditions. The focus, though, will be on disasters that have recently taken place in Italy. Once it has been established ***how*** individuals are vulnerable to volcanic activity, it is then necessary to investigate ***why*** they are vulnerable. The historic and contemporary context of behaviour and its psychological basis along with the general functioning of society, as it affects the individual, will be studied in order to establish why this situation should exist. Finally methods for reducing vulnerability will be discussed along with likely future changes in vulnerability assuming that no intervention takes place.

8.1.2 Introduction to the Etna region

Etna is one of the largest continental volcanoes in the world (Chester *et al.*, 1985). It has a basal diameter of 40 km and an altitude of 3350 metres. The volcano dominates a substantial part of the eastern seaboard of Sicily, providing an environment with higher rates of rainfall and more fertile soils than much of the rest of the island (figure 8.1). The economic, social and morphological nature of the settlements, on the flanks of the volcano, has reflected in many ways the unique conditions of the Etnean environment but, of course, these settlements are also associated with broader Sicilian, Italian, Mediterranean and European contexts.

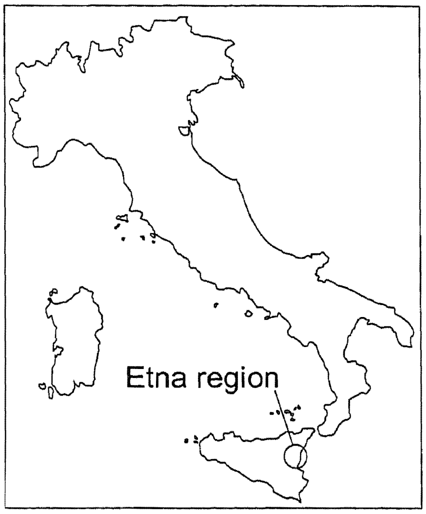

Figure 8.1: Map of Italy showing the Etna region of Sicily.

The southern and eastern flanks of the volcano are more densely populated than the north and west. The south is dominated by the city of Catania which had a population of 333,075 in 1991 (figure 8.2). Catania is an important commercial, industrial, administrative, cultural and education centre, indeed it is the most important city in Sicily after Palermo (Sanfillipo, 1991). The southern and eastern flanks of the volcano are environmentally different to those of the north and west. Generally they receive higher levels of rainfall (Speranza, 1963). They also have greater amounts of the mineral rich soils, made up of debris from the ancient Trifoglietto volcano, not covered by fresh lava flows. The main lines of communication for the east side of the island also run along these flanks. These factors have been important in influencing the location and development of settlements on Etna. Originally the main settlements were nucleated towns, but today residential developments are filling in the areas between the historic towns, as settlements on the lower south-east flank of the volcano merge towards being a single conurbation. Generally there is no settlement above 2000m on the volcano, though there are a number of scientific and tourist facilitates above this altitude. These include volcanic observatories, ski facilities and shops. The first volcanic observatory was destroyed in an eruption in 1971 and the subsequent replacement has now fallen into disrepair.

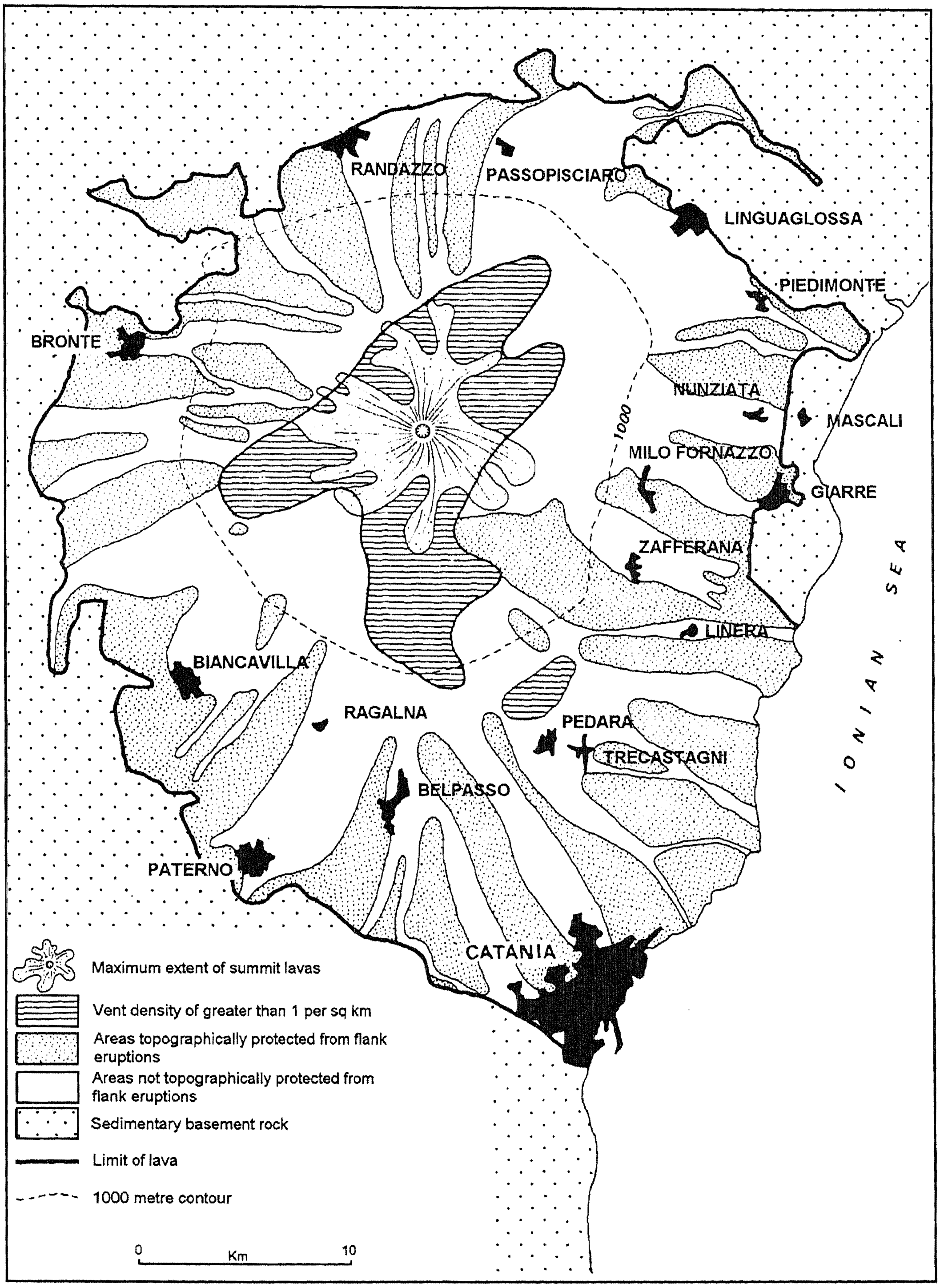

Figure 8.2: Hazard map showing relief protected areas, assuming a flow of lava from the zone with a vent density of greater than 1 per Km^2, and selected towns. (Based on Chester *et al.,* 1985, p. 309).

8.2 THE PHYSICAL GEOGRAPHY OF THE ETNA REGION

8.2.1 Geological setting

The geological setting of Etna is complex due to successive tectonic episodes of gravity-sliding and over thrusting from the north (Chester *et al.*, 1985). The volcano lies across two geodynamic domains (Coltelli and Pompilio, 1994). First, the Appennine-Maghrebian chain in the north and, secondly, the Hyblean-Maltese foreland which is part of the Pelagian block in the south. The volcano is situated at the intersection of three regional fault systems: the Tindari-Giardini fault runs NE-SE from the Eolian islands, north of Etna, to the eastern edge of the Hyblean plateau, the Mt Kumeta-Alcantara fault which runs WSW-ESE and the Comiso-Messina fault running NE-SW. This produces a stress field composed of an E-W tensile stress over a N-S compressive stress. The picture is further complicated by the weight of the volcanic edifice (Coltelli and Pompilio, 1994). This tends to create compressive forces in the basement of the edifice and produce extension features around the summit.

8.2.2 Etna Volcano

Etna is a cone shaped volcano, with gradually steepening flanks rising to the summit. Its shape is distended in the south where the flanks have a more gentle gradient than on other sides. The eastern flank of the volcano is dominated by a large area of collapse known as the Valle del Bove. This feature, with a diameter of about 5.5 km, cuts into the edifice to a maximum depth of 1000 metres producing a steep escarpment on the eastern edge of the summit area.

There are numerous vents on all flanks of the volcano. Typically these vents are cinder cones which can be over 30 metres in height. The distribution of the vents correlate with the various rifts (North East, South and less pronounced to the west) on the volcano and have a distinct relationship with height. Generally vent density increases with height on the volcano, reaching a peak at around 2,000 metres and then after decreasing (Chester *et al.,* 1985). Many of the younger vents have related lava flows that range from 1-2 km to 15-20 km in length. Older lava flows are often covered by more recent products. Many of the younger flows remain unvegetated and are clearly visible as a scar amongst the surrounding vegetation.

In terms of the features described above, the volcano can be split between the summit cone and flanks, the two areas experiencing fairly distinct types of activity. The summit cone is composed of interbedded lava and tephra (Chester *et al.*, 1985). It has a diameter of about 2 km and a height of about 260m and is situated on a plateau formed of two filled calderas: Cratere del Piano and Cratere Ellittico (Coltelli and Pompilio, 1994). As seen today the summit cone stems from virtually continuous activity in the area between the 18^{th} century and 19^{th} century after the old summit cone was partially destroyed in the major 1669 eruption.

Located over the central conduit of the volcano, the summit cone experiences fairly constant activity and as a result the morphology is frequently modified. There are several parasitic cones on the summit cone, including: the NE Crater, initiated in 1911, and the SE Crater, initiated in 1971. The central crater is in a state of constant flux, at present there are two pits, the Chasm and the Bocca Nuova. The Bocca Nuova has probably been the most active of the vents on the volcano in recent times though after the 1991-3 eruption the crater is fairly dormant with only minor degassing and collapse (Coltelli and Pompilio, 1994). In 1997 all the Summit craters became charged with magma (Global Volcanism Network, 1997). Effusive lava flows and strombolian activity are associated with each of the craters. Sub-terminal vents (ie. close to the central conduit but on the flank of the summit cone) have opened up at sites, other than at the main craters for example in 1971 three vents opened up at the base of the summit cone immediately above the 'old' volcanic observatory. The observatory was later engulfed by lava. Lava flows from vents and fissures in the summit area tend to be relatively short compared to those on the flanks of the volcano (Guest, 1982). It has been argued that the relative steepness and height of the summit region is due to the frequency of short lava flows in this region compared to the flanks (Walker, 1977).

8.2.3 Pre-historic volcanic activity

Activity, at the Etna site, probably began around 700,000-500,000 years BP (Coltelli and Pompilio, 1994). The earliest materials erupted from Etna are the Basal Tholeiitic Volcanics which produced basaltic shields, pillow lavas and hyaloclastites (Cristofolini, 1973). This alkalic series started about 140,000 BP building up volcanic centres such as Calanna and Trifoglietto. The present volcanic edifice probably originated about 20,000 years BP. Since 5000 years BP the volcano has produced mainly basaltic lava flows with associated strombolian activity. The main volcanic processes of the pre-historic volcano are summarised in figure 8.3.

	Units	Centres	Descriptions	Events	Age
Alkalic series	Recent Mongibello	Present Centre	Historic eruptions, mainly hawaiites	Minor collapse events in summit area	
		Piano		Formation of Valle del Bove	5000 BP
	Ancient Mongibello	Leone	Hawaiities, basic mugearites	Caldera collapse	
		Ellittico	Hawaiities, basic mugearites, mugearites, benmoreites	Caldera collapse	~6000-5000 BP
		Belvedere	Hawaiities, basic mugearites		
		Vavalaci	Hawaiities, basic mugearites, mugearites, benmoreites	Caldera collapse	~14,500
	Trifoglietto	Trifoglietto II	Basic mugearites, mugearites	Major phreatomagmatic activity	26,000 BP
	Pre-Trifoglietto	Calanna and other ancient centres	Mainly hawaiites	Major caldera collapse	~100,000 BP
Basalt Tholeiitic Volcanics			Tholeiitic basalt	Intrusive neck at Motta S. Anastasia	
	Alkali olivine basalt	Paterno cone	Alkali olivine basalt	Eroded cone	210,000 BP
			Sub aerial tholeiitic basalts	Adrano	300,000 BP
			Submarine tholeiitic basalts and intrusives	Acicastello/ Acitrezza	

Figure 8.3: Stratigraphy of Etna (from Chester *et al.*, 1985, pp. 78-79).

Caldera collapses of prehistoric times are thought to have lead to explosive eruptions generating pyroclastic flows (De Rita *et al.*, 1991). Evidence has also been found for the remobilisation, in the form of lahars, of deposits from plinian activity higher on the volcano. This type of activity is thought to have occurred on

Etna ~14,000-16,000 BP in the summit area. Ignimbrite producing eruptions are believed to be related to more evolved trachytic magma than the basaltic magma which has characterised the volcano during historic times. A fundamental change in the internal plumbing of the volcano would have to take place before the explosive type volcanism that resulted in ignimbrite producing pyroclastic flows would recur on Etna with the need for high level magma reservoirs to develop in the volcano (Guest and Duncan, 1981).

Phreatomagmatic eruptions have also taken place during the prehistoric period on Etna (Chester *et al.,* 1985). They were probably related to periods when the volcano had snow, in greater accumulation, in the summit area. This may have been the situation during climatic cold phases. The Trifoglietto II construct, a phreatomagmatic cone, is thought to have been formed during the Pontinian stage when the snow line on Etna would have been lower than at present, therefore allowing opportunities for mixing of water and magma (Duncan *et al.*, 1984).

Large scale slope failure was also an aspect of the prehistoric evolution of the volcano. The Valle de Bove is the most prominent of the slope failure features on Etna (Guest *et al.,* 1984). There has been much controversy over the origin of the Valle de Bove but geomorphological and sedimentological evidence point to it being a series of coalescing landslide scars (Guest *et al.,* 1984; Chester *et al.*, 1985, McGuire, 1996). There has been some debate over the extent to which its origin may be attributed to volcanic or morphological processes and this is discussed below.

8.2.4 Eruptive activity during historic times

Eruptive activity during historic times - since ~3000 years BP - has been characterised by fairly localised strombolian activity and effusive lava flows. Since 1500 AD detailed data on volcanic activity is available from exposed features (eg. lava flows) and historical records and two distinct phases of activity have been identified (Hughes, *et al.,* 1990). First, a period in the 17th century with high volume and high output eruptions ending in the destructive eruption of 1669 and associated summit crater collapse and second, a period of low output up to the present day. It is suggested that higher magmatic pressures during the first period resulted in fissures being held open for longer than in the second period, therefore allowing greater volumes of lava to be released (Hughes, *et al.,* 1990).

Localised explosive volcanism takes place around vents and particularly at the summit. Ultravulcanian activity, or explosive events in which older fragments of rock are ejected, in the summit vents typically expel juvenile blocks 30 to 300 cm in size along with non-juvenile ash (Chester *et al.*, 1985). Ultravulcanian activity typically takes place during the initial 'throat clearing' period of a strombolian eruption. Explosions can also occur when pit craters become blocked, such events are particularly dangerous because they can happen suddenly with relatively little warning. Such an explosion from the Bocca Nova in 1979 occurred when a large group of tourists and guides were in the summit area and nine people were killed and several injured.

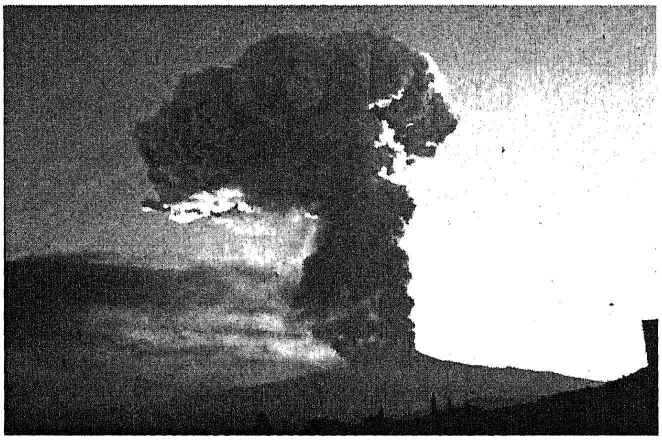

Figure 8.4: Eruptive column. (Finocchiaro Fotografi)

Pyroclastic fall, as a result of larger strombolian eruptions, has periodically affected the whole of the volcano. During the 1979 eruption, pyroclastic fall affected the southern flank of the volcano including Catania resulting in the closure of the airport (Chester *et al.*, 1985) (figure 8.4). There have been bigger explosive eruptions in the documented history of Etna. In an interpretation of a tephra fall deposit, which correlated with the documented major eruption of 122 BC, Coltelli *et al.* (1995) estimated that this eruption was of a plinian scale. The deposit was over 10 cm thick at Catania and according to contemporary accounts buildings collapsed and the Roman authorities waived taxes for 10 years (Chester *et al,* 1985). The accumulation of tephra blankets on the upper slopes of the volcano combined with rainfall or snow-ice melt have, in the past, led to lahars. There is evidence of a number of prehistoric flows but only one major one in historic times. This flow swept down the Valle de Bove, in 1755, leaving a deposit 2 km wide and up to 10 metres thick (Lyell, 1858). It has been suggested that this event might have been related to the cooler temperatures experienced during the eighteenth century (Chester *et al.,* 1985).

When volcanic activity takes place on the flanks of Etna it is usual for summit activity to cease (Chester *et al.*, 1985). Flank eruptions have taken place at fairly low altitudes on the volcano and so unlike summit eruptions are more likely to affect inhabited areas on the volcano than lava flows from the summit region. Flank eruptions vary considerably in the volume of lava produced, the eruption rates and explosivity of activity at the vent or fissure. The altitude at which the vents are located also varies. These factors are of considerable importance in determining the extent to which people living on the volcano will be affected by the activity. Flank eruptions are associated with rift zones on the volcano. The main rift zones are on the north-east flank of the volcano, to the north-north-east of the summit and on the south flank. The point of an eruption may be fairly localised, associated with one or two fissures in an area of about 100 metres, or be fairly expansive, associated with a progressive downhill fissure system (Guest, 1982) (figure 8.5). The level of strombolian activity varies. Eruptions that migrate down slope tend to exhibit strombolian activity higher on the volcano, but at lower sites activity is likely to be more effusive with the formation of hornitoes or no explosive activity at all. A flank eruption with a fairly localised centre may involve strombolian activity building a cinder cone. The style of the eruption is dependent on: the gas content of the magma and the length of the erupted fissure. The gas content of the magma tends to be affected by the level at which the fissure tapped the central conduit (Guest and Duncan, 1981). At lower levels the magma in the conduit is not gas saturated and this leads to explosive eruptions. When the conduit is tapped higher the gases have become exsolved and degassing occurs through the Central Crater, the lava therefore is erupted relatively peacefully.

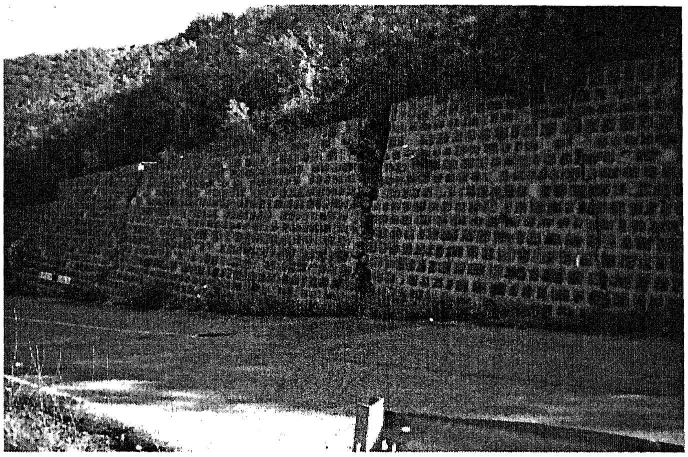

Figure 8.5: Fissure crosses a road.

Two main types of explosive volcanism have taken place during fissure eruptions: ultravulcanian and strombolian. This explosive activity is relatively minor. Ultravulcanian activity seems to occur at the upper end of a fissure or is related to areas where the magma may have come into contact with water (Chester *et al.*, 1985). Strombolian activity is a common feature of flank eruptions. Within the last 400 years 60% of flank eruptions have been accompanied by cone creating strombolian activity. Degassing at a vent may also lead to lava fountaining or, at a more moderate level of activity, spatter ramparts or hornitoes (figure 8.6).

Figure 8.6: Strombolian activity with a lava flow in the foreground. (Finocchiaro Fotografi)

Effusive lava flows have emanated from both the summit area and from fissures on the flanks of the volcano. Lava may flow from just one section of a fissure, at various places or along the whole fracture system. The behaviour of basaltic lava flows and the morphological landforms they eventually produce varies greatly. This variation is due to a number of factors including: lava rheology, effusion rate, total volume of the lava erupted, topography and duration of eruption (Chester *et al.*, 1985). The rheology of the lava is itself determined by a number of factors: lava temperature and composition, crystallinity, rates of crystal nucleation and growth, gas content, degree of polymerisation and amount of vesiculation. The chemical composition of historical lavas are similar (typically hawaiites) and, therefore, it is not a factor in the production of differing types of flows and resultant landforms. There is, in contrast, variation in the other factors and these are considered to control the nature of the generated flow fields. The temperature of the lava when erupted can have a dramatic affect on lava viscosity (Pinkerton, 1987). Lavas erupted during explosive summit region activity and from flank eruptions tends to be hotter than lava from persistent summit activity. The duration of the eruption also has a significant affect on the form of the flow field. Short duration eruptions (<48 hours) tend to produce single flows. Longer duration eruptions produce compound fields, with a complex overlapping form.

The altitude of a vent seems to have some affect on its effusion rate (Chester *et al.*, 1985). Although low effusion rates are possible anywhere on the volcano, high rates tend to be related to low altitudes. This is important because, although other factors may affect the length of the lava flow, effusion rates seem to be the most significant factor (Lopes and Guest, 1982). Low altitude flank eruptions originate not only closer to inhabited areas but are also likely to form longer flows. They are, as a result, a greater hazard to communities which are located on the lower flanks of the volcano.

Sharp *et al.* (1981), in an analysis of the relationship between earthquakes and flank eruptions, found a significant correlation in the zone immediately surrounding the volcano. They also noted that crater eruptions were more likely to precede flank eruptions than earthquakes. They found no relationship between earthquakes and summit eruptions. This suggested that there were two mechanisms for flank eruptions on Etna. First, those that are preceded by summit eruptions are related to an aseismic increase in magmatic pressure within the magma storage of Etna. Second, flank eruptions which are preceded by earthquakes are related to fracturing of the earth's crust along the E-W extension of Sicily. In this case the volcano acts passively on a system of fractures generated by tectonic activity.

8.2.5 Volcanic hazards

Assuming that the behaviour of Etna continues in a steady state activity then the main volcanic hazards that affect people can be approximated from the behaviour of the volcano in historic times. These hazards are summarised in figure 8.7. There is no evidence that volcanic behaviour is changing at this moment.

Main volcanic hazards on Mt Etna
• Lava flow • Explosive volcanic activity: strombolian activity, lava fountaining, phreatic events, ultravulcanian - ultravulcanian most apparent in area of main vents • Slope failure • Volcanic gas • Lahar • Seismic activity - volcanogenic and tectonic • Pyroclastic fall • Pyroclastic flow • Collapse - affects only summit area, products produced during collapse may affect a wide area of the volcano

Figure 8.7: Main volcanic hazards on Mt. Etna.

The current main direct hazard is from lava flows and localised explosive activity. Other volcanic and associated activity on Etna includes: volcanogenic earthquakes, slope failures, pyroclastic flows and pyroclastic fall (Chester *et al.*, 1985).

Major caldera collapse has been absent from the historic behaviour of Etna. Caldera collapses are thought to be related to the presence of high-level magma reservoirs which, it is believed have not existed in historic times (Guest and Duncan, 1981). They would probably have been a few kilometres deep, with an horizontal extent of 4-5 km. The present summit cone sits on a plateau formed from at least four infilled calderas. Smaller summit collapses may have taken place in historic times, for example after the 1669 eruption. The distinction between a volcanic event explanation of the Valle de Bove or a slope failure explanation is important. McGuire (1982) argued that the Valle de Bove was the result of a phreatomagmatic explosion related to specific climatic conditions. Because these climatic conditions do not exist today, then the replication of such a large scale slope movement is not likely now nor is significant phreatomagmatic activity. An alternative model for the formation of the Valle del Bove involving slope instability and collapse and not requiring volcanic activity as suggested by Guest *et al.* (1984) has with it the implication, however, that such a phenomena could happen today though such a process may have been piecemeal and not involved catastrophic episodes. Chester *et al.* (1985) noted that a change in two general conditions could lead to slope failure, these were: an increase in external shear stress and a low or reduced internal shear strength (figure 8.8).

Increased external shear stress	Low or reduced internal shear strength
• Overloading of slope by lavas • Excess weight from build up of a large cone or large area of summit lavas • Lack of seaward support of slope due to active fault • Dyke intrusions dilating a rift zone • Earthquakes destabilising slope • Faulting increasing angle of slope • Dome activity increasing angle of slope • Removal of support of phreato-magmatic explosions on the flanks • Caldera collapse • Breaching of a summit lake (eg. caldera lake	• Ash layer overlain by a lava flow • Waterlogging of ash layer overlain by a lava flow • Increase in pore water pressure, aquifers being trapped behind dykes

Figure 8.8: Possible causes of slope failure on Mt. Etna (Derived from Chester *et al.*, 1985, p. 184).

One of the more significant findings, in terms of hazards, is that major explosive eruptions such as the plinian activity in 122 BC have been rare during the historic activity of Etna occurring at time intervals of more than 1000 years. Eruptions capable of generating major pyroclastic flows such as those that occurred 14-16000 years ago would require fundamental changes to the plumbing system and these changes would probably happen slowly. The magma, during periods of caldera formation and pyroclastic flow production, tended to be far more evolved than the hawiite magma of the last 2-3,000 years (Chester *et al.*, 1985). There would need to be a high level magma storage with greater periods of dormancy, before the necessary differentiation was possible and more evolved gas-rich magma was produced. Explosive volcanism has also been related to wetter cooler conditions. It is likely that a low snow line and, possibly, a permanent snow cap may have been responsible for the explosive phreatomagmatic activity associated with the Trifoglietto II centre. For these conditions to exist again on Etna, there would have to be cooler climatic conditions. Such changes in climate would probably take place fairly slowly, allowing some reaction to the changing volcanic conditions.

Volcanic gases and aerosols are released mainly from open summit vents (Notcutt and Davies, 1989). These vents produce a continuous volcanic plume, even during periods of inactivity. The prevailing westerly winds drive the plume over the eastern side of the volcano. It is estimated that Etna discharges at least 25 million tons of CO_2 a Year (Allard *et al.,* 1991). The Valle de Bove, on the eastern side of the volcano, tends to funnel the plume and concentrate it in the scar. The effect of the plume has been investigated through the analysis of lichens (Notcutt and Davies, 1989). This analysis found the same level of fluoride in lichens, in areas commonly under the volcanic plume, as you would expect to find in areas of industrial pollution. This suggests that fluoride may be affecting certain animals and plants although the levels are relatively low. There is also the danger, especially in the summit area, that gases such as carbon dioxide and sulphur dioxide may become trapped in hollows during periods of calm (low wind) weather. CO_2 is heavier than air and can accumulate to dangerous levels in sheltered hollows.

8.2.6 Spatial variability in the probability of hazard

The probability that a particular eruptive process will occur and that it will affect a specific spatial area, is an important aspect of the analysis of volcanic hazard. As has been suggested in the above discussion, there is a significant difference in the nature of volcanic activity affecting the summit as opposed to the flanks of the volcano. The extensive record of dated eruptions of Etna provides an excellent opportunity to investigate the frequency of eruptions.

There have been a number of attempts at identifying patterns in the historic eruptions of Etna. In some cases the intervals between eruptions have been treated as random occurrences. Chester *et al.* (1985) report work by Wickman (1966) on the frequency of eruptions. Using an exponential frequency-distribution to describe the random process and data recording the major eruptions on Etna between 1500-1880, Wickman calculated the probability of a 'major eruption' occurring in a year as 0.14, in a ten year period as 0.79 and in a thirty year period as 0.99. In a statistical study of the occurrence of flank eruptions on Etna, Casetti *et al.* (1981) found that some 17% of eruptions, in the period 1323 to 1980, occurred in the month of November. Secondary highs were also found for the months of March (14%) and May (15.5%). They suggested these highs might be related to the fluctuations in the earth's rotational velocity affecting fissures through centrifugal pull. Imbò (also reported in Chester *et al.*, 1985) identified patterns in historic flank eruptions on Etna. He studied the period between 1755 and 1908, and argued that the length of repose between eruptions tended to cluster in groups of either shorter or longer periods of time. He noted a cycle in this pattern. The first half of a cycle was characterised by eruptions with short periods of repose and the second half, by longer periods of repose. The first half of the cycle he linked to the draining of the magma chamber the second to it filling up. The total length of an Imbò cycle is about 50-60 years. The qualitative nature of Imbò's analysis of the time distribution of flank eruptions means that different interpretations of the same data are possible. These different interpretations are likely because the amount of data available (ie. period of time) is limited and the distribution complex and variable.

Attempts to calculate the likelihood of a location on Etna being engulfed by lava have generally centred around three main variables: vent densities, the probable length of a lava flow and relief. Although all areas on Etna are a potential site for an eruption, some sites, with a particular combination of these variables, are more likely than others. Areas of high vent density tend to exist around the summit cone of the volcano and in particular, in order of decreasing vent density, along the north-east and southern rift and to the north-northeast and west of the summit (Chester *et al.*, 1985). Zones of high vent density have been mapped by Guest and Murray (1979) and Cristofolini and Romano (1980) (figure 8.9). The probable length of a lava flow reflects, as has been discussed above, the altitude of its vent. High altitude vents generally only produce short flows, while low altitude vents produce both long and short flows (Chester *et al.*, 1985). Fitting various lines (ie. mediums, maximum and minimum) and curves to historic data, it is possible to give a probable maximum length for a flow with a certain vent altitude. Assuming an eruption does not take place in areas of low vent density, it is possible to map areas that are protected by relief (Guest and Murray, 1979). Using this information Duncan *et al.* (1981) calculated the proportion of relief protected land on the various flanks of the volcano and therefore their relative 'vulnerability'. They argued that sectors below 1000m could be arranged in order of decreasing relative 'vulnerability', these were: NE, S, N, E, SW, W, SE and NW. These areas will vary over time as new lava flows change the 'lava shadow' on the volcano.

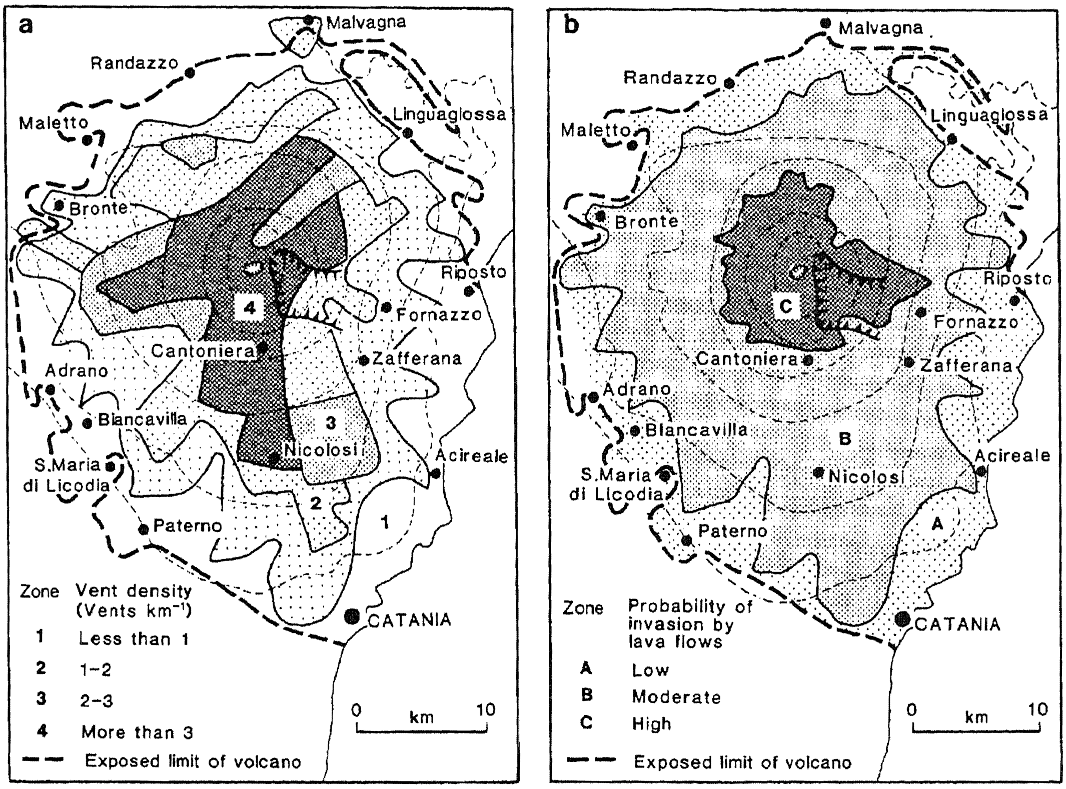

Figure 8.9: Hazard map showing vent density (a) and relative probability of invasion by lava (b). By combining information from the two maps it is possible to calculate a relative hazard score for any location. The scale has ten points A1, A2, B1, B2, B3, B4, C1, C2, C3, C4. (Based on Cristofolini and Romano, 1980).

The hazard maps that have been produced using the above variables tend to use generalised historic data. They do not differentiate between different time periods. Hughes *et al.* (1990), investigating effusive eruptions from 1600 to the present day identified phases with different eruptive styles. They argued that the 1669 eruption brought to an end a period of high-volume high output (1.19 m^3 s^{-1}) eruptive activity. This was followed by a period of low output until the mid-eighteenth century. From then onwards the output has been broadly constant at around 0.18 m^3 s^{-1}. They also identified two main types of flow field: type A which are narrow compared to length and generally produced by short duration (ie. <50 days) eruptions with relatively higher effusion rates and type B which are relatively wide for their length and are produced during longer duration eruptions (ie. >50 days). with lower effusion rates. Because type B flows require a long duration eruption, Hughes *et al.* (1990) argue that they are associated with either high magmatic pressures or unstable flanks of the volcano. In the period 1750 to today there appears to have been sectorial control with some variation in flow type between flanks. There is an absence of type B flows from the northern and western flanks of the volcano. The more buttressed nature of the western and northern flanks mean that fissures close unless magmatic pressure is high and so they tend to close after an initial phase of high effusion rate. Hughes *et al.* (1990) also noted that there was, between 1983 to 1987, an increase in the lava productivity of flank eruptions and this trend has continued with the large volume 1991-1993 eruption. This would be significant if it heralded a new, higher volume, eruptive phase as in the seventeenth century. While hazard mapping, that takes into account sectorial and temporal differences in the nature of effusive eruptions, will certainly be more accurate in the short term, it will also be more sensitive to changes in the nature of eruptions in the long term. As these changes are not predictable at present, hazard maps that use short term information might very quickly become dated.

8.3 PREDICTING THE EFFECT OF AN ERUPTION

Vulnerability analysis is the prediction of the effect of a volcanic eruption. In order for the prediction to be accurate it is necessary to build up a picture of likely post-eruption scenarios. On some volcanoes this is easier to do than on others. Because Etna is a frequently erupting volcano, it is possible to find many case studies to inform vulnerability analysis. Despite the frequent eruptions on Etna, 1928 was the last time a town was destroyed in an eruption. While this case study provides useful insights into certain aspects of an Etnean volcanic disaster, it will not enable an accurate prediction to be made of all aspects of a contemporary disaster. To counter this problem, other examples of natural disasters in Italy are drawn upon as well as more recent eruptions on Etna. These includ the Etna eruptions of 1983 and 1991-93, the dam disaster at Vaiont (1963), and the earthquakes at Belice (1968) and Friuli (1976). Analysis of the impact of earthquakes allows some understanding to be gained of the way the state, local government and civil defence might react to a large scale natural disaster.

8.3.1 The 1928 eruption of Etna

The 1928 eruption of Etna began on the afternoon of the 2nd November (Duncan *et al.*, 1996). At around 4.30 p.m. explosive activity commenced within the North-east crater. This activity continued for a number of hours and then at 6 p.m. a rift opened in the Valle del Leone. A short lava flow emanated from this rift. On the 3rd November a second fissure opened on the Serra delle Concazze. Lava flowed from 12 points along this fissure threatening the towns of S. Alfio and Puntalazzo, which are fairly high on the volcano, and also the large coastal towns of Giarre and Riposto. Luckily for the inhabitants of these towns the flow was short lived, ending a day later on the 4th November. The flow field that resulted extended about 3.6 km down slope of the fissure. On the night of the 4/5th November 1928 a fissure opened up at a lower altitude, 1200m, on the Ripa della Naca scarp (Chester *et al.,* 1985). The lava from this fissure erupted at a high effusion rate. During the 6th November the rate of discharge was large, enabling the flow to travel rapidly down slope. Parts of Portosalvo and Nunziata were destroyed and in the early evening the flow overwhelmed the town of Mascali 5.5 km from the vent (Jaggar, 1928a) (figure 8.10). By the 7th a greater part of the town had been destroyed (Chester *et al.* 1985, Giornale dell'Isola 7th Nov.). After this, the advance of the flow slowed and the east coast railway line was not broken until the 11th November. The flow stopped on the 16th November.

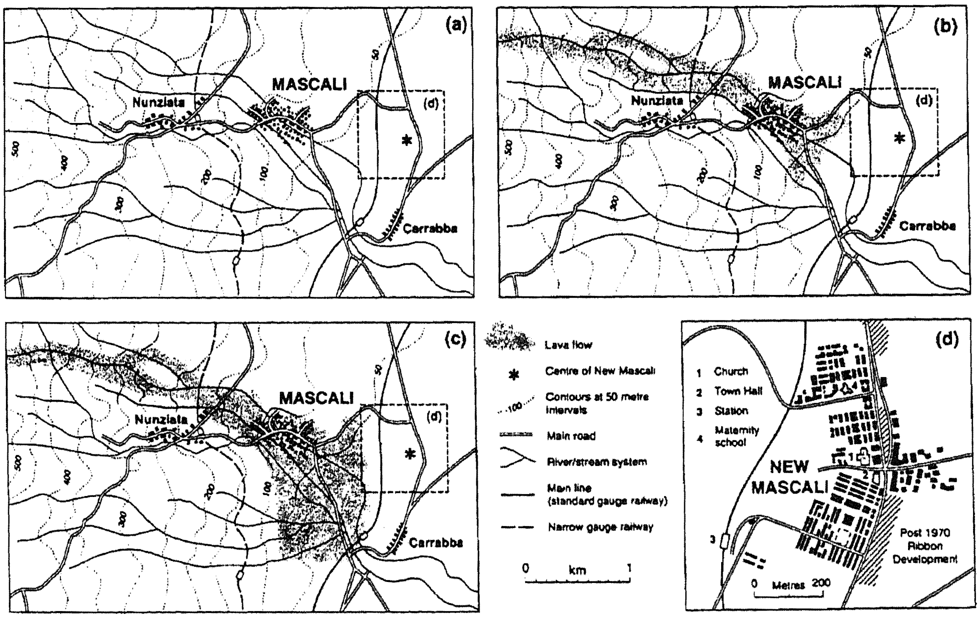

Figure 8.10: The maps show the old town of Mascali during various stages of the eruption and the location of the new town. (a) Mascali before the 1928 eruption, (b) the flow of lava on the 6-7th November and (c) The flow after the 11th November. Map (d) shows the layout of the new town. (Adapted from Duncan *et al.,* 1996).

The 1928 eruption of Etna produced a narrow fast moving flow. Importantly the fissure opened up below the zone delimited by Guest and Murray (1979), where most Etnean eruptions have originated in historic times. This meant that it rapidly achieved a low altitude in comparison to the volume of lava discharged. The flow therefore reached the highly populated zone of the volcano in a fairly short time period. The authorities had little time to react to the flow other than to aid with evacuation.

Between the 5th November when it first became obvious that the eruption threatened Mascali and the 6th November, when the flow entered the town, a comprehensive evacuation was organised. According to newspaper and eyewitness accounts, and despite the complex nature of the evacuation and the relatively short time period involved, the evacuation was both orderly and effective. There were no deaths during the disaster, though rumours of two incidents circulated at the time. Both rumours were reported by Jaggar in his summaries of the eruption (Jaggar, 1928a; Jaggar 1928b; Jaggar, 1929). The incidents involved an elderly couple and a group of three men who had returned to their houses to collect items and had been cut off from safety by the advancing lava. Interviews with those who had been in Mascali at the time and a search of the local and national media revealed no references to these incidences. It was therefore concluded that no one had died in the eruption. The people of Mascali were able to remove many of their household possessions (figure 8.11). The success of the evacuation seems to have been the result of a constructive and efficient interaction between the people of Mascali and the organisation structure involved in the supervising of the evacuation.

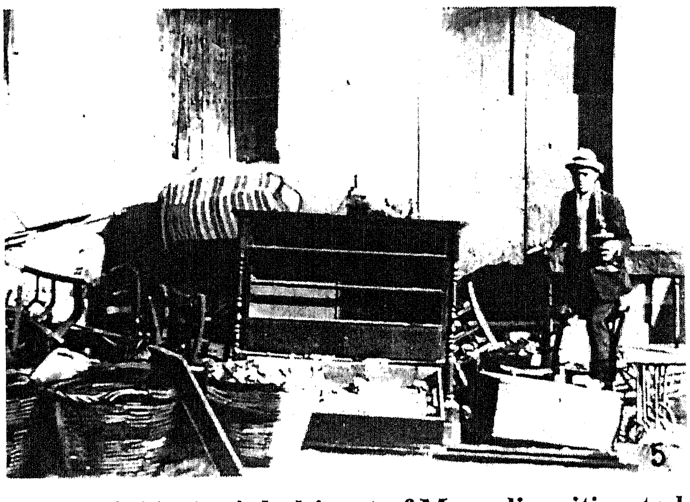

Figure 8.11: An inhabitant of Mascali waiting to have his belongings taken out of the town. (Finocchiaro Fotografi)

One feature of behaviour that is commonly blamed for deaths in disasters and the failure of evacuation plans is panic. Panic is defined in this context as irrational, self-destructive and uncontrolled behaviour resulting from exposure to a high danger environment (Sime, 1990). It is a fairly common belief that a majority of people, in close proximity to a highly hazardous environment, will tend to panic. Recent research has argued strongly against panic as a common feature of disaster behaviour (Sime, 1990; Drabek, 1986). Rather than panic individuals will tend to continue within conventional patterns of behaviour until hazard 'cues' are overwhelming and even when they realise the danger they are in they will generally behave rationally within the constraints of the environment they are in (Canter, 1990; Sime, 1990). In Mascali there was no reported incidence of panic. Instead fairly 'normal' behaviour seems to have characterised the period up to the destruction of the town. The funeral of Comm. Francisco Papadrea, for example, took place only 9 hours before the lava flow entered the town (Corriere della Sera, 6th Nov.). Contemporary photographs and film show people standing fairly close to the advancing lava flow (figure 8.12). Behaviour during the Mascali disaster can be described as adaptive to the disaster situation and generally calm.

Figure 8.12: Man watches the lava flow advancing up a street. (Finocchiaro Fotografi)

Though behaviour in the town was calm it was not passive. The day before the lava entered the town various adaptive and mitigative strategies were being acted out. The processing of religious relics and the statues of patron saints has been and still is a very common aspect of behaviour during eruptive events on Mount Etna. In Mascali the patron saint of the town S. Leonardo and various other religious relics were used to try and halt the advance of the lava (Corriere della Sera 8th Nov.) (figure 8.13).

> We thought the patron Saint of our town, S. Leonardo, could have stopped the lava, so some people decided to put the statue of the saint in front of the oncoming lava. They positioned it only 50 metres away

> hoping it would perform a miracle but it was no good. So the statue was retrieved very quickly before the lava could reach it. We took it to Riposto, for safety, until Mascali was rebuilt when we were ready to host it once again. (Respondent 3).[5]

Figure 8.13: A procession with the statue of S. Leonardo. (Finocchiaro Fotografi)

Some peoples attitudes seemed to have been more fatalistic than hopeful.

> There was nothing to do to stop the oncoming lava except hope for the best. We put our faith in God and lives in his hands - *alla mano di Dio* - We prayed. (Respondent 4).

Others attitudes seemed to have been profoundly realistic, though this view may have been coloured by the experience of the following days and years where a hope in a miracle was indeed to prove futile.

> We all hoped from a miracle from S. Leonardo but of course, this was useless (Respondent 8)

Processions of this type were happening in all the threatened towns in the area (Daily Telegraph (London), Nov. 7th). Witnesses reported that the people had great faith in their patron saint and hoped for a miracle but as the lava continued to advance they realised they were had to make other plans as well. It was a cruel irony that the 6th November, the day the lava entered Mascali, was the festival day for S. Leonardo.

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[5] The quotations are translations of passages from the interviews carried out in Mascali.

> From S Alfio it [the lava flow] glided down directly into Mascali arriving on the 6th November, a day not to be forgotten because it was our patron Saint's day - S. Leonardo! (Respondent 6)

While the people prayed for a miracle they were also preparing for the potential destruction of the town. They had plenty of time to remove items from their houses. Some had started doing this three or four days earlier, as the lava flow from the second eruptive fissure had threatened (Corriere della Sera Nov. 6th).

> There was plenty of time to leave, taking away everything possible. (Respondent 14)

> There was clearly no danger to life, for we had four or five days to retrieve all our personal things including furniture (Respondent 11)

The residents were assisted by firemen, the municipal guard and soldiers mobilised by the authorities in Catania (Corriere della Sera, Nov. 6th). Witnesses reported that each family was assisted by soldiers and were given access to a military van. With this help the people of Mascali were able to remove furniture, doors, ceramic tiles and other objects from their houses. Contemporary films show houses being stripped of all their roof tiles.

The organisational structure put in place by local government created a situation where a comprehensive evacuation was possible and orderly. In the case of Mascali, its visible expression were soldiers, municipal guard and firemen. They maintained order, facilitated and controlled the evacuation. The evacuation of the town was organised by the mayor of Catania Province, Cav. Costarelli (Corriere della Sera, Nov. 7th). General Scipioni, the local military commander, provided troops to help with the evacuation. He also liaised with Professor Ponte, of the Institute of Volcanology at Catania. Together they had made plans to build barriers to protect the towns of Riposto and Giarre. These measures were never actually needed as the threatening flows stopped a long distance from these towns. In the event the local people, not 'panicking', were able to leave the town saving many of their belongings.

The evacuation of the town was ordered by the vice mayor of Catania, Cav. Costarelli (Corriere della Sera 6th Nov.). Soldiers were heard to cry:

> There is time, stay calm, it has only just entered the Vallonazzo river. (Fichera, 1988) (figure 8.14).

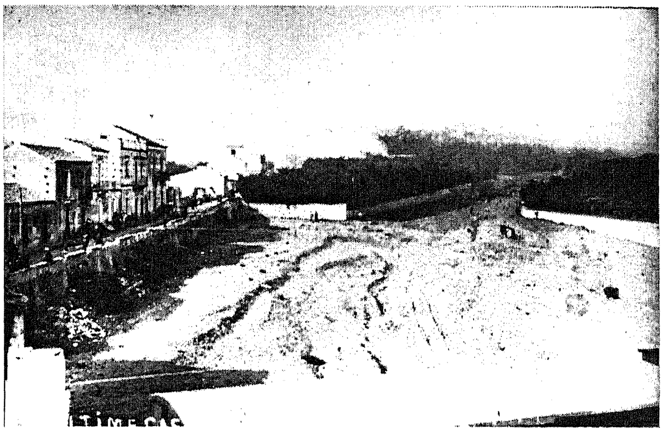


Figure 8.14: The Vallonazzo river - that was to guide the lava flow through the town of Mascali. (Finocchiaro Fotografi)

One old man was reported to have refused to evacuate because he would prefer death to losing his home (Corriere della Sera, 6th Nov.). The literature on disasters has often suggested that there is a subgroup of a threatened town's population who refuse to evacuate because they prefer death to losing their homes or they believe the hazard is exaggerated (Hutton, 1976). Other research suggests that, although this subgroup is reluctant to move during the early stages of an evacuation, when actually faced with strong 'cues' to the approaching danger, they are as motivated as other evacuees to leave the area (Hutton, 1976). The relatively higher proportion of old people, amongst those who have refused to leave and have subsequently died, is attributed to their inability to escape during the actual initial stages of a hazard event rather than their continued reluctance to move (Hutton, 1976). There were no reports of people, unwilling to leave the town, actually staying behind in Mascali.

The evacuees travelled to the surrounding towns, including Giarre, Riposto, Acireale, and Fiumefreddo (Giornale dell'Isola 15th Nov.). Although one report stated that people were being cared for in schools, churches and railway stations (Jaggar, 1928b), interviewees stated that most people stayed with friends and relatives, in second homes or hired apartments. Evacuees had to use ingenuity and their extended family to cope with the difficult situation they now found themselves in. Respondent 10 recalled that:

> Although my family had a cart pulled by horses we did not use it to leave Mascali. My father took it to the country where he sort of parked it. Meanwhile my mother and all us children left Mascali at night on foot walking to Riposto because there we would have needed a place for it and place for the horses as well.

As the lava advanced into the outskirts of the town, it was described as moving with terrible silence, without explosions, without roaring and travelling about 2 metres a minute on a 400 metre front (Fichera, 1988). The town was deserted with the doors of houses left open (Corriere della Sera, 6th Nov.). At 17.50 on the 6th of November the lava flow entered the town (La Sicilia, 3rd Nov. 1978). Witnesses reported that the lava was drawn through the centre of the town by the valley of the river Vallonazzo. Contemporary photographs and films show large crowds watching the town slowly being destroyed. Amongst the people of Mascali there was a profound sadness (Corriere della Sera, Nov. 7th). One newspaper described the situation graphically:

> The owner of a beautiful building is present at the moment the lava collides with that which, yesterday, was his home. He is profoundly sad now but his heart is firm (Corriere di Catania, Nov. 7th).

and

> Mascali dies little by little (Corriere di Catania, Nov. 7th) (figure 8.15).

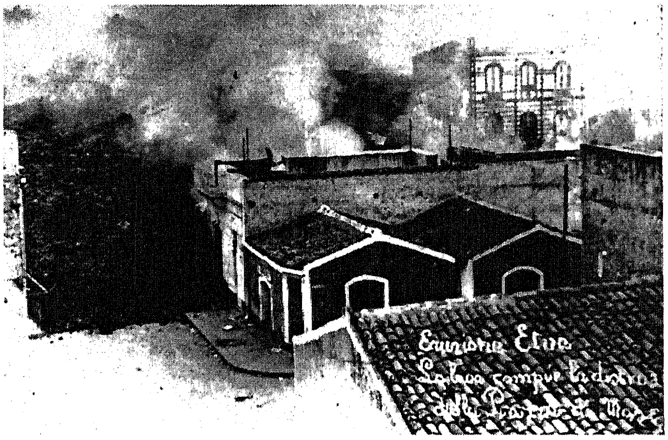


Figure 8.15: Lava advancing through the town. (Finocchiaro Fotografi)

One of the last remaining structures in Mascali was the clock tower of the church which started to ring dramatically during the night as the structure was rocked by the lava flow (Daily Telegraph, Nov. 8th) (figure 8.16). People were reported to have fallen on to their knees and prayed when they heard this sound (Daily Telegraph, Nov. 8th). At 8 a.m. the tower fell (Daily Telegraph, Nov. 8th). The last houses left in Mascali were destroyed by 3 p.m. in the afternoon (Giornale dell'Isola, 7th Nov.). On the 11th November the east coast rail line was cut by the lava flow. This restricted communications between Messina and Catania and also between Messina and Siracusa. The immediate problem of communications was dealt with by using two alternatives routes, a sea route from Messina to Catania and a longer rail route between Catania to Palermo and on to Messina (Corriere di Catania, 10th Nov.). By the end of the eruption 700 to 750 homes had been destroyed and 3,000 acres of agricultural land had been lost. A majority of the residents of Mascali were homeless as were some from the town of Nunziata.

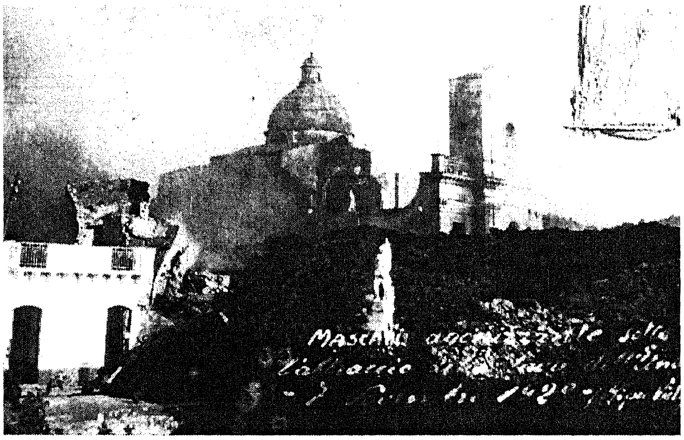


Figure 8.16: One of the last remaining structures in the town was the church. (Finocchiaro Fotografi)

The civil authorities were faced with a disaster on a number of different levels. There was the local problem of people made homeless and jobless by the destruction of housing, agricultural land and places of employment. At a regional level, the cutting of the main railway line, created a serious communication problem for the east coast of the island. The reaction of the Fascist administration was rapid and to a great extent effective. Possibly encouraged by the opportunity to provide an example of effective fascist planning, Mussolini released funds and pushed ahead the reconstruction of Mascali (Duncan *et al.,* 1996). The destruction of Mascali and its reconstruction took place within the glare of national and international publicity and there seems little doubt that part of the motivation behind the intense reconstruction process was propaganda. It is important to note, however, that although many of Mussolini's planning schemes were part of a process of promoting a fascist ideology (eg. maternity schools - the push for a larger Italian population), they were never the less part of a particular planning vision. The aims of planning and fascist propaganda, within this vision, can not be easily separated. It is difficult but therefore necessary to look at the resulting structures dispassionately, assessing their effectiveness in terms of the local conditions experienced rather than simply a more global reaction to the ideology of fascism *per se.*

On the 14th November the Minister of Public Works Giovanni Giuriati visited the site of the disaster (Giornale dell'Isola, 15th Nov.). Before and soon after this visit plans for the reconstruction of the town had been and were being devised. Unemployed agricultural labourers were to be found work by the local authorities on various farms (Corriere di Catania, 7th Nov.). A temporary line of track, to link Mascali to Borgata Strada, was authorised (Times, 23rd Nov.). After this initial assessment the *Confederazione Generale Fascista della Industria Italiana* promised 25 million lira (US$ 1.3 million) for the immediate relief of the town (Fichera, 1988). On the 11th October 1929 the government announced that Mascali was to be reconstructed on a new site 1.5 km from the site of the old town, close to the existing town of Carrabba.

The new Mascali was planned on a grid system with a fairly nucleated form, houses fronting onto the street and a large central piazza. The new town, in some ways, reflected the traditional morphology of a Sicilian town. In contrast to nearby towns, the houses were of a high quality, they had good facilities, the streets tended to be relatively wide and the municipal buildings imposing. The central piazza was, and still is, dominated by the town's church. Although of similar size and shape to the pre-1928 church, it's front façade is crowned by the Fascist torch. Other municipal buildings are similarly imposing. The railway station, at which only a couple of trains stop during the day, is grand as is the town hall which is situated in the centre of the piazza.

The reaction of the people who experienced the disaster, seems to have been universally positive. Amongst those who were interviewed, no one criticised the reconstruction process. The success of the reconstruction seems, in the minds of those who experience it, to be closely linked to Mussolini himself.

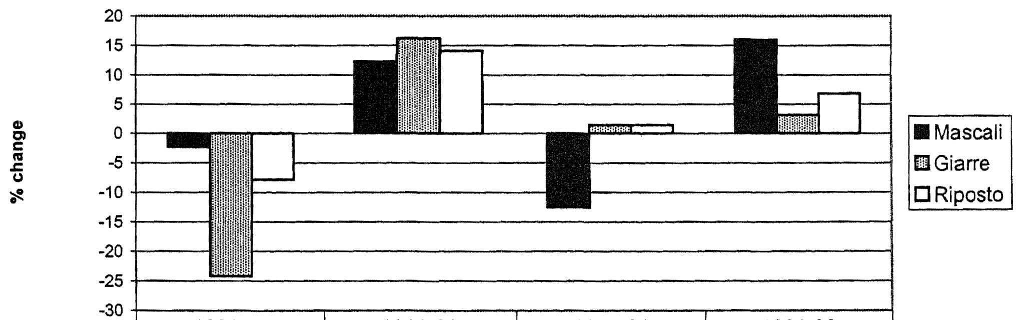
> Mascali was rebuilt not long afterwards - it was thanks to Mussolini that we didn't wait too long for our new homes (Respondent 4)

> For the reconstruction Mussolini gave about 10 to 20,000 lira to each family. The amount we were given depended on the size of your family. The families were also given a number of square metres of land in order to build their houses on...and in no time, Mussolini had the town rebuilt. By 1932-33 the first council houses *(casse popolare)* were built then came the large private estates and finally the private homes. (Respondent 9)

> Thanks to Mussolini by 1933 the council houses were finished and the first group of citizens returned to Mascali. In this year the primary

school also reopened ...I remember this well because I began to attend the school (Respondent 13)

Mussolini's visit to the town in 1937 and the propaganda surrounding the reconstruction may have created the impression, in the minds of the residents, that it was Mussolini they had to thank. It is also possible that over time the problems may have been forgotten or those that had difficulties may have moved away from the area. From an objective standpoint the reconstruction seemed to have been a notable success. This is reflected, to some extent, in the fact that though in 1931 the trend in the resident population of Mascali comuni showed a slight decline in comparison to neighbouring comuni, by 1936 the population had recovered its 1921 level and the trend in the population growth was consistent with neighbouring comuni (figure 8.17). This suggests that although some residents left the comuni after the events of 1928, they were only a small proportion of the total resident population and that Mascali did not fall into economic decline in the decades after the disaster. The comments of those who had lived through the event suggest that if anything, many of the people of the town felt that their conditions had actually improved with the building of the new town.



	1901-11	1911-21	1921-31	1931-36
Mascali	-2	12	-13	16
Giarre	-24	16	1	3
Riposto	-8	14	1	7

Figure 8.17: Percentage, inter-census, population change. The comuni chosen are similar to and neighbouring Mascali.

The reconstruction of Mascali demonstrates that a natural 'disaster' can, in the long term, be beneficial for a community. Though creating significant difficulties in the short term, the 1928 eruption allowed a new and materially improved town to be built. The particular nature of Etna's volcanism allowed this to happen. Because the lava flow that eventually destroyed Mascali was relatively narrow, though some agricultural land was destroyed, much of it was left untouched and, because of the many farmers had scattered plots, no family lost all their land. Residents could continue to farm and live in their 'country cottages'. Another important factor was the absence of casualties. It seems less likely that those who survived the eruption would look back with little complaint or grief if a significant number of people had been killed. Not only would the emotional trauma have been that much greater but also the ability of social groups (eg. families, farms or factories) to function effectively in terms of material production might have been severely limited. By providing a new town infrastructure on a nearby site, the authorities were able to empower the residents sufficiently to allow successful recovery. The eruption only affected three towns to any great extent and therefore the pressure on financial, physical and human resources was not severe as might occur after a major Sicilian earthquake (eg. that of Messina in 1908).

8.3.2 Eruptions since 1928

There have been 13 significant flank eruptions on Etna since 1928, in: 1942, 1947, 1949, 1950-1, 1971, 1974, 1978, 1979, 1981, 1983, 1985, 1989 and 1991-3 (all the main flank eruptions that have occurred in the twentieth century are summarised in figure 8.18). None have caused the same level of destruction as the 1928 eruption. The 1971 (May) and 1981 eruptions did result in the loss of agriculturally productive land around Fornazzo and Randazzo respectively. The 1983 eruption did considerable damage to the 'southern' tourist complex. The damage to these facilities was estimated at ~$30 million (1983 US dollars) (Chester *et al.,* 1985). The 1985 eruption further damaged the cable car system. The 'state' has played an increasingly important role after each of these eruptions. This has included increased monitoring, active engineering interventions and the provision of compensation for losses incurred.

Date	Location of eruption	Effect on population
1942	high level eruption	little effect on populated area
1947	eruption associated with NE rift	some woodland and agricultural land destroyed
1949	fractures near summit	little effect on populated area
1950-51	fissures in Valle de Bove	threatened Fornazzo
1971 (April)	fissures near summit	Observatory destroyed
1971 (May)	fissures (1800 m) east sector	threatened Fornazzo and S. Alfio
1974	fissures (1675 m) west sectors	little effect on populated area
1978	fissures (2800 m) east sector	only grazing land destroyed
1979	fissures (1800 m) east sector	cut communication to Fornazzo
1981	fissure north-west sector	threatened town of Randazzo
1983	fissure south sector (2400 m)	destroyed tourist complex
1989	fissure north east sector	threatened town of Fornazzo
1991-93	fissure east sector	threatened Zafferana

Figure 8.18: The effects of Twentieth century flank eruptions (Derived from Chester *et al.*, 1985, pp. 358-359).

8.3.3 Recent Italian 'natural' disasters

Most major Italian 'natural' disasters, in recent years, have resulted from seismic activity. These have included events at Val de Belice (1968 - Sicily) and Friuli (1976 - northern Italy). The Vaiont dam disaster (1963 - northern Italy), where a landslide into the reservoir caused a wave to break over the top of the dam, was a major 'natural' disaster that was not directly related to seismic activity. Although different in terms of the type of damage done, these earthquakes are probably the best opportunities to examine the modern Italian response to a major disaster.

On the 14th January 1968, after a couple days of precursory tremors, a period of major earthquakes hit the Val de Belice area of Sicily (King, 1973). This continued for six weeks. The Val de Belice is situated in the western interior of the island and was an area of extreme poverty. Of those affected by the earthquakes: 280 died, 500 were seriously injured and in total 51 villages were affected. In some of these towns all of the housing stock was destroyed. The poverty inherent in these towns meant that the housing stock was of an unstable rubble masonry type which collapse easily in an earthquake.

The disaster seemed to highlight the inefficiencies within the local administrative emergency response (King, 1973). Emergency aid took a great deal of time to reach the victims of the earthquake. Local emergency care was overwhelmed by the scale of the disaster. The 50,000 people made homeless had to survive in very cold conditions in tent communities and later in barracks. The authorities, aware of the shortage of accommodation and opportunity, encouraged survivors to move to other parts of Italy and Europe. They did this through the provision of travel grants. This resulted in 15,000 people leaving the area.

The Val de Belice earthquake highlighted the deficiencies present in the Italian response to disasters of this type. A long term commitment was needed, if the process of reconstruction was eventually to succeed. In the event people were still housed in temporary accommodation ten years after the earthquake. It was the visit of the Pope to the area in 1982 and his comments on the conditions under which the survivors were still living, 14 years later, that stung the regional authorities into action (Chester *et al.,* 1985). Until then money intended for reconstruction had been absorbed by an inefficient and corrupt administrative system.

Robert Geipel (1982), in his research on the 1976 Friuli earthquake, analysed the effect of the process of reconstruction on the region. On the 6th May 1976 the Friuli region of Italy was struck by an earthquake measuring 6.4 on the Richter Scale: 939 people were killed, 2,400 injured, 32,000 houses were totally destroyed and a further 57,000 houses were made uninhabitable (Geipel, 1982). In September, of that year, another earthquake hit the area. Many houses that had been repaired, were again made uninhabitable. The psychological affect of this 'second blow' was considerable and with winter approaching the authorities were forced to requisition hotels along the Adriatic coast.

The experience of those who had lost their houses in the Val de Belice earthquake was known by the people of Friuli so that they demanded - *Dalle tende alle casa* (straight from tents to houses) (Geipel, 1982). Despite this people did spend time in barracks. Indeed while some fulfilled their role as temporary accommodation, others became the site of more permanent residence. The barracks were looked on favourably by various groups of people including *inter alia*: young families trying to move out of the family home, the families of constructions and trades people who had set up businesses to service the barrack towns.

One of the aims of the reconstruction laws, that were passed after the disaster, was to limit out-migration from the region (Geipel, 1982). People were only allowed to invest their compensation in the region where their losses had occurred. Although there was a sharp loss of people immediately after the earthquake, in the longer term the number that emigrated after the earthquake did not exceed that experienced in previous years. This was in sharp contrast with the large scale and planned exodus after the Belice earthquake. Maintaining the economically active population within the disaster affected regions means that a return to previous levels of economic activity is possible. A large out-migration of the young may mean a local economy will remain stagnant. In the case of the Belice earthquake, the out-migration may have only accelerated a process that was already taking place (ie. large scale migration from the Sicilian interior). It is, therefore, probably important to qualify criticism of the Belice compared with Friuli by saying that limiting out-migration is only a positive move if any recovered local economy can provide livelihoods for those who might consider and have an opportunity to move elsewhere. The response of a community to a natural disaster will reflect the economy within the affected region.

Although the reconstruction laws seemed to halt the exodus from Friuli, it did not stop the social fabric of the region changing. The semi-rural lifestyle, that was common before the earthquake, disappeared, as knowledge of traditional practises were lost (Geipel, 1982). This occurred because the older generation were no longer actively involved in their traditional lifestyles and were therefore not passing on the skills, through demonstration, to their children. There was also a movement of the population from the mountains to the plain. Part of this movement resulted from younger people moving closer to other places of work which tended to be on the plains. People were free to transfer their compensation within the region and this seems to have resulted in long term trends being speeded up as the population suddenly became more mobile within the region.

Geipel (1982) surveying the attitude of the survivors of the earthquake concluded that in general people felt their housing quality had improved, many now lived in detached houses, but that the fraternity of the old communities had been lost. Respondents also felt that the character of the old towns had been lost with the destruction of the historic town centres. While the reconstruction process enacted after the earthquakes at Friuli stopped the region falling into economic and social collapse, it did not return it to its pre-earthquake state. A new social and economic environment emerged out of the rubble. The new landscape of Friuli had both advantages and disadvantages over the old.

Quarantelli (1979) noted that the Italian army have, for historical reasons, played a very central role in disaster response. Indeed after the Vaiont Dam disaster, he observed that although the military wanted to withdraw from the latter part of the initial disaster operation, a period where communications were being re-established, the lack of a suitable organisation to take over their role meant they were unable to do this. Although the Italian army took a primary role in the state's response to the disaster, other organisations were also involved. These included the Carabinieri, fire service and American army. Also a number of different units were involved in the Italian army's response and this led to some confusion and duplication in the early stages of the disaster (ie. 1-8 hours).

It is now argued that the potential for an appropriate disaster response has improved since the 1960's in Italy (Chester *et al.,* 1985). Since the 1970's disaster response has been co-ordinated by an Extraordinary Commissioner (ie. the Friuli and Avellino disasters), by the minister for Civil Protection (Etna, 1983) and, when dealing specifically with volcanic crisis, by the Civil Defence authorities working with the Gruppo Nazionale per la Vulcanologia (Etna 1989 and 1991). These measures have ensured that recent responses have been co-ordinated and to a great extent are effective, within the prescribed parameters of immediate disaster response within particular environmental conditions.

8.4 VULNERABILITY OF THE POPULATION

8.4.1 Location

It has been suggested in the previous section, that the probability that a type of activity will affect a particular location varies considerably around Etna. The nature of an individual's vulnerability will depend to a great extent on their location within the area and the location of other important aspects of their economic and social life.

Volcanic activity on Etna does not present a great threat to life, except in the summit area, near a lava flow front or close to an eruptive vent or fissure. Access to the summit area is now controlled, after the 1979 accident when a group of tourist were caught by a sudden explosive event within the Bocca Nuova. Tourist trips are now generally terminated some distance away from the summit cone, progress barred by a fence with warning signs and at such a distance from the summit as to discourage even those who would ignore the signs and try and walk on (figure 8.19). Scientists and mountain guides are the only major groups who now visit the summit area.

Figure 8.19: A fence with sign warning tourists not to go any nearer the summit cones.

At a fairly high altitude on the volcano, there are a number of areas of development that have a relatively high level of probability of being covered by lavas. These include: ski facilities, hotels and restaurants, scientific monitoring stations and shops at Cantoniera and ski facilities above the town of Linguaglossa. Some of the boutique shops at Cantoniera are actually on wheels so if they are threatened by lava they can be removed. These areas are visited by many tourists each year but the tourists would be unaffected by the hazard at these locations because it is not a threat to lives or health, only property.

The location of homes on the flanks of Etna can have a significant affect on the probability that they will be destroyed by a lava flow. Various hazard maps have been constructed showing sectors with varying levels of risk. All maps of Etna, that attempt to show relative hazard, suffer from a number of inadequacies. All rely on historical data to predict future events. Often the number of events that can be drawn upon to construct predictive models are insufficient. This is a special problem on Etna because of the great number of variables that are believed to affect eruptions and in particular lava flows (eg. slope, altitude, sector of the volcano etc.). There have not been enough eruptions to be able to assess the effect of one of these variables while holding the others stable. General models, as a result, have to be used across different conditions on the volcano. In an attempt to access sufficient data to produce stable models, researchers have been forced to use data generated from thousands of years of volcanic activity. By using these data, assumptions are often made about the stability, over time, of many of the volcanic processes and in particular the internal plumbing of the volcano. As has been discussed above there is evidence that this has changed during even fairly short periods of time (Hughes *et al.,* 1990).

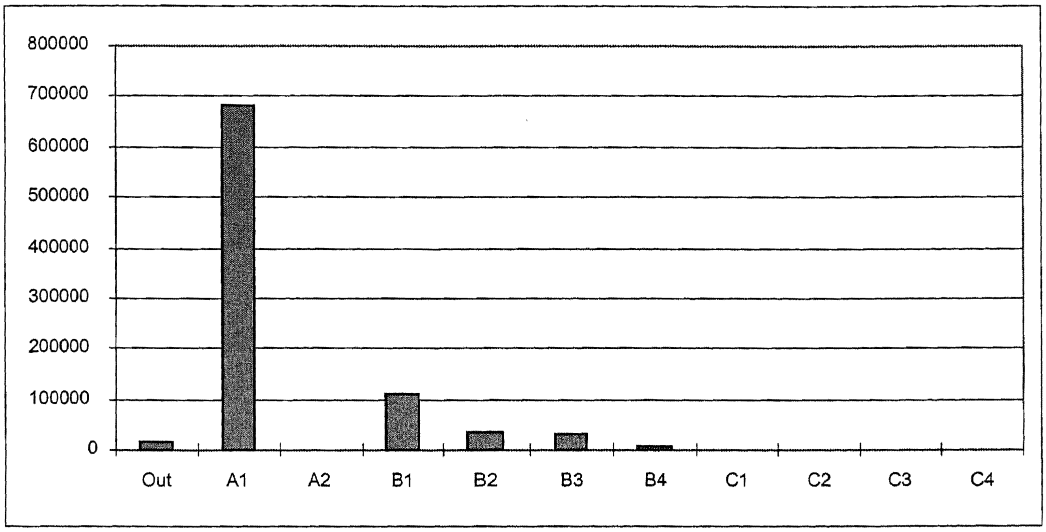


Figure 8.20: The population at various levels of hazard - A1 - is the lowest level of hazard, C4 - is the highest, Out - is a town outside the maximum extent of lava cover but still within mapped area. Derived from Cristofolini and Romano's (1980) hazard map of Etna. Population calculated by taking the central town of each comuni as the spatial location of the population of that comuni.

Cristofolini and Romano (1980) mapped hazard by dividing the volcano into 10 areas of increasing probability of engulfment by lava flows and local explosive activity (figure 8.9). By taking the main town in each comuni (typically there is only one) and locating it on the hazard map it is possible to calculate the total population within each of the zones. This reveals a falling trend of population with increasing hazard and a majority of the population located in the zone of lowest hazard (figure 8.20). Despite having a large percentage of the population in the zone of lowest hazard, the map also reveals that there are nearly 865,532 people whose homes are at some risk of being destroyed by lava flows. Some 184,872 of these people live in a zone where there is a 'moderate' chance that their homes would be destroyed a lava flow (ie. zones B1 to B4).

The hazard map produced by Cristofolini and Romano (1980) attempts to combine the impact of explosive activity immediately around a vent with the more distal affect of lava flowing from that vent. The basic concept behind this scale is that vent density graduates the hazard within zones of equal probability of engulfment by lava. There seems to be a problem with this method of scaling. In areas with a low probability of engulfment (A), because there are no areas of vent density above 2 per km^2 (zone 3-4) there are only two scores possible A1 and A2. In contrast, areas with a high probability of engulfment (C), have four possible scores C1-C4 despite the fact that there are only very small areas with a vent density of less than 2 per km^2 (zone 1-2). As a result while the difference between A2 and B2 is only 2 for B2 to C2 it is 4. In other words, while keeping vent density constant, hazard increases twice as much between zones B and C as it does for A and B.

An alternative method of estimating the relative hazard of different towns situated on Etna can be achieved by making a number of assumptions about the behaviour of the volcano. (1) That future volcanic activity will broadly reflect trends apparent in its past behaviour. (2) That the most likely site for a future vent is somewhere within the area with a vent density of at least 1 per km^2 (Chester *et al.*, 1985). (3) That there is an equal probability that a lava flow will emanate from any border of the area with a vent density of at least 1 per sq. km. (4) That the altitude of a vent will affect the potential length of a lava flow. By making these assumptions it is then possible to map areas that are sheltered from lava flows by relief (Guest and Murray, 1979). By fitting trend lines and curves to historic data on lava flow lengths and widths, it has been noted that the likely maximum lengths of lava flows tend to decrease with altitude (Chester *et al.*, 1985). Using the 80% shell, fitted to flow length and vent altitude data, to estimate the probable maximum length a lava flow from a vent at the lowest possible point within the area with a vent density of more than 1 per km^2, it is possible to delimit an area outside which lava flows would not be expected to reach. It is then possible to categorise every town on the volcano as being in one of five classes of volcanic hazard (figure 8.21).

Class	Description
1	Outside the 80% shell or relief protected
2	Between the 80% shell and 1/3 of distance between the 80% shell and area of the area with a vent density of more than 1 per km^2
3	Between 1/3 and 2/3 of the distance between the 80% shell and area of the area with a vent density of more than 1 per km^2
4	Between 2/3 of distance between the 80% shell and area of the area with a vent density of more than 1 per km^2 and the edge of the area of the area with a vent density of more than 1 per km^2
5	Within the area with a vent density of more than 1 per km^2

Figure 8.21: Five classes of volcanic hazard.

If the main town is used to locate a comuni population the following approximate pattern of population at relative risk can be shown.

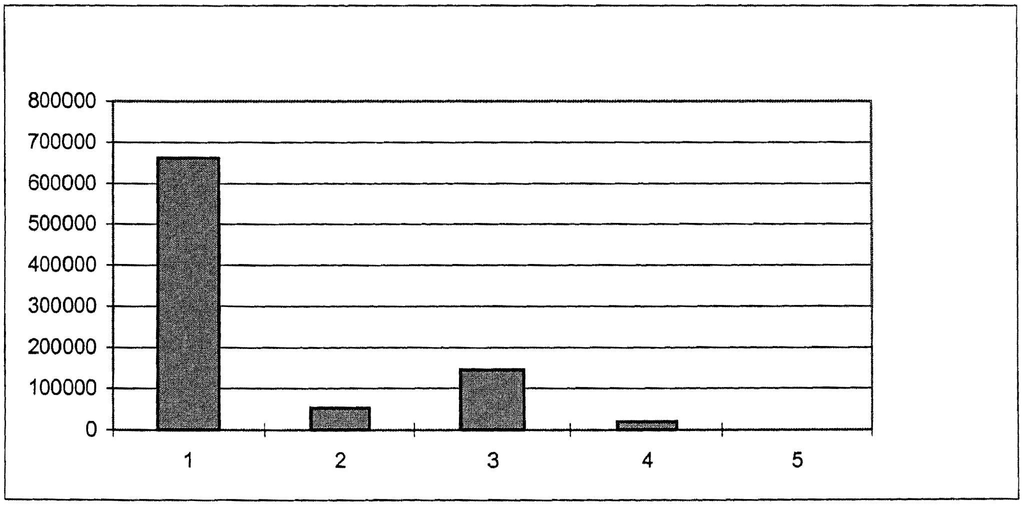


Figure 8.22: The population at various levels of hazard. Population calculated by taking the central town of each comuni as the spatial location of the population of that comuni.

This method gives some indication of the varying relative probabilities of invasion by lava flows faced by towns with different locations on Etna. As with the Cristofolini and Romano (1980) map, a large majority of the population are in the lowest risk sector and there are none in the highest risk (figure 8.22). But still there are a considerable number of people living in a situation of medium risk. This population is concentrated on the eastern and south-eastern flanks of the volcano (figure 8.23).

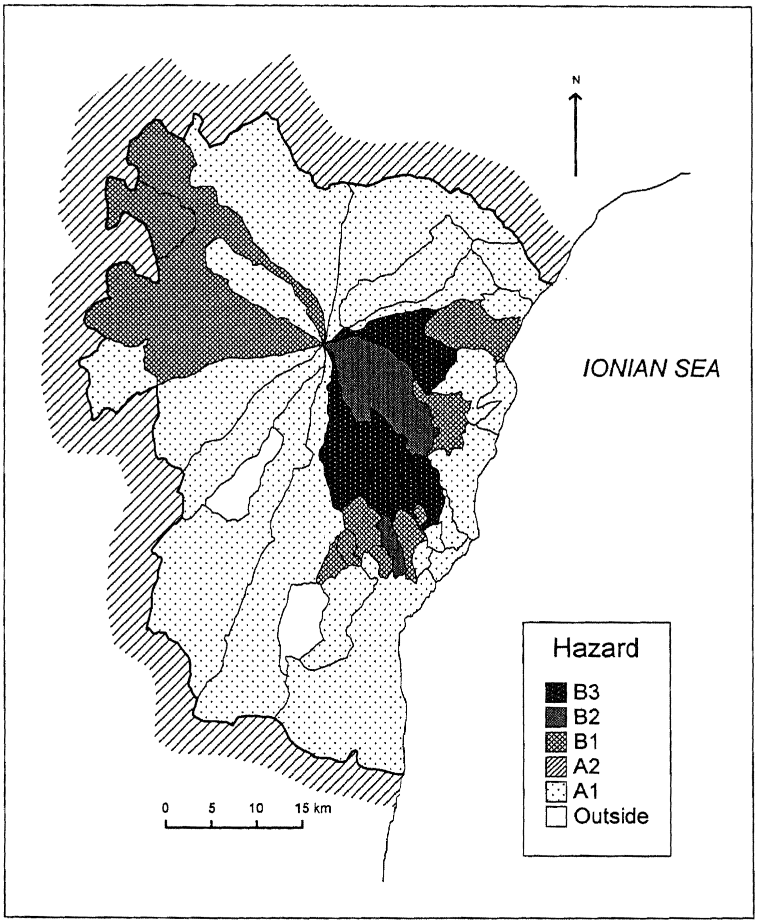


Figure 8.23: Map showing the level hazard for the main town in each comuni, as calculated from Cristofolini and Romano's (1980) hazard map. The comune centre on the summit of the volcano and the edge of the map is roughly equivalent to the maximum extent of the lavas.

The position of a town can dramatically affect the relative hazard it faces. Similarly the threat to agricultural land, industries and other economically significant sites will be determined by location. The reliance of an individual or group on a particular town and/ or site will determine the level of direct threat that the potential of a lava flow poses to important aspects of their life. Farmers on Etna have intentionally or unintentionally, it is not clear which, manipulated this situation to their advantage. By traditionally owning non-contiguous plots of land they have reduced the chance that all of their land will be destroyed by a single lava flow (Chester *et al.*, 1985).

The opposite situation is true of Catania. Although most of the industrial areas are based to the south of the city on the flood plains of the Simeto river, and outside the maximum extent of Etna's lava, the old centre of the city and many of the new residential developments are in areas that have been covered by lava in the past. In the case of Catania a very large number of people would potentially lose both their homes and source of work if the city was to be overwhelmed by a lava flow. Any lava flow that overwhelmed Catania would, inevitably also have destroyed much of the densely populated area north of the city in which a large proportion of Catania's commuting workers live. The location of Catania is not only significant for those living and working in the city. Catania is an extremely important service centre for the province of Catania and comuni bordering the province (Banco di Sicilia, 1989). People rely on it to provide the type of goods and services that can not be found in the smaller urban centres. The town also has a major University, an important banking quarter and is the location for regional government and judiciary. The economic and social significance of the city means that individuals living away from the volcano may also be vulnerable to volcanic hazard.

8.4.2 Self protection

The volcanism on Etna, as has been discussed above, is not an extreme threat to lives or health. The threats that do exist are generally localised to a site of active volcanism and are comparatively easy to avoid. Lava flows are only dangerous to someone who can not move out of their way because they are trapped or otherwise incapacitated. The typical slow advance of a flow means that it is often possible to out walk it or at least outrun it. There have been cases of spectators being killed when lava flows have encountered water and reacted explosively. In 1843 at least 36 spectators were killed by a phreatic explosion at the flow front as the lava encountered a pond. Spectators still gather to watch advancing lava flows (figure 8.24). Vents on Etna present a hazard to a localised area. The frequently active vents in the summit area are a particular hazard and as noted in the last section access to the summit area is now carefully controlled. Restriction to the summit area also means that fewer people are in an area where gases, importantly CO_2, can accumulate in depressions. The effect of the plume on vegetation has been noted (Nottcut and Davis, 1989) and in places levels of fluoride in vegetation may be enough to affect grazing animals.

Figure 8.24: Spectators watch an advancing lava flow from less than 100 metres.

As noted in the previous section, tourists are largely barred from the summit area. Groups of scientists, however, are frequent visitors to this area. Their knowledge of volcanism, it could be argued, allows them to be in this area safely. But there is also evidence that familiarity with a hazard may also induce overconfidence and underestimation of potential hazards amongst those who are frequently exposed to hazards. The number of volcanologists killed (14 since 1979 - Fisher *et al.,* 1997) in the last 18 years bears testimony to the dangers they are willing to place themselves under in order to extract data or, possibly act as they believe volcanologists should act. The deaths at Galeras volcano were associated with a conference visit to the volcano rather than an ongoing volcanic crisis that might justify higher than necessary risks being taken (Kerr, 1993). There is an ongoing debate about when dangerous sampling of volcanic products can and cannot be justified. The inadequacy of remote sensing techniques at present is used by some as evidence for the need to continue sampling in areas of high risk. It is also true that various groups, that face a higher than average level of danger, often develop a strong intra-group culture. Doing something dangerous is perceived as lifting them above the ordinary mass of people, allowing them feelings of superiority and elitism (Lopes, 1987). In a factory situation different groups, identifiable by their type of work, will have particular relationship with the work activity and risk (Bellaby, 1990). It seems likely that a similar division of a workforce may affect groups of volcanologists as with any other group of people working in an environment that at times involves high risk. With the teams of volcanologists working as part of the Montserrat Volcanic Observatory there appeared to be something of a dichotomy between those that favoured a cautious approach to the monitoring of volcano and those that had a more risk taking attitude (Aspinall, 1996). The author was part of a large group of scientists that had visited the summit of Etna shortly after a period of activity which had littered the area with pyroclastic fall. Only two members of the group were wearing helmets (figure 8.25). Significantly the visit was not carried out in order to sample or record information for an ongoing research project but was instead a workshop excursion. There must be some doubt that, despite safety recommendations being made (eg. - Aramaki *et al.*, 1994), scientists will necessarily behave in a safer way.

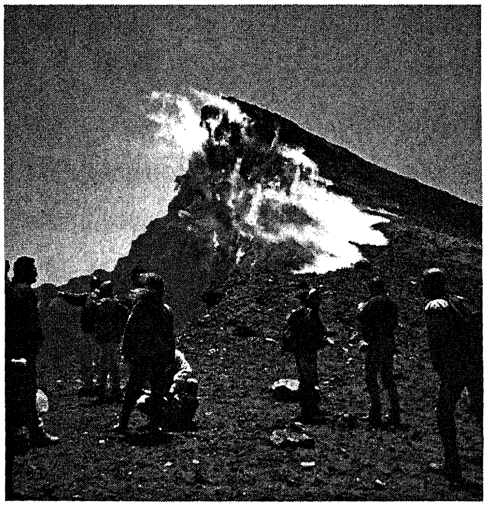


Figure 8.25: Group of scientists at the summit of Etna, only two were wearing helmets.

The relative safety with which a lava flow can be viewed may entice individuals into potentially dangerous situations. The slow movement of lava flows in comparison to other volcanic products, however, also allows the residents of towns in its potential course to remove significant items from their homes and places of business.

A threat to life might exist if a lava flow were to reach the city of Catania before it had been properly evacuated. Although it is likely that there would be at least a number of days between the identification of a threatening lava flow and it reaching the outskirts of the city, the delay might actually make the organisation of an evacuation more difficult. Unless it was rigorously enforced people might not leave their homes or might return to them. Decision would have to be made about whether people could take things from their homes and if so how much. A poorly organised evacuation could leave people trapped in the city or might lead to confrontations and violence. If decisions about the process of evacuation were not taken ahead of the crisis period it seems likely the situation could degenerate into chaos.

8.4.3 Physiological and psychological resilience

Physiological resilience is not so important an aspect of an individual's susceptibility on Etna as it is on other volcanoes. The slow onset of the critical period of the eruption, means that the physiological stress of the event is greatly reduced. Evacuations are usually possible and often take place within the fairly large window of time afforded by the eruption, though this is not always the case. Eruptions like that of 1928 and 1981 may only provide warnings of a matter of hours. This means that those with low physiological resilience (eg. the young, old, ill) are not subjected to very extreme environments but to slightly more severe environments than that which they have been used to. During a typical eruption on Etna a town is initially threatened by a lava flow for period that can last a day or so to months. The threat will then either recede as it becomes apparent that the flow will not reach the town or will force an evacuation. The evacuation will probably be fairly orderly, and therefore not physiologically stressful. This is because the time between the order to evacuate a town and the lava flow reaching it, is usually sufficient for people to leave in an ordered manner. There is also generally sufficient time, between the first indicators that a town may be threaten by an eruption and the order to evacuate, to effectively plan the evacuation. The advancing lava also provides a very tangible sign and the hazard can be readily appreciated by the community.

Although the evacuation may be relatively free of physiological stress *per se*, the whole 'disaster' episode may have an indirect physiological affect on the individual. The physiological reaction of the body to states of uncertainty, worry and depression, can be profound. Research suggests that psychological states play an important role in illness (Totman, 1990). They mediate the relationship between environmental factors and health outcomes. The psychological affect of anticipating and then seeing your home and community destroyed can be profound (Brown and Perkins, 1992). Psychological attachment to place will be an important factor in the physiological resilience of the individual on Etna. It is likely that residents who have lived all their lives and possibly have had generations of their families living in a particular location are going to have a stronger feeling of place attachment than others. The nature of their attachment to place is not purely an interaction with the physical environment *per se*, but more importantly with the role it plays in the social functioning of the village or town.

In this regard the relocation of the residents of a town after it has been destroyed, can be important in reducing the negative psychological effect. By carefully planning the resettlement of people, not only can the negative psychological impact of the disaster be reduced but also a potentially flourishing settlement created.

The extent to which the towns on the flanks of Etna are populated by long-term residents varies. The towns around Catania and along Etna's seaboard, have seen considerable in-migration in the last 50 years. In some cases the population of the towns have doubled in a decade due to new houses being built and immigration into the towns. In contrast during the last 50 years the towns not in these two areas have suffered a constant out-migration. This is particularly true of the towns on the NW flank of the volcano. It seems likely that new residents, though often economically attached to the town of their residence and in particular their property, will not feel the same psychological attachment. There will therefore be a difference in how people will react to an event with which a town is destroyed.

8.4.4 Livelihood and resource resilience

Individuals and groups will be differentially affected by a destructive eruption in terms of their source of livelihood and resources. The nature of the productive units that the individual or group relies upon, the resources that they can draw upon, the spatial distribution of these productive units and resources will influence the extent to which they are affected by an eruption and ease with which they can recover from it.

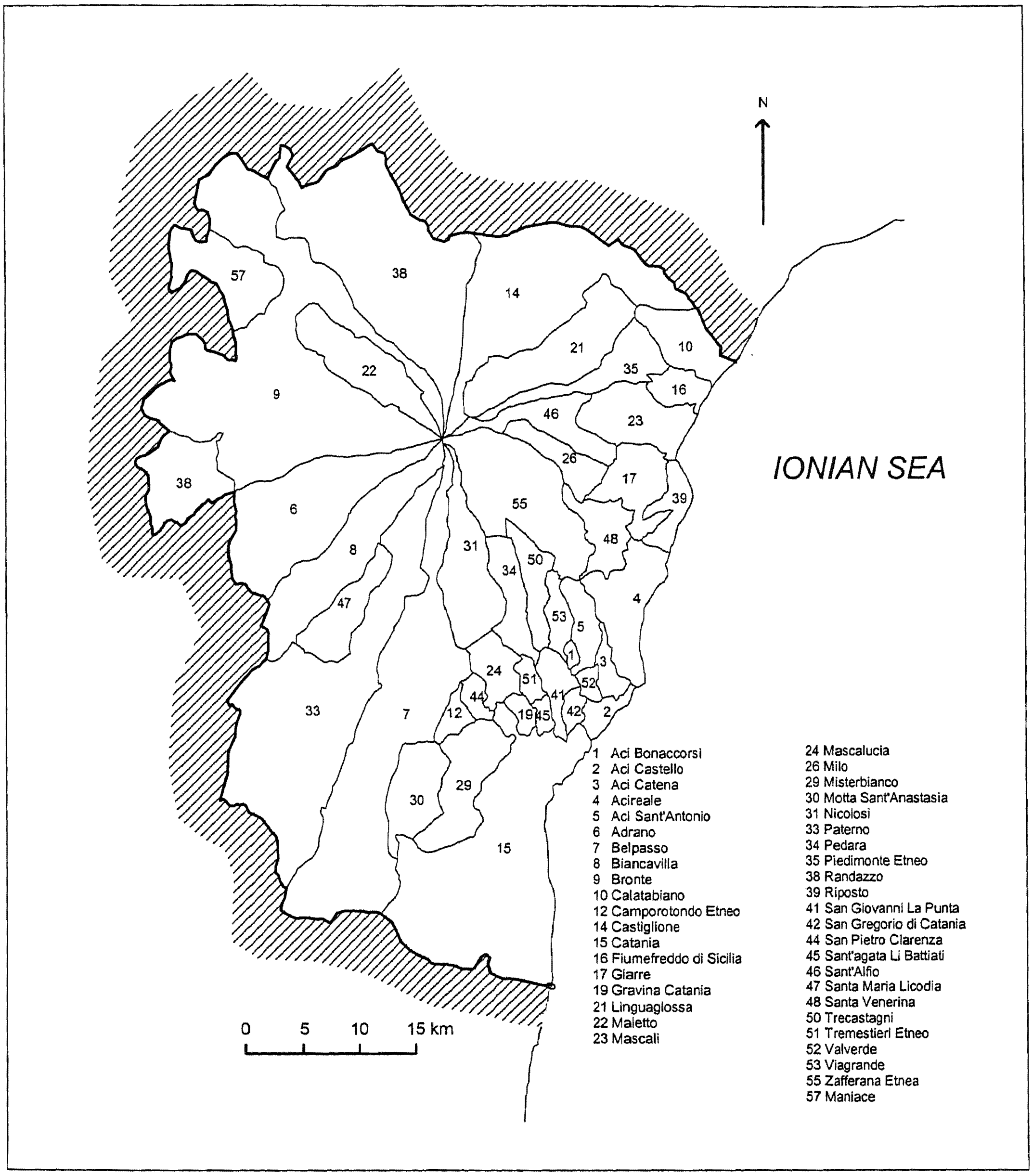


Figure 8.26: Map of comuni on the flanks of Etna.

Analysis of census data show that the forms of production that people living on the slopes of Etna rely upon has, in the last forty years, changed considerably. In 1951, 41% of the working population of comuni (figure 8.26), within the limits of the maximum extent of lavas, were involved in agricultural production. By 1961 this figure has fallen to 35% and in 1991 it was only 14 % (figure 8.27). The change is towards greater employment in the service sector. This change had not been uniform across the Etna area. The change to service employment has tended to be more apparent on the southern and eastern flanks of the volcano. This is principally due to the existence of the administrative and economic centre of Catania and the industrial zone at Belpasso-Misterbianco in the south.

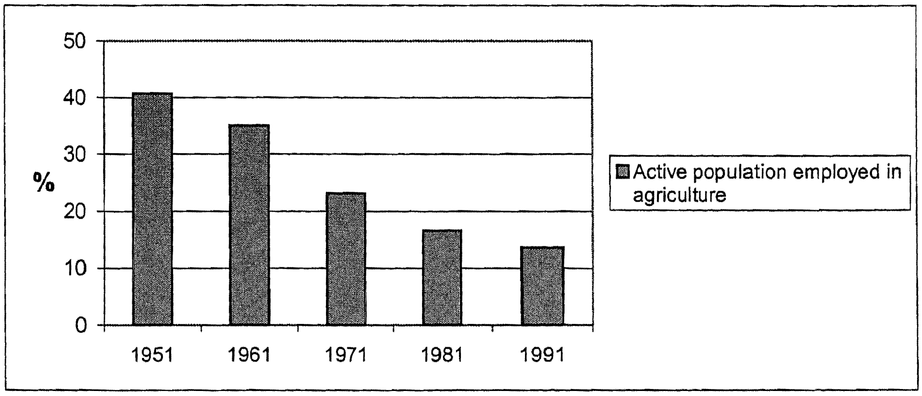


Figure 8.27: Proportion of the economically active population in Etnean comuni who work within the agricultural sector from 1951 to 1991.

Sicilian agricultural workers and land owners have traditionally lived away from their land in central towns (Semple 1932, Unger 1953, King and Strachan, 1980). There is some debate about the exact reason for this practice but certainly the protection offered by a town against the banditry has been an important factor (King and Strachan 1980). This means that a lava flow is unlikely to destroy both the lands of a farmer and their home town, which would include their home and other material resources. This benefit is slightly undermined by the character of lava flows at different altitudes. The variation and mean widths of lava flows tend to be greater at lower altitudes (Lopes and Guest, 1982). Most towns, as discussed above, tend to be at lower altitudes. The probability that a lava will reach a particular area, however, also decreases with altitude. There is, therefore, the extreme possibility that a wide[6] lava flow will affect a low altitude area but it is more likely that the area will not be affected or that the width will be close to the mean (~1.5 km). The benefit of having land distant from homes was apparent during the destruction of Mascali, where, as recounted above, some farmers were able to stay in farm buildings in the aftermath of the disaster. Another spatial characteristic of farming in Sicily is the non-contiguous nature of land holdings (Chester *et al.*, 1985). This means that a farmer is less likely to loose all their land to a lava flow. This was apparent during the 1971 eruption, where most of the

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[6] Maximum width below 500 m has been estimated from a sample of 47 lava flow fields as ~4 km (Lopes and Guest, 1982).

farmers who lost vineyards and other areas of agricultural land still had areas that remained undamaged because the plots of land were separate (Clapperton, 1972).

Many of those employed in agriculture work as tenant farmers or farm labourers (King, 1973). Their situation is less stable than that of land owners. The loss of land and the financial hardship of their landlord or employer might mean that they lose their jobs or are moved off the land but, conversely, this group might be able to cope with this situation better than others. They are traditionally a group that has seen the greatest level of immigration or labour migration. It is possible that the flexibility they have, in not being tied to damaged property or partially destroyed land and their knowledge of labour markets elsewhere, might allow them to exploit the situation. On the other hand if they are not able to exploit the labour market they may be left without any means of support and have to rely on the state or others. It is also true certainly in the past and still to some extent in the 1990's that the labourers working as either 'braccianti' or day labourers or under the 'gabella' system as tenant farmers were and are extremely poor. With very low levels of financial resources, their ability to recover after a disaster may be very limited.

The effect of an eruption on those employed in the service and industrial sector would vary depending on the location of jobs. Some service sectors jobs are located in all the towns on the flanks of Etna, others are found in the larger towns and cities such as Catania, Acireale and Giarre-Riposto. Manufacturing jobs are located in the industrial zones of Belpasso-Misterbianco and Catania. Many of those employed in manufacturing and service jobs commute between their home town and work. This means that in the case of a lava flow these individuals would be less likely to loose both their jobs and their homes. The concentration of industrial and administrative sites in a few economic centres does mean that a single flow could have a devastating affect on both a great number of peoples livelihoods and also the regional economy of Sicily. Of these economic important areas the Catania industrial zone is south of the city and thus beyond the maximum extent of lavas and so is highly unlikely to be affected by a lava flow. It might be affected by tephra fall but this would only cause fairly superficial damage and, therefore, would probably not be particularly serious. However Catania, Acireale and Giarre-Riposto are all within the maximum extent of lava flows as is the currently expanding Belpasso-Misterbianco industrial area. The destruction of one of these economic centres would not only be devastating for those who lived in them but also for a large number of commuting workers.

Very few households in Sicily hold insurance against any type of damage whether it be earthquake, fire or volcanic (Chester *et al.*, 1985). This was confirmed in the survey of householders, carried out by the author and reported in more detail later in this chapter. In Trecastagni where only 3% said that they had insurance against fire, none thought they had insurance against earthquake damage although 9% said they were not sure. In a similar vein 89% of respondents said that neither they nor anyone they knew had insurance against damage done by volcanic eruptions. The other 11% responded that they did not know whether any friends or family had any insurance against volcanic activity. No one said that they knew someone who did have insurance against volcanic damage. The destruction of a majority of a person or groups resources and source of livelihood would represent unrecoverable loss.

Resources can be authoritative as well as material. Authoritative resources are the means by which an individual can dominate others. Often the two types of resources are closely allied. In Sicily there is a long tradition of patronage (King, 1973; Schneider and Schneider, 1983) (as will be discussed in section 8.5.2). Individuals and groups have widely used the power they have over the distribution of jobs and contracts to generate support and favours. The position an individual has, in reference to these power structures, will be very important in determining recovery after a volcanic eruption. After the 1968 Belice earthquake towns that had not been hit very heavily enjoyed a stream of tax favours, public works allocations and subsidies for years after the event while people from heavily hit towns were still living in barracks (Schneider and Schneider, 1983).

Spatially the northern half of the Etna region is poorer than the south. Mapping unemployment, as a general indicator of poverty, illustrates this (figure 8.28). Apart from pockets of higher unemployment in the south, mainly associated with agriculturally dominated comuni, the north appears to generally have a much higher rate of unemployment than the south. The ability of northern comuni to recover from a disaster might be less than that of the south, if victims were expected to use their own financial and other material resources within the recovery process. On the other hand the south of the region is more densely populated which means that a flow within this region will have an affect on a greater number of people.

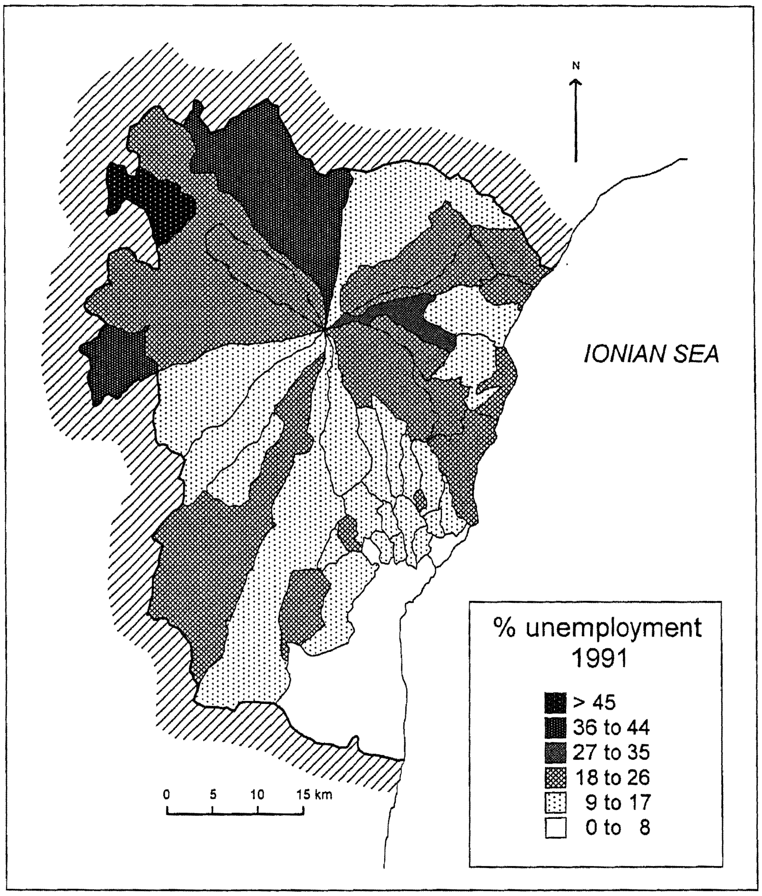


Figure 8.28: Unemployment amongst economically active population.

Within many of the towns, and especially in the city of Catania, there is a wide variation in the economic prosperity of inhabitants (Sanfilippo, 1991). This may lead to a stratification of the resident population in a disaster situation as some will find recovery easier than others. Within Catania there is a large and growing immigrant population. In 1988 it was estimated to be around 5,000 (Maggio, 1991). It was estimated that of these, possibly half were illegal immigrants. If these individuals were to lose their possessions it is likely that the government would not compensate them. All the buildings lost in the 1991-3 eruption had been illegally built and as a result the owners of these buildings received no compensation for their loss (figure 8.29).

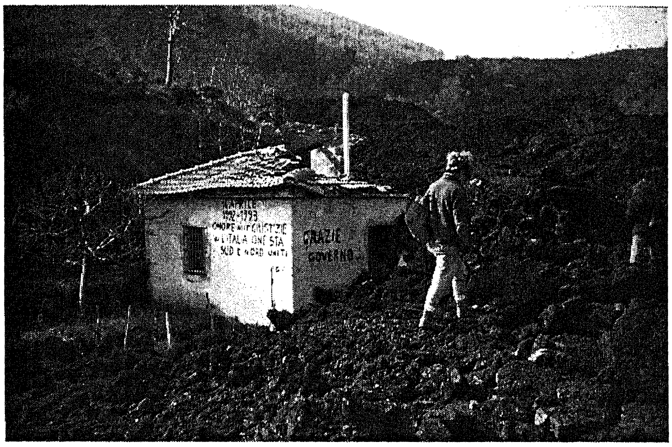


Figure 8.29: An illegally built house destroyed in the 1991-93 eruption.

8.4.5 Emergency organisation response

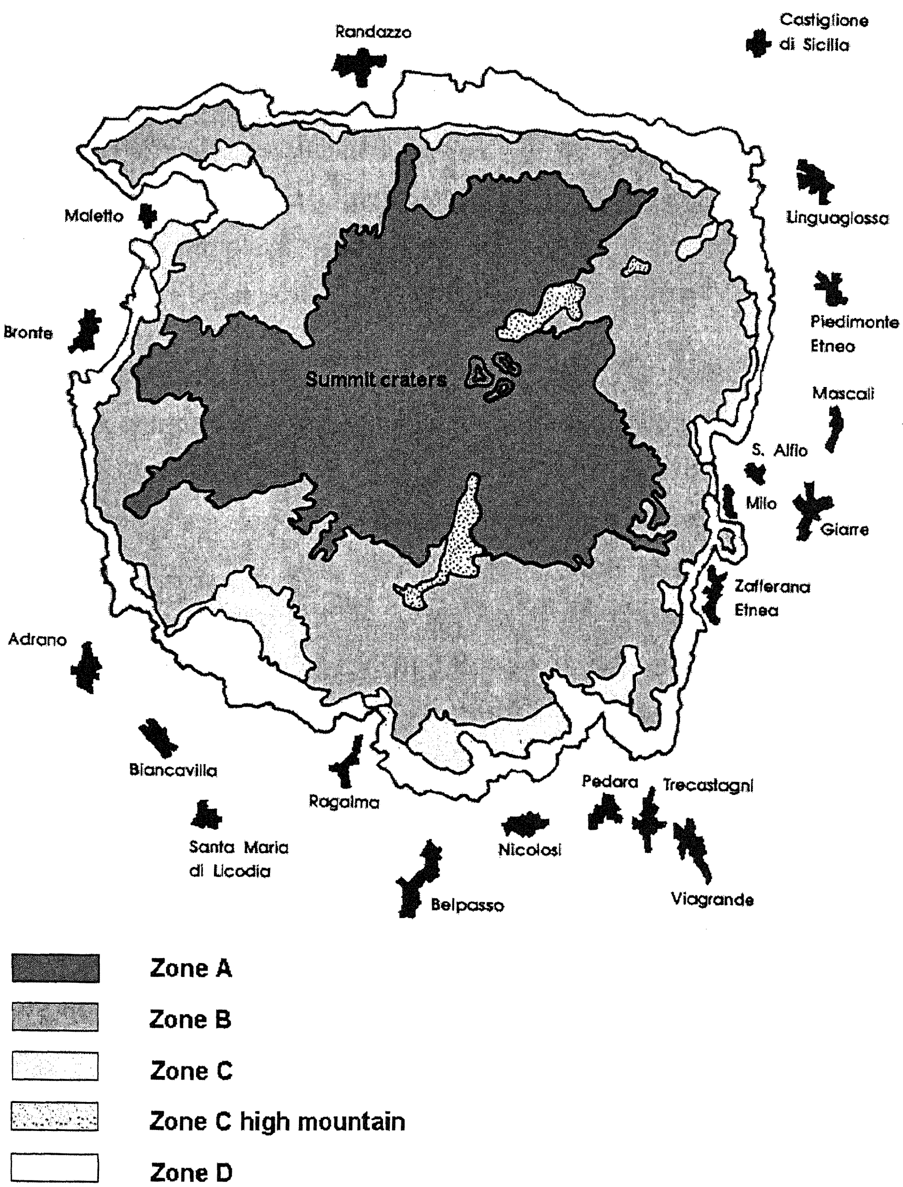
Organisational response to a volcanic eruption in Italy had been fairly haphazard before 1979. This typically involved a loose grouping of interested groups coming together around the time of an eruption including the civil defence, police, army, local administration, national government and an assortment of scientists. The response was usually reactive, with assessment and planning taking place during the eruption itself but, because of the slow movement of lava, this did not create an evacuation problem. Even during the 1928 eruption, which had a relatively rapid onset for Etna, the organisational response allowed a successful evacuation of the town. But the system as it stood did not allow the integration of volcanic monitoring with emergency planning and more generally the formation of long-term plans for the area. This situation changed after the 1979 summit deaths (Chester *et al.*, 1985). A scientific and consultative committee (Comitato di consulenza Technico-Scentifico per il vulcano Etna) was made up of members of the University of Catania and the Institute of Volcanology (Catania) to advise on volcanic and seismic hazards. The Italian disaster management model, of putting a Minister of Civil Defence in charge of co-ordinating the work of the various bodies involved in the emergency, was used during the 1983 eruption. It was during this eruption that the first serious attempts at diverting a lava flow since 1669 were attempted. This was a major undertaking and involved a partially successful diversion of a lava flow, though the flow might not have reach any towns even if it had been allowed to flow on unimpeded. The relationship between a minister of civil defence and the scientific community was permanently cemented with the formation of the CNR-Gruppo Nazionale per La Vulcanologia a body which co-ordinates monitoring activities on all Italy's volcanoes.

Etna is now carefully monitored through the use of seismic stations, tilt meters, the analysis of gases emanating from the volcano, permanent video cameras and remote sensing techniques. In July 1989, for example, a significant increase in seismic-volcanic activity meant that scientists and civil defence were expecting the eruption that came in September (CNR-GNV, 1990). Unfortunately although most eruptions are preceded by seismic swarms not all seismic swarms are followed by eruptions. This makes the task of interpreting readings from monitoring equipment difficult. The flank eruptions that have taken place since 1983 have been characterised by intense monitoring and, in the case of the 1991-93 crisis, attempts at diverting lava flows (CNR-GNV, 1992). With both the 1989 and 1991-93 eruption there were no loss of life and only minimal loss of property, but, on the other hand, loss of life is not typical of eruptions on Etna and the lava flows from both these eruptions emanated from high on the volcano and were, therefore, not the threat to settlements that lava flows emanating from fissures lower on the volcano are. The 1989 eruption saw the propagation of a SE fissure from the SE crater down to 1500m. The civil defence response was to prepare villages that were identified as under threat. Soldiers were left to monitor the lower end of the fissure which in the end did not produce a lava flow (CNR-GNV, 1990).

The 1991-3 crisis led to an active intervention against a lava flow that was threatening the town of Zafferana (figure 8.2). This included the building of earthen embankments and the use of explosives near the top of the flow in order to create a secondary flow. The earth embankment halted the flow for some time and a secondary flow was generated which coincided with the halting of the flow front that was approaching Zafferana. Critics have pointed out that the flow was fairly extended and might have stopped anyway before reaching the town (Personal communication - R. Romano). Environmentalists complained that the sights at which the interventions took place were an ugly scar within the Mt. Etna Regional Park and that areas of beech forest had been unnecessarily destroyed (Barberi and Villari, 1994). In contrast some of the scientists involved in the interventions complained that environmental organisations had dangerously delayed operations by pressurising the local authorities who had initially, as a result, refused permission to use heavy machinery in the environmentally sensitive area of the Valle del Bove. Recent research suggests that the flow might have continued 3 km beyond its actual end point, overrunning Zafferana possibly, pushing the debate in favour of the interventionists (Calvari and Pinkerton, 1999).

The 1983 and 1991-93 eruptions involved relatively slow moving lava flows that emanated from points away from settlements and so were ideally suitable for the type of intervention that was carried out. The 1991-3 lava flow stayed generally within the Valle de Bove, an uninhabited area, that could contain the secondary lava flows created after the intervention and so gave the scientists and civil defence time to carry out their engineering schemes. Future lava flows will not all be suitable for this type of intervention. The relatively fast flowing lava flow that was experienced during the 1928 eruption could not easily have been dammed nor diverted, simply due the speed with which the lava flow was advancing.

The absence of permanent barriers for protecting villages and a greater regulation of building in high risk areas has been noted by some critics of the present civil defence regime. Permanent barriers, it has been argued, would be useful in protecting against the fast moving flows discussed above (Personal communication - R. Romano). But, as was first noticed by White (1945), permanent improvements in protection lead to an increase in risky behaviour. Flood plain protection led to greater amounts of flood plain settlement and while the typical yearly high waters were contained by the improved protection, the '7 year flood' over stretched the defences and destroyed the property of the expanded population. In all flood losses tended to increase as a result of protection measures. There is no reason to believe a similar scenario would not occur on Etna. The cost of building barriers to protect all the towns with a medium hazard would be great and other design problems, such as how to integrate the drainage system on the volcano with such barriers, would also have to be overcome.



Zone A: Nature reserve zone where the environment must remain intact. Activities allowed in this zone, under strict regulations, include animal gazing, tree felling, scientific research, excursions, down hill and cross country skiing, mushroom picking, vehicles only allowed on existing tracks.
Zone B: Zone of general reserve, where agriculture, forestry and animal grazing are allowed only when they are strictly necessary for safe guarding the natural and scenic environment.
Zone C: Protected zone, where transformation of buildings and land is only allowed when it aims at improving the amenities of the park.
Zone D: Controlled zone, where all activities are allowed under limited supervision.

Figure 8.30: Different zones of the Etna National Park - (derived from Russo, 1992, p. 46).

The foundation of the Etna Regional Park has led to some planning restrictions being imposed on new building at higher altitudes on the volcano (figure 8.30). The principal aim of the park has been the protection of the natural environment but, because much of the 'natural' undeveloped land is near the summit of the volcano, it also delineates the borders of the area of highest lava invasion probability. The area of restricted building does not, however, cover any area around the already established towns. It is questionable whether building regulations would have a significant affect in a society within which illegal building is commonplace. Indeed the only home to be destroyed in the 1991-3 eruption was an illegal building on the edge of the town of Zafferana (figure 8.29).

Since 1669 a lava flow has not entered Catania. The effect of the approach of a flow and its entrance into the city would be quite different from any other volcanic crisis of the twentieth century. The lower slopes of Etna above the city are densely populated and so a serious problem would exist before the lava even entered Catania. Although the emergency organisations and city authorities would inevitably have some time to organise their response, it would still be a considerable task to control and implement an evacuation of a city of Catania's size. The problem would probably result from the amount of time available for people to remove belongings from their houses. Catania is a crime ridden city (Sanfilippo, 1991) and whether or not an upsurge of crime took place within the emptying city it seems certain that people would perceive this threat and might therefore be reticent about leaving their homes. Policing the evacuated city would be extremely difficult and conflicts might develop. Looting and crime are often absent from disasters (Wenger, *et al.* 1975). Where looting and violence does occur it is generally the result of the underlying pressures in society and the disaster only acts as a catalyst. Catania, with its problems of urban malaise, might well be a case where a potentially chaotic situation could develop into a one of conflict.

In summary, though the emergency organisation on Etna has developed considerably in the last twenty years, there is some doubt over whether they will be able to prevent the destruction of a town in the near future. The organisational system seems capable of preventing any lost of life, producing the maximum warning time from the first indications that an eruption is taking place and acting within favourable conditions to influence the course of lava flows. Limited by modern technology and knowledge, it is unlikely that anything could be done to stop a very extensive or fast flowing lava flow. There is scope for restricting new development or even trying to gradually reduce activity in areas that are deemed to be highly hazardous. This has been started in the area of the national park but is undermined there by the independent spirit of the Sicilians and the ineffective policing of illegal building.

8.4.6 Reaction of family, communities, social organisations and society in general

As was illustrated in the case study of Mascali, the resilience of a community combined with effective outside intervention can allow the successful reconstruction of a town on Etna with few scars to show from its experience. Indeed the town can flourish as a result. The political situation today is very different to the one that existed in 1928. While the Fascist regime had strong central control over a party structure at a local level, the modern political system is more fragmented with a semi-autonomous Sicily and a local administration that has much power. It is also a system that is prone to corruption and reflects vested interests and clientism. The increased size of many Etnean towns also means that rebuilding will a greater task than in 1928.

The destruction of one of the towns on the slopes of Etna would probably not have a great effect on the economy of the island in general. It is likely that the money that would inevitably flow into the area afterwards would have a significant affect on the economy of surrounding towns as the rebuilding of settlements in or near their original site is typical on Etna. Some towns however are economically more important than others. The Belpasso-Piano Tavola industrial area, for example, employs a considerable number of people and with the industrial development along the Adrano-Catania Superstrada is economically significant for the whole island. When the 1928 lava flow cut the east coast rail line and road, there was major disruption of the commercial activities of Catania and Syracuse (figure 8.31). It is likely that the effect would be similar today.

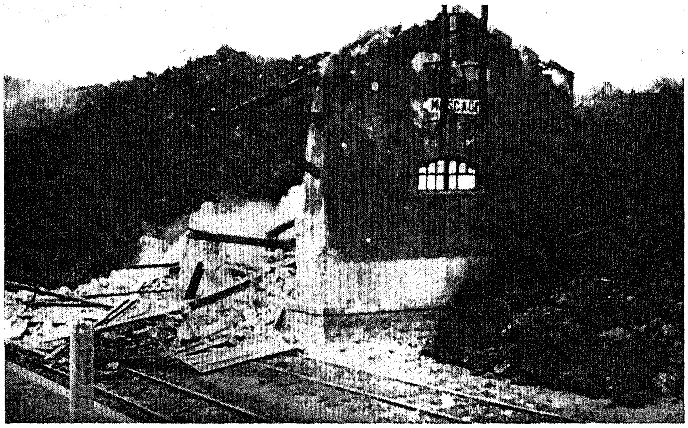


Figure 8.31: The main Messina-Catania rail line is cut in 1928. (Finocchiaro Fotografi)

The destruction of part of Catania could have a more significant effect on the economy of the eastern half of the island and indeed on Sicily as a whole. Catania is an important port while also providing commercial, legal, administrative, cultural and educational services to the island. As has been mentioned above, the siting of many of Catania's new industries and airport to the south of the city, outside the area affected by lavas, has reduced the potential impact of a lava flow on the island. The cost of the reconstruction process would still be huge even if only the central and northern parts of the city were partially or totally destroyed. The weight of this bill would fall not only on Sicily but also on the Italian state and probably the European Union as a whole. The reverse side of the 'disaster' scenario is that the destruction of Catania, though in the short term causing significant problems for Sicily, would lead in the longer term to a influx of capital and give considerable boost to the construction industry. The extent to which this would benefit the island's economy would depend on there being an available labour force and organisations able to respond to this demand. If this was not available then companies from the mainland might exploit the situation, siphoning the capital away from the island.

8.5 CHANGE IN VULNERABILITY

The last section concluded that the inhabitants of Etna were susceptible to volcanic activity principally in terms of their: location decision making, their livelihood and resource resilience and the way society on Etna would be affected by an eruption. These three susceptibilities are the result of a number of different processes acting within society and across time and space. All three susceptibilities, though, are related to two general factors. These are:

- The evolution of the structure and social systems of the region
- Individual and collective constructions of the Etnean environment

These elements link together as place, the geographically located nature of social structure, systems and institutions and the situated character of individual representations and behaviour. Because a volcano's location does not alter, place is very important in defining volcanic vulnerability.

8.5.1 The evolution of the economic and social system of the region

The particular human landscape of Etna has its roots in regional history. Though individuals are largely free to act as they want, the situation they act within is heavily influenced by this given history as is the way they perceive it. The regional history provides institutionalised practices, social systems, social representations, allocation of physical and authoritative resources and a particular landscape. It is within this preordained context that the individual acts.

The first settlement on Sicily probably took place before 20,000 BC (King, 1973). The earliest evidence of settlements date from the Upper Palaeolithic and occurred along the northern, western and south-eastern coasts of the island. At around 4,000 BC Neolithic culture arrived from the eastern Mediterranean. These settlers were farmers, breeding animals and cultivating the land. On the Eolian islands, off the north of the main island, they traded in obsidian which was plentiful in this region. At around 3000 BC metal working was introduced to the island first with the copper age and then in 2000 BC the bronze age. The two main bronze age sites on Sicily were at Castelluccio (between Ragusa and Noto) in the south east of the island and Thapsos (between Siracusa and Augusta) in the east of the island. At around 1250 BC the island was invaded by the Sicals, from the east, and Ausoianans, from the west. The main settlements were now situated inland to lessen the chances of attack which tended to come from the sea. There were three main 'tribes' in Sicily at this time, the: Sicals, Sicans and Elymians. The Sicans, it has been suggested, lived on the slopes of Etna, near to the present day town of Adrano, but were reportedly driven east by its eruptive activity (Sanfilippo, 1970; King, 1973; Chester *et al.,* 1985). This was a period when Etna was exhibiting a more explosive form of activity than that which is experienced at present. If this was the reason that the Sicans moved it would be the only recorded example of a large scale movement away from Etna as a result of volcanic activity. Certain factors may have made this movement more likely to have been done then and less likely for it to have been repeated after this period. The population on Sicily at this time was still mobile. Although the land was being cultivated, settlements were probably only semi-permanent and could be moved if a particular site was threatened. There was also plenty of land that had not been exploited. These factors may have influenced the exodus. These conditions would not exist again on Etna after this period, possibly explaining why another exodus from Etna has not happened.

The Greek settlement of the island began with the establishment of Naxos, on the east coast of Sicily, in 734 BC (King, 1973). Importantly, in terms of the settlement of the slopes of Etna, one of the two cities to be established in the ten years after Naxos was Katane (founded in 729 BC), situated on the present day site of Catania. During the period of Greek rule in Sicily, the towns developed into powerful city states. They were relatively independent, raising their own armies and being sometimes in conflict with each other. Catania was to become an important trading centre for the grapes and olives which the Greeks had introduced to the area (D'Agata, 1992). Once having been established, the site of Catania was to continue to flourish despite it suffering various catastrophic events during its history. King (1973) argues that part of the reason for Catania's settlement was the fertile volcanic soils in and around it. A water supply was guaranteed throughout the year because of its location next to the Simeto river and below the springs running off Etna. Its coastal situation would also have been important to a maritime trading culture and its position mid-way between Naxos and Siracusa would have avoided conflict with these cities. Once established, Catania flourished. The reasons for its growth have changed over time but its importance has been great enough for the town to have been rebuilt a number of times on its original location. It was partly destroyed by lava in 693 BC, 424/25 BC and 1669 AD. This is despite the fact that if it was located a few miles south it would be outside the limits of the lava flows from Etna. These lava flows had destroyed a considerable part of the city in 1669. The location of Catania was also to have considerable influence on the area surrounding it. Acting, in the following centuries, as an economic, administrative, educational and religious centre not only was the city itself to grow but so were the surrounding towns. This aspect will be explored in the next section.

Other smaller centres were established by the Greeks on the flanks of Etna, these included Adranion (Adrano) and Akis (Acireale) (Sanfilippo, 1970). These were agricultural towns, cultivating olives and vines that were brought to the island by the Greeks. These towns themselves were to expand over the centuries and were to become important secondary urban centres within the province. The introduction of the vine to Sicily was to be a very significant factor within the settlement of the flanks of Etna. The zone between 250m and 750m altitude were ideally suited to viticulture (Speranza, 1963) and the establishment of settlements that would allow farmers to exploit this zone took place in the following centuries. Importantly, this zone is generally one with a medium probability of being invaded by lava.

The island, in the following centuries, fell under the control of various empires and nations. The Roman conquest of the island began in 264 BC and was complete by 210 BC (King, 1973). Much of the island was subdivided into large estates - latifundia - with the aim of providing the Roman army with grain. These estates were worked by slaves and the poor conditions under which the slaves had to work led to two slave wars (135-132 BC and 104-101 BC). The tradition of large estates owned by absentee landlords which was started with Roman rule and was to be consolidated under subsequent rulers, and become a central feature of Sicilian economic and cultural life. Not only did it place a large amount of power in the hands of the local managers of the land but it also condemned the majority of the population to the insecure and powerless life of serfdom. The interaction of a distant government, with a local social system, produced the conditions within which a black market and clientelism thrived. The black market in this context was simply a local economy existing outside the control of a system of foreign, changeable, government. It was out of the these conditions that the importance of patrons grew and the policing of the social system by local codes of conduct.

During the fifth century AD the island was raided by Vandals and Ostrogoths and then was incorporated into the Byzantine empire. Sanfilippo (1970) argues that very little information about developments in the Etna region can be discerned from this period, it is not until the Arab (8^{th} Century) and Norman period (11^{th} Century) of rule that notable developments are apparent. During the period of Arab and Norman rule the Alcantara and Simeto rivers became important lines of communications (Sanfillipo, 1970). A number of important towns were established on the north-western flanks of the volcano. These included: Castiglione di Sicilia, Maniaci, Maletto and Randazzo. During the periods of Norman and Aragonese rule the regional parliament was situated in Randazzo on three occasions. The other flanks of Etna were still largely covered in woodland and had not been populated. The other major centre, apart from Catania, was Adrano around which lay rich agricultural land that was cleared of forest.

Norman rule was replaced by the Aragonese and then direct Spanish rule in 1409. Under both the Normans and Aragonese a feudal system of land ownership operated, with much of the profit from the land being siphoned away from the local economy. The period of Spanish rule did not bring prosperity to the island as the Spanish were looking towards the Americas and trade within the Mediterranean was declining. As a result Sicily declined under Spanish rule (Sanfilippo, 1970; King, 1973). However, for the Etna region Spanish rule was not all bad. When a large part of Catania was destroyed in 1669 by lava and in 1693 by an earthquake, the Spanish viceroy had a new urban plan drawn up by the Palermo Architect Vaccarini in 1700. The new city's design was grand and placed Catania in a good position to take an increasingly important commercial role within the island's economy.

The period of Bourbon rule from Naples began in the middle of the eighteenth century. It continued the stagnation of the Sicilian economy and saw a number of revolts against rule from Naples that culminated in Garibaldi's landing at Marsala in 1860 and the eventual unification of Italy. Between 1806 and 1815 there was short period of British rule on the island during which a reform of land ownership and the government of the island was attempted. This was only short lived and the island subsequently returned to Bourbon rule from Naples.

Unification brought new, wider and heavier taxation to Sicily, as the new state sought to establish itself and organise its civil service, navy and army (D'Agata, 1992). The new regime did, however, institute a number of large civil projects that were to have an important impact on the Etna region. This included the building the Messina-Catania railway line (1866), its extension to Syracuse (1869), the Vittorio Emanuele II hospital in Catania (1880) and the *Circumetnea* railway (1895) which linked most of the large towns around Etna. Combined with an extensive programme of line construction over the rest of the island, many of the major towns in the Etna region were linked by rail to major cities in Sicily. This helped to increase the economic significance of these towns, and especially Catania, lying as it did at a number of important routes north, south and west.

The fascist regime, that came to power in the 1920's had both a direct and an indirect impact on the region. Mussolini's strong desire to strengthen the manufacturing industrial sector of the Italian economy led to preferential investment in the north of the country (Finlay *et al.*, 1986) and on the whole the economy in Sicily declined during the period of Fascist rule. Indirectly, it was part of the process that was to leave the Christian Democratic Party as the main political force in Italy after the war (Williams, 1984). The Fascist party did this by colluding with other centre right parties and therefore effectively discrediting them after its fall leaving the way free for the Christian Democrats to dominate the political process for the following fifty years.

The economic and social system is a product of history. The transfer of resources is a central factor in this relationship. Importantly power stems from the ownership of resources whether they be authoritative or material (Giddens, 1979, 1984). The way resources are contained within a society has an important influence on the nature of that society. In Sicily the historic situation with a majority of the resources lying in the hands of a few landowners and the middle class, through whom the landed class exploited the land and the peasant majority, was a social system that showed considerable resistance to change. The way in which land, as the main material resource of the time, was controlled, was central to the historic social system. Typically absentee landlords placing their land under the control of the gabelloto or middle-person who having a monopoly on production wielded enormous power (King, 1973). It was only in the twentieth century that, through the availability of other means of making a livelihood, that the power of the landlord was diminished. This resulted principally from the labour migrations of the period. The landless, and to a great extent resource-less, workers were able to sell their labour overseas, so breaking the monopoly of the landlord (Schneider and Schneider, 1983). They returned with or sent back to their families foreign currency receipts that allowed the purchase of land, property and businesses. It also exposed them to different cultures and societies and so empowering them with knowledge and skills. Various attempts during the century to reform land ownership, though in its prescribed objectives generally failing, did have its affect on Sicilian society. A transfer of power from the landed class to more diffused political and economic groups resulted. The patronage of the gabelloto was replaced by the patronage of the administrator and politician. With post war efforts to stimulate and strengthen the southern economy through programmes such as the *Cassa per il Mezzogiorno* and encouragement of the siting of large scale industrial enterprises in the south, enormous economic power sat with bureaucrats and other decision makers. This was also combined with the Christian Democrat's power base lying in the south. It has been argued that they maintained this through patronage, especially through the giving of administrative jobs (Schneider and Schneider, 1983). Wade (1980) argues that it was a synthesis between the interests of northern Italian industrialists and the Italian political structure that has resulted in the failure of the growth of the industrial sector in Sicily. The relationship between political parties and political structure was complex, varying between places. While the political parties were heavily influenced by northern industrialists in Rome, local party officials were more interested in maintaining their power base in Sicily. Thus officials were able to manipulate the siting and construction of industrial projects through lobbying individual ministers in a way that benefited their own interests. The result was poorly sited, often unfinished and ultimately unsuccessful industrial plants. In Catania power, from the 1960's onward, was wielded by the Christian Democrat Mayor Nino Drago (Vulliamy, 1993). His power lay in the relationship between three main interest groups the political class, Mafia and main Catanese businessmen. Under his rule patronage and corruption flourished (Vulliamy, 1993). The ranks of municipal workers were swelled with party supporters, the contracts for large scale developments were awarded to the favoured and many major city projects were left unfinished. Only in the 1990's, after the nation wide onslaught on corruption, did the Christian Democrats lose power in Catania and the old system of power was shaken.

Connections are, as a result, significant in Sicily because they will determine access to resources. The family is an especially important institution in Sicily. The family you were born into has a strong affect on aspects such as the type of job you will be able to get, where you will live and who you will marry. It should be emphasised that, though the family is important in Sicilian life, it is not the cause of southern 'backwardness' or underdevelopment. *Amoral familism,* or the pursuit of the family good to the exclusion of a civic consciousness, was identified as a necessary mechanism for distributing resources and power in a society dominated by scarcity (Banfield, 1958). It was a response to underdevelopment rather than the cause. Some even argue that the view that the Sicilian lifestyle as innately conservative, was probably exaggerated in reference to the past and is certainly questionable today. It is argued for example that Sicilian woman have wielded considerable power through their contractual and moral power in the family and because of the protection of their dowry and its direct inheritance by her children within the family (Gribaudi, 1996). Conservative family values can be found throughout Italy, it is only because the issue of the conservative family was caught up in the ongoing north-south dialogue that it came to be a stereotype for the south. Today, as with northern Italy, exposure to different lifestyles through the media, especially television, greater opportunities to travel and an expanded education system has meant that the apparent conservative Sicilian lifestyle is now fast disappearing (Vessels, 1995).

The migrations that have taken place in the late 19th Century and 20th Century have not only changed the nature of power within Sicilian society but have also had an important impact on the nature of settlements on Etna. In the 20th century the development of settlements within the Etna region has been strongly linked to in and out migration within the region. Taking a traditional migration metaphor, the area has been affected by 'push' and 'pull' factors related to the changing social and economic nature of the region. This has led to 'out' migration from certain areas and 'in' migration to others. These movements have been complex, including international migration, return flows and interregional movement.

Since the 1950's there has been a fundamental change in the nature of the settlement pattern of the region. Before 1950 the population was based in agro-towns whose location was strongly linked to agriculture and the environment. This was true of the Etna region although in the south settlements have developed in relation to the commercial centre of Catania (Chester *et al.*, 1985). Agro-towns are settlements where land workers live centrally and commute daily to tend their fields (King and Strachan, 1980). Their positions on hilltop sites has been linked to spring sites (Semple, 1932), an avoidance of the malarial lowlands (Unger, 1953), to maximise the use of lowlands for agriculture and the need for defence (King and Strachan, 1980). In the Etna volcanic region, their position can certainly be linked to spring lines. The towns of the 'fertile crescent' on the eastern and southern flanks of the volcano are positioned on sites where springs emerge from the old Trifoglietto volcano (Clapperton, 1972). The extent to which the volcanic environment favours different types of agriculture has also affected the historical location of the agro-towns. The eastern and southern flanks of the volcano have some of the highest rainfall figures in Sicily about 1000 mm on average a year (Speranza, 1963) and the soils of the old Trifoglietto volcano are highly fertile (Clapperton, 1972) both allowing an intensive form of agriculture. In contrast, the northern and western flanks of the volcano have favoured a more extensive form of agriculture (Ruggiero unpublished, Chester *et al.,* 1985); annual rainfall is between 500-600 mm (Speranza, 1963) and on average there is less land under 2000m compared to the southern and eastern slopes (Duncan *et al.*, 1981). Historically the agro-towns on Etna have been concentrated between 150 and 600m (Platania, 1932), the zone most suitable for intensive cultivation the northern and western flanks of the volcano with comparatively less land below 2000m are less intensively cultivated (Duncan *et al.*, 1981). The northern and western flanks of the volcano are relatively isolated from lines of communication and the commercial centre Catania and are therefore less attractive for development.

Areas of high altitude, greater than 1000 metres, are described in the literature as the 'regione boscosa' (wooded region) and above 1,750 metres as the 'regione deserta' (desert region) (Clapperton, 1978, Speranza, 1963, Poli *et al.*, 1981). Above 1000m is a wooded zone rising to barren scrub where much of the land is 'sterile' due to lava cover and generally only suitable for extensive agriculture such as sheep grazing. It is difficult to distinguish whether the absence of towns from this area is principally due to the high volcanic risk or to the lack of farming opportunity. The effect on the level of vulnerability is significant in that historically there was no settlement of this very high hazard area. This has changed in recent years with the growth of tourist facilities. Attempts to promote Sicily as a tourist destination have been unsuccessful and compared to its Mediterranean neighbours, it has a very low numbers of tourists (Di Bella, 1982). This is strongly related to the absence of a large scale package tourist sector. Etna is on the schedule of many of those tourists that do visit Sicily, and the tourist development in the summit area reflects this trade.

The decline of the 'mountain rural economy' in the latter part of this century has been an important factor in the changing settlement pattern on Etna (Ruggiero, unpublished). The 'intensification' of agricultural production has led to a fall in the number of agricultural jobs and the development of a difficult market for small scale farmers to compete in. This has meant that the towns of the west and north of the region have suffered economic decline and indeed the railway line between Alcantara and Randazzo has recently closed. It is only where the tertiary sector has grown, that the economy of these agro-towns has supported the population in employment (Ruggiero, unpublished). The growth of the ski industry in Linguaglossa has led to the creation of tertiary sector employment where other similar towns are in economic decline. The decline in the agricultural sector of the western and northern towns has encouraged out-migration in the last forty years. The attraction of work in Western Europe, Northern Italy and the Catania area has drawn many away from their home towns. Unlike previous migrations this century, though, many of the movements are temporary. It is common for the migrant not even to cancel his or her registration of residence in their home comuni.

Catania has acted as a growth pole to the south-east side of region (Banco di Sicilia, 1989). Since the 1950's urban malaise and high property costs within Catania have meant that many people have moved to dormitory settlements (Sanfilippo, 1991). This has combined with the growth of industrial and service jobs in and around Catania so that towns within commuting distance of Catania have rapidly developed over the last forty years. This has been both a result of Catanese moving out of the city and also from other Sicilians moving for jobs in and around Catania (Petino, 1961). The traditionally agriculturally based towns have become a focus for this development. New apartment blocks and modern villas have covered much of the traditionally agricultural land on the outskirts of the towns. Most of the housing stocks of these towns have doubled, often in under a decade. The demand for housing has led to the value of land rising dramatically and its use for agriculture production to decline (Sanfilippo, 1991). The growth of small industrial firms in the Belpasso-Piano Tavola area has made this area extremely attractive to in-migration (D'Agata, 1992).

The growth of second home ownership in the Etna region has had an important effect on the economy of the towns where this phenomena is common. The coastal area of the region and the 'mountain' towns on the eastern and south-eastern flanks of the volcano are popular with second home owners (figure 8.32). The effect of second home ownership on the local economies of agro-towns is mixed. Initially jobs in construction are a boost to the local economies. The effect of temporary residence on local services is damaging in the long term as is the sale of agricultural land on local employment (Di Bella, 1974; Di Blasi, 1983).

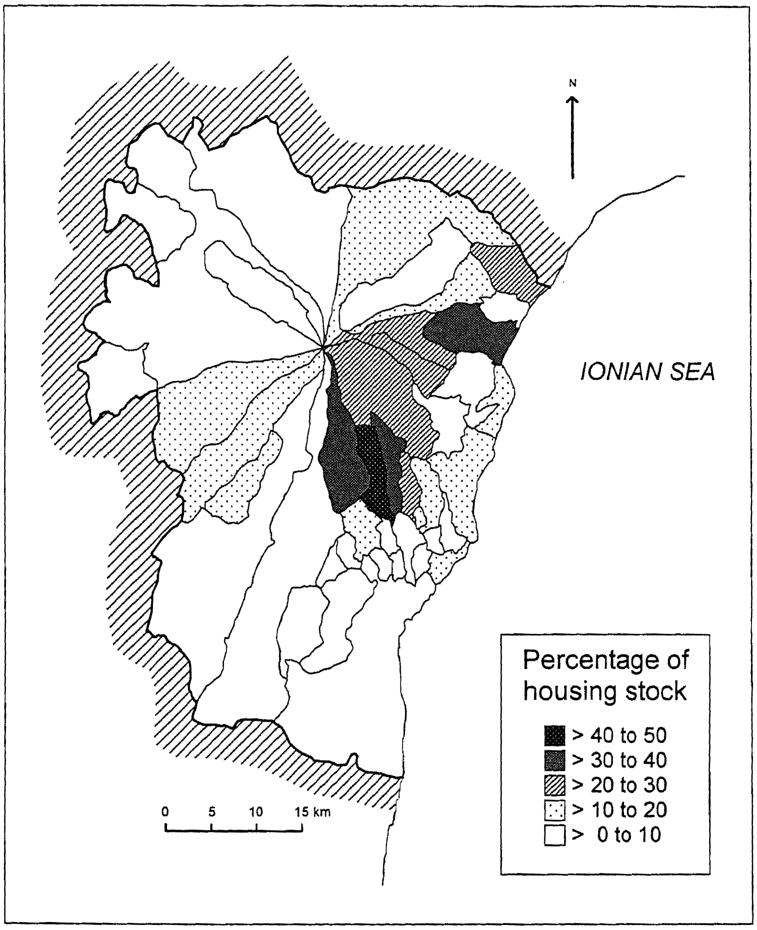


Figure 8.32: Second homes as a proportion of all residences.[7]

The growth of settlements near the city of Catania and the relative decline of the towns on the western and northern flanks of Etna has been due to the changing economic and social structure of the area as discussed above. This can be more formally tested by using data from the Italian census. Using a measure of in and out migration for the Etnean comuni it was possible to model settlement growth and decline between 1951 and 1991 (outlined in section 7.4.3). It was hypothesised that in and out migration rates for a comuni would be explained by the nature of its economy and its potential for being a dormitory settlement for Catania and other significant points of economic growth.

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[7] The source and method of calculation for all Etna region variables can be found in appendix B.

Economic indicators	Description
Structure of economy	• Percentage of economically active population employed in agriculture for the year stated. • Percentage of economically active population employed in industry for the year stated. • Percentage of economically active population employed in the service sector for the year stated. • The percentage change in numbers of economically active individuals employed in agriculture within the decade indicated. • The percentage change in numbers of economically active individuals employed in industry within the decade indicated. • The percentage change in numbers of economically active individuals employed in the service sector within the decade indicated.
Indicators of wealth	• Percentage of households living in rented accommodation in year indicated. • Percentage of houses without running water in the year indicated. • Percentage of houses without an inside lavatory in the year indicated • Percentage of houses without an inside bathroom in the year indicated

Figure 8.33 Indicators derived from Italian census (See appendix B).

The nature of the economy of a comuni was captured using census data on areas within which people were employed, changes in employment rates between these areas and indicators of wealth (tables of census variables - appendix B). The available measures were only used if they discriminated between comuni - if there was meaningful variation. For different decades, therefore, different indicators were available. The main indicators are listed in figure 8.33. The available variables were entered into a principal components analysis (PCA). PCA would produce a smaller number of uncorrelated components that explained the variation between comuni. These and other variables illustrating the other proposed determinants of in or out migration were then used as independent variables in an ordinary least squares (OLS) regression equation to model migration. It was believed that a number of other factors might be important in predicting in and out migration as well as the economic situation within the comuni. These other factors included the attractiveness of comuni as dormitory settlements for Catania, comuni that were seeing their agricultural sectors expand in the 1950's and comuni in an around the Belpasso-Piano Tavola industrial zone. These factors were represented using a number of 'dummy' (ie. absence/ presence of condition). Comuni that would be attractive to commuters, for example, were coded as one and those that were not as zero.

The comuni containing the city of Catania was not used in the analysis. Catania is a completely different entity compared to other towns on the flanks of Etna. Not only is it many times bigger but it has an entirely different economy which functions not only at a regional but national and international level. While other comuni in the Etna region have a dominant direction to their migratory flow, Catania has both a high level of out migration and in migration.

8.5.1.1 Migration between 1951 to 1961

An initial PCA was carried out on 9 of the variables listed in figure 8.34. The analysis revealed 3 components with eigen values of over 1, the cut of criterion being used in this study. Together these three components explained 77% of the variance within the dataset. A Varimax orthogonal rotation was then applied to these components, the results are shown in figure 8.34. The first component explained 34% of the variance in the data set, the second 26% and the third 18%.

	Component		
	1	2	3
%agr51	-.975		
%ind51	.863		
%ser51	.802		.482
% with loo inside 51	-.717		
ag51-61		.846	
ind51-61		-.830	.445
% of houses with water 51		.730	
%Of accomdation rented 51	.449	.600	
ser51-61			-.928

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 4

Figure 8.34: Rotated Component Matrix for 1951-61.

When the weightings on the first component were examined (weightings of <0.4 and >-0.4 were suppressed to avoid over cluttering the table) it appeared that this dimension measured the extent to which a comuni had an economy based in the service or industrial sector rather than agricultural. If the scores for component 1 are mapped, comuni scoring relatively highly on this dimension cluster along the south-eastern seaboard of the Etna region (figure 8.37). The second component describes comuni whose agricultural sector was shrinking less quickly than in other areas, whose industrial sector was not growing as much and whose inhabitants tended to live in rented accommodation. Comuni that scored highly on this component tended to be from the north of the region, though some of the eastern comuni also scored fairly highly (figure 8.36). The third component describes comuni that did not see as great a growth in the service sector as other comuni, it was fairly large already, but instead saw an increase in industrial employment (figure 8.38).

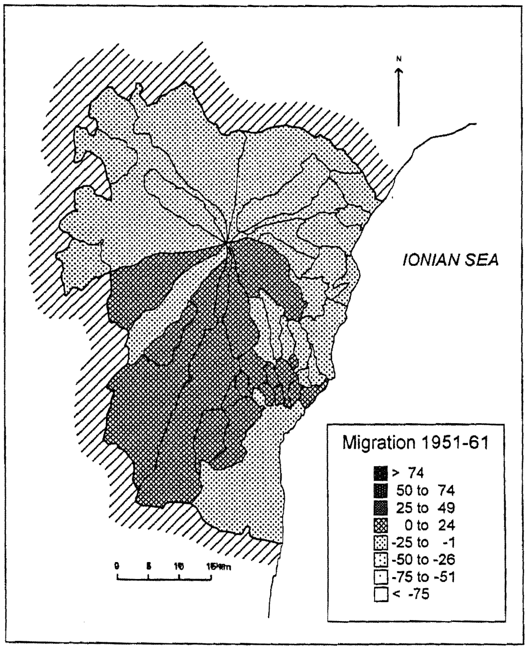


Figure 8.35: 1951-61 M.I.

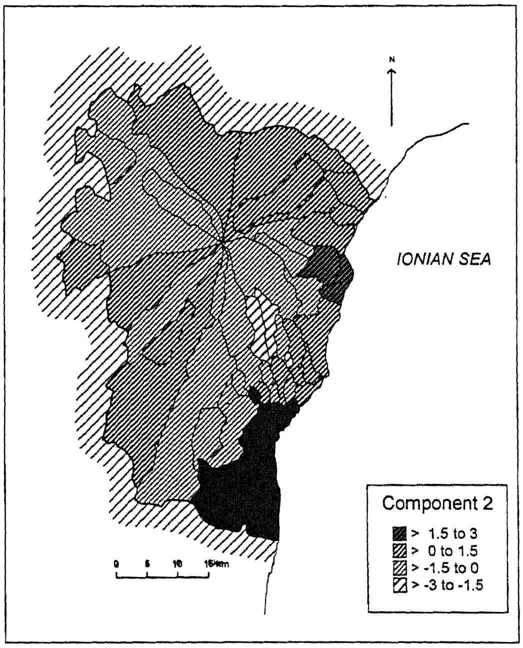


Figure 8.36: 1951-61 component 2.

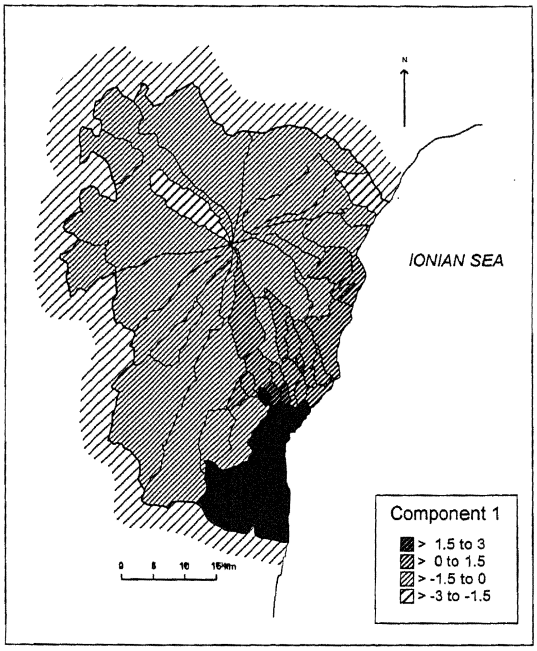


Figure 8.37: 1951-61 component 1.

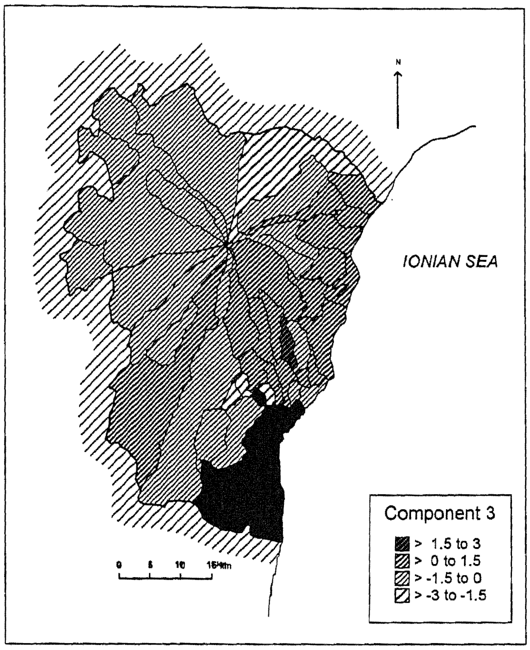


Figure 8.38: 1951-61 component 3.

Comuni that experienced in migration between 1961 to 1971 tended to be located in the south of the region and those with borders contiguous with Catania (figure 8.35)[8]. After some exploratory analysis it was decided that the third component was unrelated to in or out migration. The first two components were felt to be important reflecting a declining agricultural sector in the north of the region and growing service sector in the south east. Two other variables were believed to be important in modelling in and out migration, these were areas that, during the 1950's, saw an expansion of agricultural production as the flood plains of the Simeto valley were exploited with new technology (Ruggiero, unpublished) and comuni contiguous with Catania (figure 8.40 and 8.39). Contiguous comuni would, it was hypothesised, experience in-migration because they would be ideal sites for commuting to Catania. They were small historic towns close to Catania and with a more pleasant climate and attractive living environment. A slightly different variable was used to model the growth of dormitory settlements for decades after 1951-61. These reflected improving communication links and rising

[8] The maps show all comuni in existence in 1991. Where they did not exist in the decade being analysed the value of the area they were separated from is shown on the map and, in the analysis, the variable is not included. Comuni created between 1951-91 include Valverde, Milo and Maniace.

residential density[9]. It was hypothesised that these factors would gradually, over the decades, push commuter developed away from Catania and up the volcano.

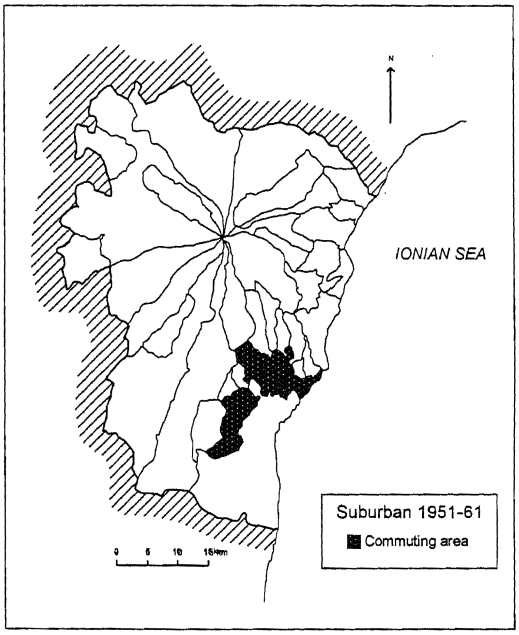


Figure 8.39: Commuting area 1951-61.

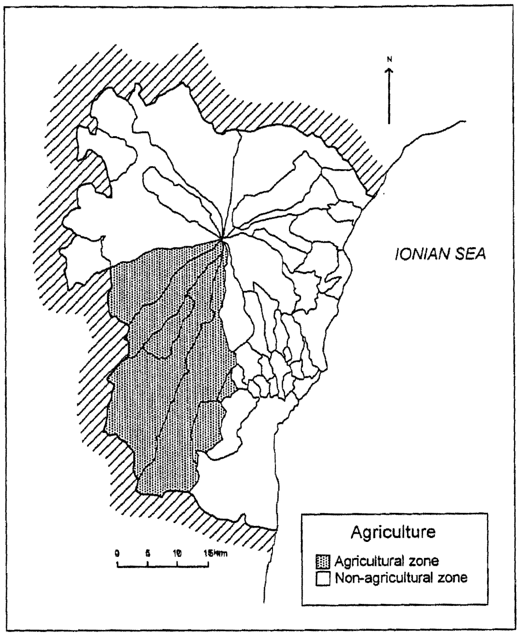


Figure 8.40: Agricultural zone 1951.

The model produced with these four variables is summarised in figure 8.41. The model explained 73% of the variation within the data set. It should be remember that the number of cases within the model were low and therefore some caution should be exercised in interpreting the explained variation but still the model predicted migration in and out of comuni fairly well.

[9] It is assumed that density/demand would be correlated with land rental prices and so higher density would make a comuni less attractive to developers. It is also possible that high residential densities would be unattractive to developers *per se*.

Model Summary b

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.873[a]	.762	.733	5.0212

a. Predictors: (Constant), AGRI, Component score 1 COMUT61, Component score 2

b. Dependent Variable: %MPOP61

Figure 8.41: Summary of model for the period 1951-61.

When the standardised coefficients of the model were examined it appeared that comuni near to Catania, in the south west of the region, with a relatively large service and industrial sector, were likely to have a high in-migration rate (figure 8.42). On the other hand comuni, that had an agricultural sector that was not declining as much as in the rest of the region and an industrial sector not growing as much as else where, were seeing relatively little growth.

Coefficients a

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-7.003	1.098		-6.376	.000
	Comuting 1961	13.760	2.450	.610	5.616	.000
	Component score 1	2.946	1.086	.303	2.713	.011
	Component score 2	-2.204	.853	-.227	-2.583	.014
	AGRI	12.172	2.304	.492	5.283	.000

a. Dependent Variable: %MPOP61

Figure 8.42: Coefficients of model.

8.5.1.2 Migration between 1961 to 1971

The variables that were available for the decade 1961 to 1971 are shown in figure 8.43. When these were put into a PCA three components were extracted, with eigen values of greater that 1, these explained 76% of the variation within the dataset. These components were then rotated using the Varimax method. After this rotation the first component explained 30% of the variance, the second 25% and the third 21%. The component structure was very similar to that observed for the period 1951-61[10]. The first component seemed to reflect comuni that had an

[10] Though the direction of the signs are reverse the findings are the same.

established industrial and service sectors and only a small number of people employed in agricultural in 1961 but which had not seen a great rise in industrial employment between 1961 and 1971. The second component described a dynamic comuni that experienced great change in its economic structure during the decade. This change saw a sharp decline in agricultural employment and an increase in service and industrial sector employment. The third component seemed to identify comuni with a high level of housing quality.

	Component		
	1	2	3
%agr61	-.964		
%ind61	.951		
%ser61	.731		
ag61-71		-.929	
ser61-71		.805	
ind61-71	-.457	.704	
% with loo inside 61		.454	
% of accomdation rented 61			.835
% of houses with water 61		.408	.800
% with inside bath 61	.514		.661

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 5

Figure 8.43: Rotated Component Matrix for 1961-71.

Migration during the period 1961-71 is shown in figure 8.44. The main areas of in-migration during this period were around Catania and in the comuni of Giarre. Comuni on the northern, western and south-western flanks all experienced out migration during this period, the highest rates found amongst those on the northern flanks.

Preliminary analysis revealed that only the first component had a significant relationship with migration between 1961 and 1971 (figure 8.45). In this decade competition from intensive farming techniques was putting extreme pressure on the extensive agriculture that was practised particularly in the north-west of the region. The extent to which this might affect a comuni was measured by recording the percentage of agricultural land within a comuni given over to rough grazing (Figure 8.47). The third variable used in the analysis one which identified the closest comuni to Catania. These comuni, it was hypothesised, represented the most suitable sites for commuting into Catania. The examination of in-migration into three comuni on the edge of Catania revealed figures that made them extreme outliers. If these comuni had been left in the analysis they would have biased the model. It was decide, therefore, to remove them. All three comuni were subject, in the 1960's, to the construction of a large number of villas and flats to serve the growing demand of the Catanese work force. It seems likely, therefore, that the very great level of in-migration they experienced during this period was due to these residences being filled. The underlying reason for their construction presumably being demand and so their growth fits the above hypothesis. These three variables were then used to model migration. The resulting OLS regression model explained 75% of the variance (figure 8.48).

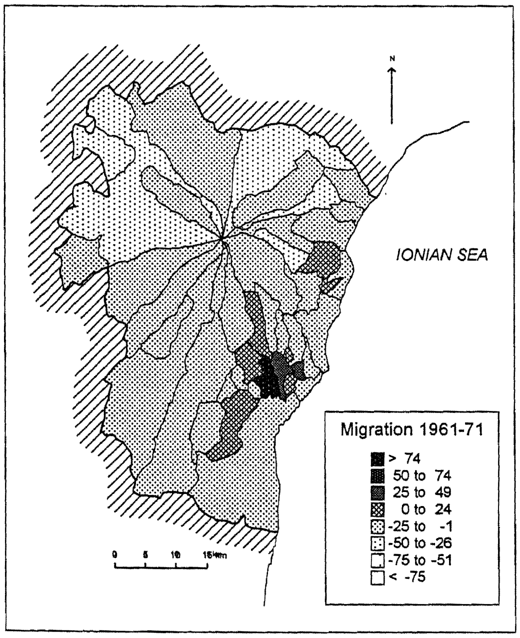


Figure 8.44: MI index for 1961-71.

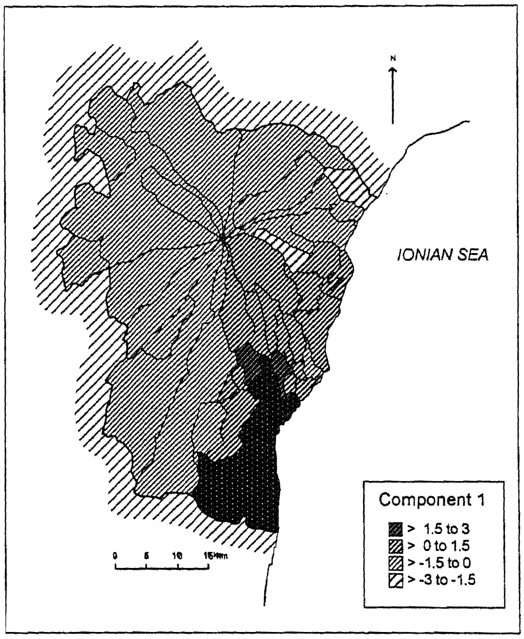


Figure 8.45: 1961-51 component 1.

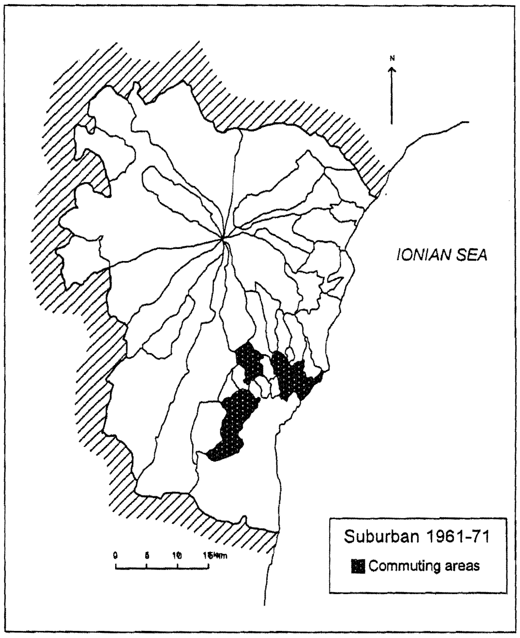


Figure 8.46: Suburban area 1961-71.

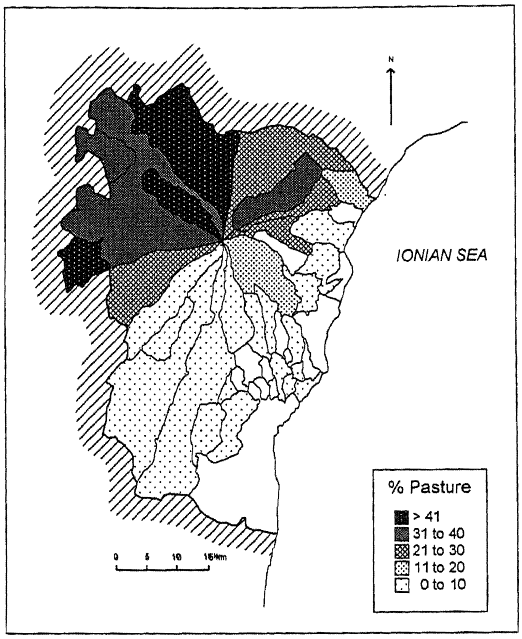


Figure 8.47: Percentage of pasture land - 1961.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.876[a]	.767	.746	7.3127

a. Predictors: (Constant), %pasture, COMUT71, Component score 1

Figure 8.48: Model Summary for MI index in the period 1961-71.

When the coefficients of the model were examined it was clear that the two most important determinants of in-migration were whether a comuni was close to Catania and if it had an established industrial and service (figure 8.49). Having an agriculturally based economy of which a large proportion was based on rough grazing would predict a high level of out-migration during this period.

Coefficients [a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-7.257	1.652		-4.392	.000
	Comuting 1971	18.718	3.764	.482	4.973	.000
	Component score 1	5.358	1.518	.369	3.529	.001
	% pasture	-.282	.097	-.272	-2.920	.006

a. Dependent Variable: %MPOP71

Figure 8.49: Coefficients for the model.

8.5.1.3 Migration between 1971 to 1981

The variables entered into the PCA are shown in figure 8.50. The analysis revealed three components with eigen values of greater than 1. Together these explained 80% of the variation within the data set. These three components were then rotated using the Varimax technique, after which the first component explained 29% of the variation in the data set, the second 28% and the third 23%. The weighting of the individual variables on each component were then examined. The first component described a type of comuni which had a large existing service sector but which was experiencing a slowing down in the growth of industrial employment. The comuni on the lower eastern flanks of the volcano and immediately north of Catania seemed to be particularly of this type (figure 8.52). This first component again seemed to reflect economic growth in the comuni around Catania. The absence of a growing industrial sector, as a part of this component, probably reflects the end of the period of heavy investment in industrial plants associated with the concentrated growth pole approach of the Cassa per il Mezzogiorno (fund for the south) in the 1960s (King, 1987). The second component distinguished a type of comuni which generally had a higher level of housing quality (figure 8.53). The third component identified comuni which saw a declining agricultural sector and a growing service sector (figure 8.54).

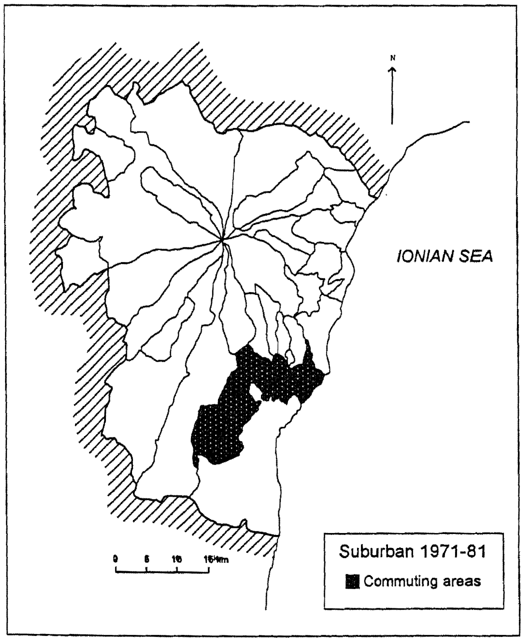
Rotated Component Matrix [a]

	Component		
	1	2	3
%ser71	.818		
% of accomdation rented 71	.813		
% with inside bath 71	.761		
%agr71	-.705	-.511	
% with loo inside 71		.931	
% of houses with water 71		.835	
%ind71		.659	
ag71-81			-.950
ser71-81			.777
ind71-81	-.462	-.449	.565

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 8 iterations.

Figure 8.50: Rotated Component Matrix



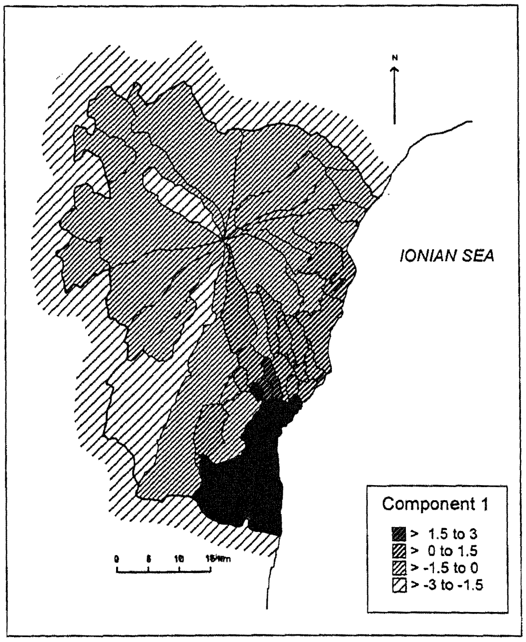


Figure 8.51: Suburban area 1971-81. **Figure 8.52: 1971-81 component 1.**

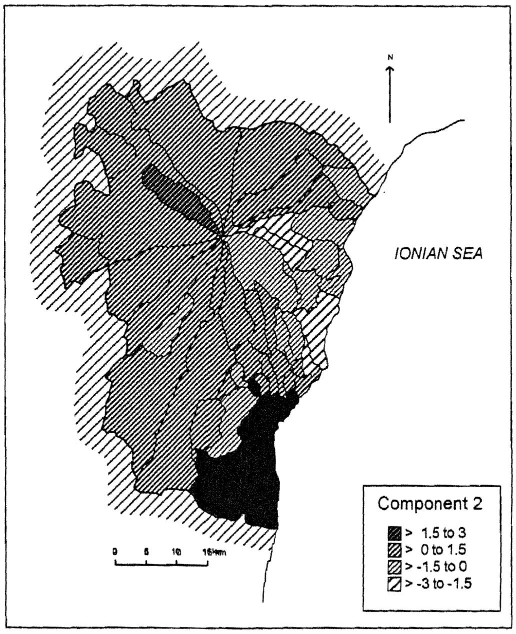


Figure 8.53: 1971-81 component 2.

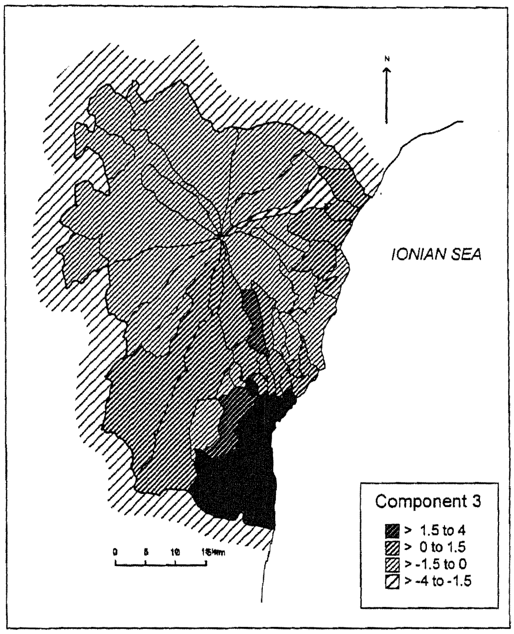


Figure 8.54: 1971-81 component 3.

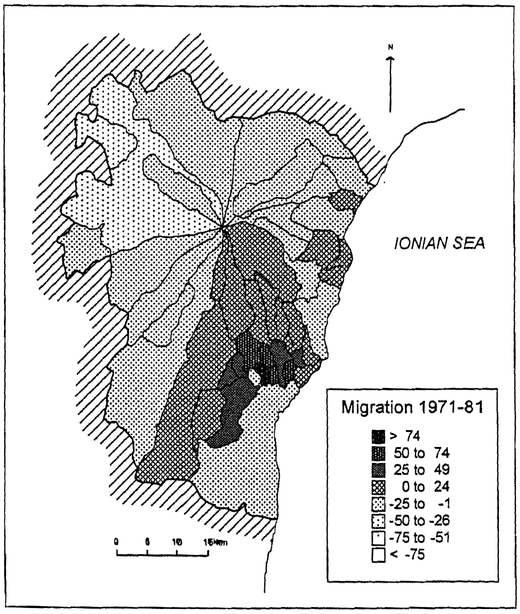


Figure 8.55: MI index between 1971-81.

Migration during the period 1971-81 is shown in figure 8.55. In-migration was highest amongst the comuni immediately around Catania, though the area contiguous with these comuni was also experiencing in-migration. The western and northern comuni generally experienced out-migration, Bronte and Maniace suffering the highest losses. The first and second components had a statistically significant relationship with the migratory index for the period of 1971 to 1981 and so were used as independent variables in the regression equation. A variable measuring comuni that were close to Catania was also introduced as an indicator of attractiveness to commuters (figure 8.51). The comuni included not only those that were contiguous but also those that were close to Catania. This was intended to model the effect of the high density of existing commuter settlements and the resulting affect on prices and the availability of accommodation. The resulting model explained 82% of the variation within the migratory index. (figure 8.56).

Model Summary [b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.914[a]	.835	.822	3.866E-02

a. Predictors: (Constant),Component score 2 , component score 1 , COMUT81A

b. Dependent Variable: @MPOP81B

Figure 8.56: Model Summary.

When the standardised coefficients for the model were examined it was apparent that comuni scoring highly on the first and second component and those that would be easy to commute to Catania from were the most likely to have high in-migration (figure 8.57). As with migration between 1951-1961 and 1961-1971, the two most important factors in encouraging in-migration seem to have been the development of the Catania commuter belt and comuni with large scale service sector employment.

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	2.014	.008		238.077	.000
	COMUT81A	8.772E-02	.018	.455	4.874	.000
	Component score 1	3.814E-02	.008	.417	4.773	.000
	Component score 2	3.173E-02	.007	.347	4.610	.000

a. Dependent Variable: @MPOP81B

Figure 8.57: Coefficients for model.

8.5.1.4 Migration between 1981 to 1991

A final PCA was carried out for the period 1981 to 1991. The variables that were entered into that analysis are listed in figure 8.58. The analysis revealed four components with eigen values of 1 or more. These four components explained 94% of the variance in the data set. The components were then rotated using the Varimax method after which the first component explained 31% of the variance, the second 29%, the third 21% and the fourth 13%. The first component, as it had done on the previous analysis, described a comuni that had a large service sector, low agricultural employment and good quality housing. Comuni that scored highly on that component tended to be clustered in the south-east of the region (figure 8.61). Weightings on the second component revealed a class of comuni with a small, though large for the region, industrial sector which declined over the decade more than in other areas and a small agricultural sector that declined less than in other areas. The third component represented comuni that saw a large increase in the service sector over the period and a similarly large decline in agriculture. The four component represented comuni that had a large proportion of people living in rented accommodation.

	Component			
	1	2	3	4
%ser81	.815			
%agr81	-.813	-.470		
% with inside bath 81	.810			
ind81-91		-.880		
%ind81		.839		
ser81-91			.952	
ag81-91		.654	-.700	
% of accomdation rented 81	.472			.842

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 9

Figure 8.58: Rotated Component Matrix for period 1981-91.

In migration during this period was highest amongst the comuni on the south-eastern flanks of the volcano (figure 8.60). Particular high spots, for in-migration, centred on the mountains towns in this sector. Out-migration was again experienced by most of the comuni on the northern flanks of the volcano. The first component was found to have a significant relationship with the migratory index and were therefore used in the regression equation. Two dummy variables were added into the model, one representing potential commuting settlements and the other comuni in and around the Belpasso industrial site (Ruggerio - unpublished). The commuting variable for the period 1981 to 1991 differed from that proceeding because it ignores comuni directly around Catania which by this stage had very high housing densities and as a result little land for development or available housing (Sanfillipo, 1991). This, it was hypothesised, had led to a leap-frog affect where the comuni that had seen the largest rise in population in the previous decades were now not so attractive to commuters and so were ignored. The second dummy variable represented comuni that were being affected by the growth in small scale industrial enterprises in the Belpasso-Piano Tavola area.

Model Summary [b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.856[a]	.732	.710	8.8917

a. Predictors: (Constant), POLE, Comuting 1991, Component score 1

b. Dependent Variable: %MPOP91

Figure 8.59: Model Summary.

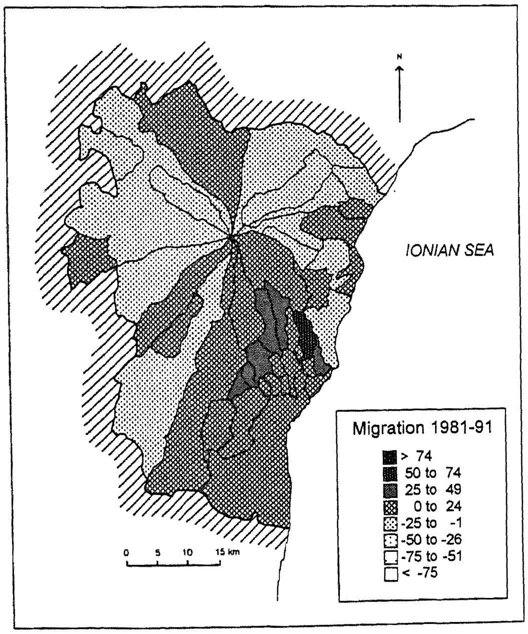


Figure 8.60: MI index 1981-91.

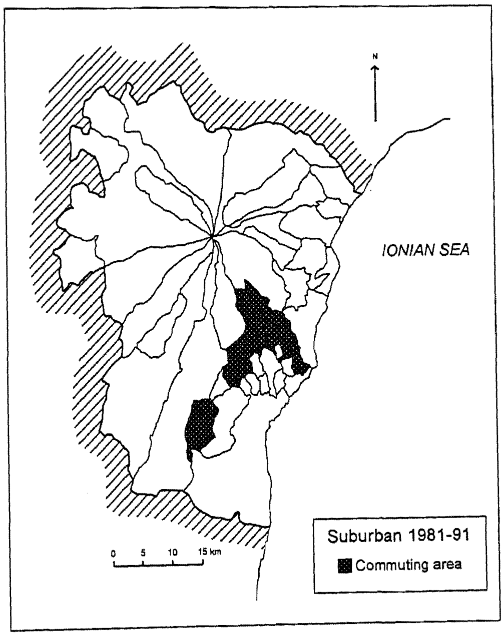


Figure 8.61: Suburban area 1981-91.

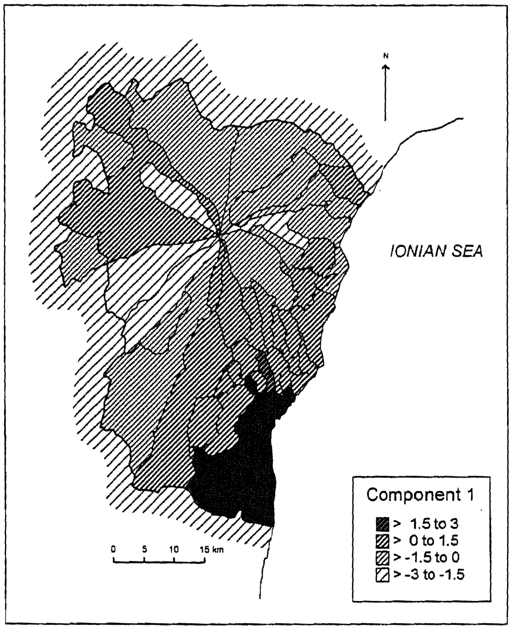


Figure 8.62: 1981-91 component 1.

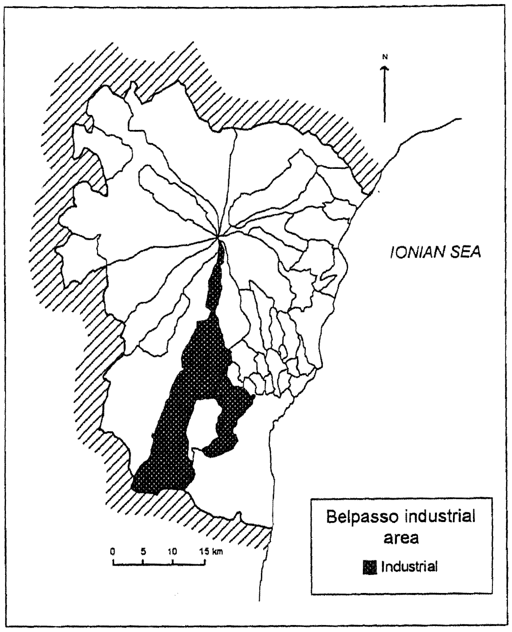


Figure 8.63: Belpasso industrial area.

These four variables explained 71% of the variation in the migratory index (figure 8.59). The most important predictor of migration seemed to be whether the comuni was attractive to commuters or not (figure 8.64). As with the previous analysis, comuni with a large and/ or growing service sector would have high in-migration.

Coefficients [a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	3.067	1.626		1.887	.067
	Commuting 1991	27.583	3.904	.636	7.065	.000
	Component score 1	6.065	1.507	.367	4.024	.000
	Belpasso indus. area (POLE)	16.613	5.552	.265	2.992	.005

a. Dependent Variable: %MPOP91

Figure 8.64: Coefficients of the model.

8.5.2 Overview

The historical situation of material and authoritative resources lying with a landed and middle class in Sicily which left the land-workers powerless and vulnerable has been eroded by economic and social change within Sicily, Italy and the wider world. The opportunity foreign labour markets offered and the development of new labour markets in and around Etna has freed many of the land worker class from the domination of the old land ownership system. The influx of capital into the region and the political system that has existed in Italy after the Second World War has led to the emergence of new groups with access to authoritative resources. Thus while the inhabitants of Etna have been freed from the influence of the landed class the newly emerging social systems have led to new forms of domination.

The macro economic and social changes within the Etna region have had an important affect on individual vulnerability through location. The analysis described above seemed to suggest that population growth, other than natural increase, was strongly related to changes in the economic structure of the region. Comuni with a relatively large or growing service sectors, close to Catania had high rates of growth through in-migration. The location of these comuni is mainly in the south and south-east of the Etna region but, significantly, within this zone the centre of gravity for in-migration has moved northwards with time. This seems to be due to a lack of land and improved communications making areas further north more desirable for development. Whilst between 1961 to 1971 the main concentration of the rapidly growing comuni was immediately around Catania, by the 1980's it had moved up the flanks of Etna. The analysis suggested that this was the result of pressure on land within a growing commuter belt forcing the development of sites further away from the urban centre with the result that an increasing number of people are living in areas with a relatively high probability of lava invasion.

Although social and economic change within the region has reduced the extent to which individuals are vulnerable because of a lack of access to physical and authoritative resources, it has led to an increasing number making themselves susceptible through location.

8.5.3 Individual and collective representations of the Etnean environment

The presence of settlements and communities in areas of hazard are the result of people reacting to specific situations existing within places and over time. These situations present the individual with both perceived and physical constraints and opportunities. Vulnerability, as has been demonstrated above, is not just the result of constraints or lack of opportunities but also can result from the taking of opportunities. Thus vulnerability stems not just from societal marginalisation but can exist in a case of relative prosperity. This then implies that an individual has made a choice beyond the simple provision of the basic needs of life. The ability of an individual to accept *discernible* vulnerability lies in their, and the groups they belong to, particular vision or representation of their condition. The individual acts in accordance with their representation of the situation. This representation is moulded not only by their psychological and biological make-up but also by their own social history. Behaviour therefore reflects the social world that exists outside the immediacy of the situation. This also means that an individual's representation of a situation may be as much a response to this social world as the direct experience of the situation they are within.

In order to explore the representations of situations within which vulnerability to volcanic hazard emerge a sample of 200 residents of the town of Trecastagni were interviewed (interview schedule appendix A & table of results appendix C). Trecastagni was chosen because it is situated in the highest, settled, zone of hazard. 86% of the sample had lived all their lives in the province of Catania. Those that had moved to the province had mostly done so for work whether this was for another family member or themselves. Thus for a majority of respondents, their vulnerability was closely tied to their place of birth. For these individuals the attraction of staying in the area of their birth was great or elsewhere was not attractive. The attraction of their home seemed very significant when the responses to the interviews were analysed. Not only did the respondents tend to emphasise the benefits of living where they did but they were also less forthcoming about its faults. Only 21% had ever thought about moving away from Trecastagni and of these, approximately half had done so because of the problems inherent in the town and half because of the attraction of a job elsewhere. This move, for many, would have been closer to Catania, the problem being with commuting, and therefore not out of the Etna region.

The attachment felt by the residents of the town to their home was highly significant. It was not an uncritical relationship, almost all of the respondents condemned some aspect of the services of the town or the environment they lived in, rather a forgiving bond. There seemed to be a duality in their relationship with their home, in that they could dislike aspects and yet still feel a need to remain in the town. Thus 89% of respondents agreed or strongly agreed with the statement that it would be a great loss if the town were to be destroyed by lava. Although this statement is not unambiguously related to the town alone, it also refers indirectly to their place of residence, it still gives an indication of the residents strength of feeling.

Most residents felt that the town provided the necessary services. They saw its 'mountain' situation as one of the main environmental benefits. This meant that the climate was cool, the air was clean and they were surrounded by beautiful countryside. The town was also largely free of crime and allowed a 'quiet life'. The relative size of the town did mean that some of the services needed by respondents were absent, particularly larger or specialised shops, a better transport network, cultural facilities and, especially, places for young people to meet. A problem that many respondents indicated applied to the whole Etna region was the lack of work for young people. There was also a hint, but only from a very few people, that there was a problem with youth crime and that this was related to the dual problem of unemployed teenagers with nothing to do. A final important perceived problem was the cost of living 31% commented that Trecastagni was an expensive place to live.

Out of all the people interviewed only five indicated, unprompted, that the chance that the town would be destroyed by lava was a problem. More respondents stated that earthquakes were a worry (9) and a number of these said that they had thought of moving away from Trecastagni because of the fear this induced in them. It seemed that for a majority of respondents the danger posed by the volcano was not a significant problem for them.

The respondents perception of the volcano was explored further by first asking them about their general feelings towards the volcano and whether they felt it was either a threat to property or a health hazard. Very few respondents, when asked what they thought generally about the volcano said that they feared it. Of those that did a majority of them rationalised their fear with their location in Trecastagni by arguing that they were a safe distance from the volcano.

> I fear it even though we are not very close to it here (Respondent 31)

Many respondents suggest a duality in their relationship with the volcano. It could both be something that was very attractive to them while at the same time being quite destructive.

> It is beautiful although everyone fears it to some extent (Respondent 110)

> ...the volcano is beautiful - unpredictable and as a result of this it is dangerous (Respondent 69)

> It is incredibly beautiful - it is a natural wonder - but then again, at times, it causes great fear (Respondent 71)

The volcano was seen as a tourist resource, partially because of the natural beauty of the region

> The volcano gives us work - because of the tourism - but at times it also causes great problems (Respondent 10)

> ...it is a resource to us (Respondent 2)

Although some respondents felt that it was an under-utilised resource and the authorities charged with promoting and developing tourism could do more.

> ...with greater thought and intelligence - it could be exploited more (Respondent 127)

A final group of respondents seem to feel a strong bond with the volcano. They seemed to feel grateful to the volcano.

> ...it is a privilege to able to breath the clean air it provides us with (Respondent 49)

> ...it is the best place for people to live around here (Respondent 153)

They used words that seemed to demonstrate an almost personal relationship with the volcano, giving it human like characteristics.

> It is with us for better or for worse. It is an important presence in my life (Respondent 168)

> ...like a human, its moods changes as a person's does (Respondent 94)

> It lives with us - it is calm (Respondent 123)

> ...we cohabit (Respondent 141)

> It is a presence you usually feel only from time to time - but then again you can never really ignore it (Respondent 19)

When the respondents were asked directly whether they felt that either their land or property was at risk, 67% felt that it was not. Most of those that said that it was, related this to the threat from earthquakes, only two said that they felt there was hazard from lava flows. These two both stated that a fissure could open up anywhere on the volcano and this might be near the town. Fewer respondents (15%) felt that the health of the inhabitants was threatened by the volcano and again most of these attributed this hazard to earthquakes. One respondent did suggest that gases released by the volcano during eruptions might also threaten the health of those in the town. Interestingly, less that half of those who indicated that they felt there was a threat to health, land or property from the volcano in the town had mentioned this in relation to the problems of Trecastagni. This indicated that even for those who felt threatened by the volcano, this problem was not high on their minds and needed prompting for them to recall.

In an attempt to measure the magnitude of individual feelings of threat, interviewees were asked to respond to a series of attitudinal statements about potential threats from the volcano. These statements represented a number of different facets of threat including: the probability that a lava flow might enter the town, the emotion attachment felt by the individual towards the town, protective behaviour, individual threat and the probability of being in a situation of individual threat.

Although only 62% of respondents felt that there was no real danger of the town being destroyed by lava, 24% responded neutrally to this statement. When actually presented with a choice of saying that there was no chance of lava reaching the town respondents who had said that the volcano was a threat to property could not agree with this. A significant proportion, up to 40%, could not discount the risk completely. A higher percentage, nearly half, could not discount the chance that a lava flow might not come close to the town. This suggested that part of the coping mechanism, for some individuals, might lie in the belief that although a lava flow might come close to the town it was unlikely to actually enter the town. This belief may have been strengthened by the number of recent lava flow that have passed close to towns without actually entering them (eg. 1991-93 eruption).

Almost half of respondents (48%) felt that they would not suffer great financial hardship if Trecastagni was destroyed by a lava flow. It was not possible to say whether this was an assessment based on an individual's actual economic situation or a response to worry over the possible consequences of an eruption. Interestingly those that believed that they might suffer financial hardship were more likely to indicate that they had taken precautions to limit the extent of the damage that might be done if the town was destroyed by lava (eg. had money saved, land or property spatially separated etc.). The actual number of respondents who indicated that they had taken precautions was only 2% and so they were only a small group.

But it might be argued, for this group, that their confidence stemmed from the belief that they had taken precautions. For a majority of those that felt that they would not suffer financial hardship, their feeling of security probably stemmed from their belief that they could easily endure the period after the destruction of a town.

Despite almost half of respondents feeling that the destruction of the town would not cause them financial hardship, 89% indicated that it would be a great personal loss if it happened. The perception that an individual could financially survive the destruction of the town can be contrasted with the individual's assessment of what their emotional reaction to such an event would be. In the latter case a great number of those who felt that the destruction of the town would not cause them financial hardship, indicated that it would still be a great personal loss. This finding demonstrates the significance of attachment to place.

At an individual level, 83% of respondents agreed that the volcano did not represent a danger to the inhabitants of the town. Despite this finding, a much smaller proportion, 41% of respondents, believed that there was not a 'high chance' that they or a member of their family would be close to a dangerous eruption. It seemed that many respondents thought that although being close to an eruption was quite probable, the actual chance of it affecting them was much lower. This seemed to hint at a form of self-deception; a 'it will never happen to me' attitude that may have been linked, as has been mentioned above, to the number of recent lava flows that have come close to towns without actually entering them. There is no reason why a lava flow, that might come close to Trecastagni, would not enter the town.

Despite the apparent confidence of a majority of respondents, that there was not a threat to their town, most seemed wary of the dangers posed from being close to eruptive activity. Only 23% of respondents agreed that 'being close to a lava flow was not dangerous' and 71% indicated that they avoided areas of volcanic activity. This is an interesting finding because very few people have actually been killed or injured as a result of volcanic activity, while many thousands have loss property and land. The difference between behaviour, that is implicit with 'avoiding areas of volcanic activity' and that which is involved in moving from a town that might be destroyed by a lava flow, lies in ability and ease of action. In the former case this might only involve not visiting the summit of the volcano or areas close to a lava flow front. In contrast, to move from a threatened town would create a huge number of conflicts with other interests and might even be impossible. The cognitive response of the individual to this problem seems to be to seek a rationale to justify their behaviour, as suggested in chapter 6 section 4. For the respondents, their continued residence in Trecastagni was justified through the general belief that the town was not under threat. This general belief was bolstered by supplementary attitudes and representations that tended to confirm this. The belief, that Trecastagni's distance from the summit of the volcano meant that a lava flow was unlikely to reach it, was frequently stated. Some felt that, with advances in scientific and engineering practice, a town might well be protected from a flow. Others felt that the negative consequences of a lava flow would not be excessive, for example they would not suffer great financial hardship if the town was destroyed. A final group had a fatalistic or religious attitude toward a potential event. They tended to believe that they had little control, it was chance, fate or God that would determine its affect on them.

Figure 8.65: A shrine to the Virgin Mary.

Religion and, more generally, spiritual beliefs have, through out history, played an important role in people's representations of Etna and the threat it poses (figure 8.65). Before Greek colonisation of the island there was evidence that the local population had associated the volcano with supernatural processes. A Sicel temple to the fire god Hadranus was found near Adrano at the foot of Etna (Chester *et al.* 1996). During the Greek and Roman period, Etna was associated with various myths, the common attitude seems to have been that volcanic processes were essentially unpredictable and in the hands of the gods (Chester *et al.*, 1996). Incense and goods would therefore to be offered to appease the gods and therefore protect people's lands. This fatalistic belief continued in the Christian era. Chester (1996) argues that the Catholic church in Sicily was heavily influenced by

Augustine and Irenaeus theodicies, that natural calamities were a punishment for sinfulness and that good, through self-sacrifice, could emerge from such events. Developing from these theodicies and a history of appeasement through prayers to specific gods, was a tradition in the use of holy relics. This took and takes the physical form of processions of holy relics and statues of patron saints to the sites of eruptive activity in order to achieve intercession over a revengeful natural environment. Most notable amongst these religious acts is the use of the veil of St. Agatha to protect the city of Catania. The veil of St Agatha was first processed in 252 BC, the year after her martyrdom, an act that was attributed with saving the city from an advancing lava flow. Similar processions seem to have occurred during most subsequent threatening eruptions. It seems clear that for many, religious beliefs play a significant role in their representations of the volcano.

It was suggested in chapter six that individuals cognitively reduced the risk they perceive from a volcano because of the dissonance they experience having made a decision in the past that now seems to have put themselves at unwanted risk. It is very difficult to test a process of cognitive dissonance outside experimental simulations because none of the important factors are controllable. The only possible method is to use a naturally occurring variable such as distance from point of hazard to group respondents and assume that it plays a causal role. In this case whether a person had made an active decision to move to Trecastagni was used. Distance was rejected as the variable of interest because firstly it is uncertain whether residents of the Etna region have a clear understanding of differences in relative hazards on the volcano and secondly, because knowledge of an area decreases itself with distance. Instead, whether an individual had moved to Trecastagni or lived all their life in the town, was used to test whether a dissonance affect was apparent (ie. whether an individual had taken a bad behavioural decision). The theory would predict that individuals who had moved into Trecastagni, having chosen Trecastagni over other towns in the area, would feel that the town was not more hazardous than other places compared to those who had lived all their lives in the town. It would be predicted that they had sought out information to support their decision to move there over other towns to reduce the cognitive dissonance they must be feeling. People who had lived all their life in the Etna region on the other hand could be more comfortable with the cognition that the town was more dangerous because they were not located there as a result of their own actions. This affect would only heighten a background process of dissonance reduction because none of them had left the Etna area despite frequent eruptions. The proposal was therefore that respondents who had moved to Trecastagni would be more likely to believe it was safe from volcanic hazard than those who had lived there all their lives but that on the whole a majority of respondents would feel the town was safe. It is important to note that almost all of those who had moved to Trecastagni had done so as adults, they were also only a small percentage of all respondents (15%).

There was general support for the above proposition (figure 8.66). Only one or 3% of those who had moved to the area felt that Trecastagni was at greater risk than other towns in the area compared to 33% of those who had lived there all their lives. This difference was statistically significant ($p=0.001$) and the relationship was not confounded by demographic variables such as age or gender. Also, those that had moved to Trecastagni did not appear to be 'risk takers' when it came to the dangers of volcanic hazard, they were more likely to avoid areas of volcanic activity (90% compared to 67%) and to believe that being close to a lava flow was dangerous (72% compared to 56%). This lent some support to the proposition that the process of cognitive dissonance is important in the construction of individual's representations of volcanic hazard.

			q9. Is there a greater danger tc property, from an eruption, in this town compared to other towns?		
			Yes	No	Total
q1. Have you lived all your life in Trecastagni?	Yes	Count	56	115	171
		% within q1. Have you lived all your life in Trecastagni?	32.7%	67.3%	100.0%
	No	Count	1	28	29
		% within q1. Have you lived all your life in Trecastagni?	3.4%	96.6%	100.0%
Total		Count	57	143	200
		% within q1. Have you lived all your life in Trecastagni?	28.5%	71.5%	100.0%

Chi-Square Test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.446[a]	1	.001
N of Valid Cases	200		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.27.

Figure 8.66: Crosstabulation between q1. Have you lived all your life in Trecastagni? and q9. Is there a greater danger to property, from an eruption, in this town compared to other towns?

These beliefs have developed within a community in which everyone had to confront the same potential event. Their development, and the development of general representations of the area that they feed into, takes place within this community and hence the similarities between individual representations. It seems likely that an individual's underlying goals and knowledge about a potential eruption affects the information they receive and assimilate which in turn will affect the formation of representations.

As has been noted above, very few respondents had general household insurance or had said that they had insurance against volcanic activity. Of those that said that they had taken other forms of precaution - only 4 out of the 200 respondents - this related principally to second homes. Ninety three percent of individuals believed that the state was responsible for reconstruction after a disaster. This finding hinted at a confidence amongst respondents that they themselves might not have to fend on their own after a volcanic disaster. Although the fact that they did not have insurance against theft or fire, and would not expect the state to aid them in that situation, suggested that a lack of insurance might not just result from confidence in aid from the state. The justification for the belief that the state should aid citizens in the case of natural disasters included the blunt:

> well that's what they here for (Respondent 107)
>
> The citizen is not able to bear such a cost (Respondent 22)

Through the reasoned:

> The state should help citizens in their moment of need when damage is no fault of their own (Respondent 148)
>
> The state must act a guarantor for events over which the citizen has no chance of controlling (Respondent 65)

Some argued that because of the taxes paid the citizen was guaranteed protection

> The citizen pays taxes and they must therefore be offered security by the state...(Respondent 109)
>
> The citizen does not have the opportunity to plan ahead for such damage - even if they are to blame the state must still help (Respondent 18)

Another argument was that because the State allowed hazardous behaviour, in this case building in an area that might be affected by a volcanic eruption, then it was responsible the consequences of 'lawful' behaviour.

> The citizens construct their houses in accordance with the law - therefore they should be guaranteed health (Respondent 36)
>
> ..because the state allowed development of areas of risk (Respondent 189)

It was also argued that the State had the responsibility and knowledge to protect a town against a lava flow. If it did not satisfactorily use this knowledge or carry out this duty then it was responsible for the consequences.

> The state should act against this (a lava flow approaching a town) - by for example building a canal to the sea - if this doesn't happen then they must answer for this (Respondent 153)

> ..because it (the damage done by a lava flow) is not caused by the citizen (Respondent 82)

The importance of respondents belief's that the State should play an active role in the control of exposure to volcanic hazard, was emphasised by the finding that 94% of respondents felt that the stopping of construction in areas of high risk was a good idea.

> the opposite would not make sense (Respondent 71)

Combined with the finding that respondents did not feel there was a threat to Trecastagni, it can be assumed that they would not feel that the restrictions applied to them.

Those that felt that construction should not be controlled, more than it is at the moment, generally argued that it was important for people to take responsibility for their own actions. They were also likely to have argued that the citizen would have to help themselves in the event of a natural disaster. But this group were a tiny minority amongst the responding group.

A fairly large group of respondents, 70%, believed that it was possible to control lava flows. This belief may have been encouraged by apparent recent successes in diverting lavas in 1991-93. A sizeable group believed that it was not possible and those that felt it was possible did not have complete confidence, often adding that it was 'relatively' possible. Respondents had mixed feelings when asked whether they thought that building permanent barriers around towns might be a good idea. Some felt it would be, others however were sceptical about whether it would work or not. It was possible to conclude that although some individual's confidence seemed to stem from their belief that intervention was now possible and would be likely to succeed the majority's confidence seemed to come from their view that a lava flow was unlikely to reach them because of their distance from the volcano. The potentially dissonant cognition that that they were living on a volcano seemed to be have been replaced by the cognition that though they were living on a volcano their town was a safe distance from it.

The interaction of the social and economic constraints and opportunities presented by social systems at the macro level, as discussed above, with individual and social representations of the threat posed by the volcano are important. It seems that individual and social representations of volcanic threat are formed and developed in order to enable the exploitation of opportunity and the sufferance of constraint rather than as a direct response to an observation of volcanic processes. This is important because it suggests that individuals and groups living on Etna will not attempt to change their own situations of vulnerability as a direct response to volcanic threat. Their vulnerability is only likely to change with action unrelated to volcanic threat or changes in the behaviour of the volcano. While this will lead to a large number of people reducing their own vulnerability, given the macro economic and social processes operating within the Etna region, other people will be behaving in such a way as to increase their vulnerability. As people move away from the area, for example, others will be moving in.

8.6 CONCLUSION

The definition of vulnerability used in this thesis is that an individual would be vulnerable if a hazard event could deprive them of basic human necessities and/ or the means by which they would be satisfied in the future. Given the present behaviour of the volcano, few people on Etna are vulnerable in the long-term. This is largely the result of the nature of the volcano and its location within a Western European state. Because people historically have not been killed or injured during a volcanic eruption on Etna, the main threat is to an individual's livelihood and resources both directly through the destruction of their own means of generating a livelihood and indirectly through its affect on society at large. In Sicily it is likely that the affect of an eruption on an individual's means of generating a livelihood, though severe in the short term, would be mitigated against in the long term by reconstruction projects initiated and sponsored by the Italian state and the European Union. While people may not be vulnerable in the long-term, it is likely that many will suffer hardship and not regain their previous levels of living. The worse affected by this are likely to be those people with relatively low levels of authoritative and allocative resources.

Short term problems are more likely to be experienced by those who have a low level of resources, have a majority of their resources and source of livelihood located in one place or who do not have a network of support they can call upon in an emergency. These individuals will often be those who lack material and authoritative resources but may also include those working in service or industrial jobs located in the same town. People who have moved to the Etna region from elsewhere in Sicily or outside the island may not have a network of support they can fall back on. It may be difficult for them to move items out of their residence because they would have no where to store them. They would therefore be likely to loose a greater proportion of their resources than others who had somewhere to move goods.

Some individuals, families and groups would have greater access to the reconstruction process than others. As has been demonstrated above, Sicilian life is still dominated by patronage and clientism and an absent of connections might severely hamper recovery. This does not mean they are vulnerable, they would not be deprived in long run of basic human needs, but that their recovery to their previous level of prosperity would be hindered. The extent of this problem may be determined by the scale of the damage. This would affect the level at which the reconstruction process was managed. The destruction of part of a small town on Etna might well result in a fairly localised response with funds being distributed through existing administrative bodies utilising local building contractors. In this situation there is probably more opportunities for existing patterns of patronage and inefficiencies to affect the reconstruction process. In Zafferana the author spoke to a resident who was still waiting, ten years after a minor seismic event had damaged part of her house, to receive emergency funds that had been released at the time (personal communication). In a major event it is likely that control of the reconstruction process would move from the local administration to a regional or 'special' body which, though possibly affected by local patronage, would not have an existing situation of corruption. Though, as with the Belice case, once a body starts on the process of reconstruction, and therefore comes into contact with the local social systems and patterns of power, it is quite possible that it will be corrupted.

The effect of an eruption may not necessarily have a negative influence on the livelihood or resources of individuals. In the Etna region there are those whose basic needs are as yet not being met. This is especially true of those who live within the large urban estates within and on the edge of Catania. Within these estates, since they were built in the 1960's and 70's, unemployment, crime and poverty has become rife (Vulliamy, 1993). The effect of an eruption for these individuals may, as was apparent in the case of Mascali, Friuli and Belice (after the reconstruction process was started), lead to an improvement in their circumstances. The state would be forced, by their destruction, to do something about the estates. It seems likely that any future development would be an improvement on the present situation.

Some groups will be susceptible because they may be unable to access the reconstruction process. These might include illegal immigrants, who because of their lack of official status may be refused help. Though difficult to estimate, there may be as many as 4,000 illegal immigrants living in Catania (Maggio, 1991). People who own illegal housing may also find that they do not have access to reconstruction money. As the illegal building of property or its non-registration is relatively common in Sicily, this may be a fairly significant problem if this group was refused compensation (Vessels, 1995).

The likely reaction of the Italian state and European Union to a large scale 'natural' disaster means that a majority of the inhabitants of the Etna region are not vulnerable except in the short term. The burden of an eruption has been effectively transferred from the individual or small group to the state or union of states. This is significant because while the flanks of Etna continue to be populated and developed the potential cost of a disaster to the state increases. This problem is exacerbated by the absence of insurance systems for redistributing losses. While in a country with a tradition of insurance, the cost of loss is distributed across the population through organisations separate from the state. In Italy the state would have to use its own reserves or debt to pay for the reconstruction process. The effect of a major eruption on the economy of the country, therefore, might be significant. There is therefore an onus on the Italian state to think carefully about the implications of an eruption and in particular a 1669 type scenario and to draw up plans to deal with such an eventually.

Although this analysis has revealed that few residents of the Etna region are vulnerable to the volcano in the long term, there is still a need for change. One particular problem is the issue of who should pay for the costs of a major eruption. There are a number of other problems. First, that residents who may not be recognised by the state as either having rights to reconstruction money *per se* or for particular aspects of their livelihood or resources (eg. non-registered housing) may be vulnerable to an eruption. Second, without an existing plan for the evacuation of Catania there is some potential for loss of life in the case that the town should be overrun by a lava flow. Third, some groups, particularly those with little power, may find it difficult to satisfy their basic needs in the period immediately after a disaster.

Tentative recommendations for future disaster planning might be:

- A debate about the potential cost if a large scale eruption should take place. If the state is unprepared to pay for a reconstruction programme it must decide whether development on Etna should be controlled or whether alternative methods of raising revenue should be encouraged (eg. private insurance, a special form of taxation linked to new residential development on the flanks of Etna). This type of debate would also raise people's awareness of volcanic processes.

- Further control of development would be welcomed by those already living in the 'mountain' towns on Etna and by the conservation lobby. It seems logical to use the knowledge of more hazardous areas to stop new building in these areas which are generally higher on the volcano.

- A major plan for the evacuation of Etna in a 1669 type scenario. Decisions would have to be made about how many household goods people could remove from their homes, up to what point people could still be in the city and where people, especially those without other homes, family or friends, would find accommodation.

- A general policy of reducing patronage, corruption and encouraging economic development would reduce the short term vulnerability of the least powerful residents on Etna in the event of a disaster. This is going on as part of the normal functioning of the Sicilian administration and Italian state, the argument that it would also reduce volcanic vulnerability could be used to add impetus to the general policy.

Some of these recommendations would be fairly difficult to implement. The existing situation of corruption and circumnavigation of existing planning regulations and laws would make the enforcement of new regulations difficult and so make the policy ineffective. But new regulations would not be unwelcome by existing residents of towns. In the survey of residents of Trecastagni it was found that a large majority of residents would support a limit on new development on Etna. Many saw this as more a limit on environmental destruction rather than a way of reducing a future reconstruction bill. Either an actual limit or a special taxation (ie. enforced insurance) might be introduced to reduce new development.

The evacuation of Catania would need a great deal of planning if it were to function properly in an emergency. In the last year a tentative evacuation plan has been constructed (personal communication - S. Calvari). To be successful, though, it would require a great deal of inter-organisational co-operation. The goal of reducing corruption and increasing the economic prosperity of residents on Etna is of course a huge goal and not one that could be part of a vulnerability mitigation programme. Rather the bodies charged with these tasks should be made aware that a by-product of their work would be a reduction in volcanic vulnerability. They then could use this information to aid their own work.

CHAPTER NINE: CASE STUDY OF THE FURNAS REGION OF SAN MIGUEL

9.1 INTRODUCTION

The area around Furnas volcano (San Miguel island - Azores) is similar to the Etna region in certain regards. It is a peripheral region on the edge of Europe and as a result has been, for Europe, relatively economically underdeveloped. The economy, historically, is based on agriculture with relatively low levels of medical care, literacy and life expectancy. In recent years, though, it has had a considerable amount of economic aid from both Portugal and the European Union. It had not seen the type of industrial development that has occurred in and around Catania but education, medical care and infrastructure have all moved towards a European norm over the last 10-20 years as they have done in Sicily. The two regions, though similar in some economic and social domains are very different in others.

San Miguel is part of an archipelago of islands, the Azores islands, located midway between Europe and the Americas in the North Atlantic ocean (figure 9.1). The islands stretch across 1450 km of ocean (Chapin, 1989). They have autonomous regional status within the Portuguese state with their own legislative assembly and government, granted after the 1974 revolution under the 1976 constitution.

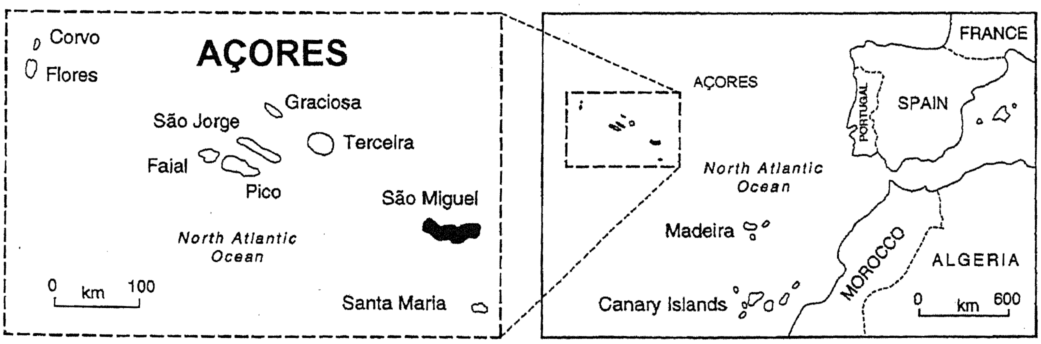


Figure 9.1: The location of the Azores (based on Chester *et al.*, 1999).

San Miguel and the adjacent Santa Maria, to the south, are the most easterly of the islands of the Azores. The islands as a whole lie at the intersection of the westerly winds of the northern hemisphere and the south-east trade winds and the climate of the island, because of its position, is mild. The average summer temperature in Ponta Delgada, the capital of San Miguel, is ~17-20° centigrade (taken over the period 1951-80) and the average winter temperature is 13-14° centigrade (Serviço Regional de Estatística, 1987) (figure 9.2). The average temperature over the whole year is 17.3° centigrade. The island receives a fairly high level of rainfall. The average yearly volume of rain falling on Ponta Delgada of 1020 mm for the period 1951-80. Fifty three percent of the population of the archipelago live on San Miguel. This is probably linked to its size and fertility. The climate has allowed the residents of the islands to grow a variety of crops such as tea, tobacco, oranges, passion fruit, wheat, sugar cane, woad and archil.

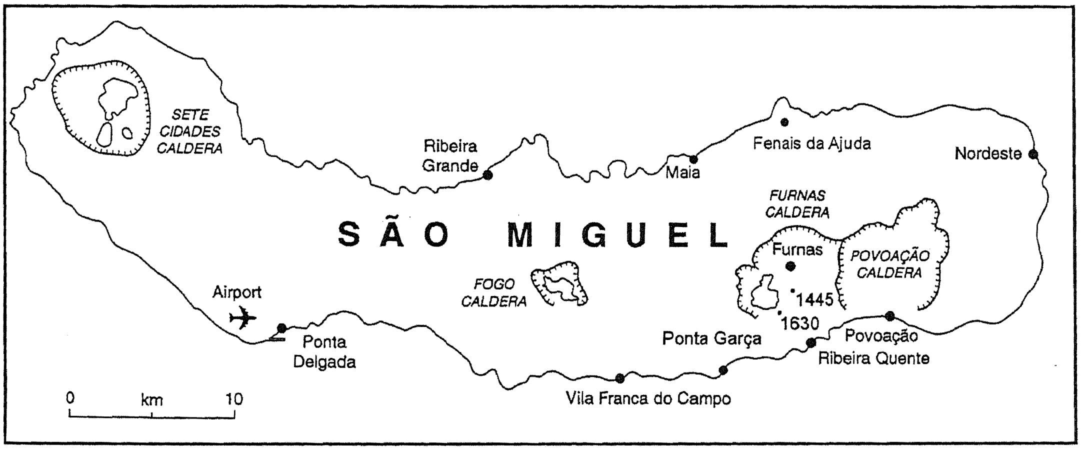


Figure 9.2: The island of San Miguel, showing the towns mentioned in the text, main volcanic structures and the site of the 1445 and 1630 eruptions (based on Chester *et al.*, 1999).

Ponta Delgada is both the capital of San Miguel and also the seat of the regional government of the Azores. The main harbour and airport are both located in Ponta Delgada as are most of the main institutions including: banks, administrative departments, libraries, large shops and the main campus of the University. Almost all of the towns on the island are located along the coast, the interior for the most part being mountainous. The village of Furnas is the main exception to this rule being situated a number of miles inland within the caldera of Furnas volcano. Other towns and villages around the Furnas caldera include Villa Franca do Campo, Ponta Garça, Ribeira Quente, Povoação, Maia and Fenais da Ajuda (figure 9.2). The economy of these towns is to a great extent dependent on farming and fishing and allied trades such as distilling. In the larger towns there is also some service employment in shops and cafes.

9.2 VOLCANIC HAZARDS AT FURNAS

9.2.1 Geological setting

The Azores are located at the junction of three major tectonic features: the mid-Atlantic ridge, the east Azores fracture zone and the Terceira Rift (Guest *et al.*, 1996). San Miguel itself is located at the eastern end of the Terceira Rift which is responsible for the NW-SE features on the island such as the Congro graben on the flank of Água de Pau Volcano and the Mosteiros graben on the flank of Sete Cidades volcano. A secondary structural system is also apparent north of Ponta Delgada where the fractures follow a more EW trend.

Furnas volcano is the most easterly of the three trachytic active central volcanoes on the island, (Zbyzewski, 1961, Booth *et al.*, 1978, Moore, 1990, 1991a, 1991b) the others are Sete Cidades and Fogo (also known as Água de Pau) (figure 9.2). Furnas has, in the past, had major ignimbritic forming eruptions. Furnas is thought to have produced a steep walled caldera after a major eruption around 30,000 years BP but subsequent collapses, including a younger caldera have complicated the geomorphology (Guest *et al.*, 1996). On the volcano's flanks, outside the caldera complex, there are some small trachytic centres and many basaltic cinder-cones with associated lava flows. The fracture systems around Furnas include: a WNW-ESE system that affects the whole volcano and which seems to have shown mainly vertical movement (Gaspar *et al.*, 1995), on the southern flank a N-S trending fracture, a possible NW-SE fracture system and the suggestion of an E-W fracture system control the deeply incised valleys of Lomba do Mosquito and Ribeira do Pico do Ferro.

9.2.2 Pre-historic activity

Booth *et al.* (1978) produced a chronology of eruptive activity on San Miguel for the last 5,000 years. They recognised ten explosive eruptions that had occurred within the Furnas caldera which they named, chronologically, 'A' to 'I' plus the historical eruption of 1630. Almost all the eruptions show evidence of phreatomagmatic activity (Guest *et al.*, 1996) (figure 9.3). This is probably because lakes have existed within the Furnas caldera throughout this period. Plinian to sub-plinian activity have been the most common style of eruptive activity.

Furnas Chronology	
Between ~5,000 BC and ~ 300 BC	Furnas 'A'
~300 BC	Furnas 'B'
~100 AD	Furnas 'C'
Between ~100 AD and ~900 AD	Furnas 'D' and 'E'
~900 AD	Furnas 'F'
~1200 AD	Furnas 'G'
~1400 AD	Furnas 'H'
1440 AD	Furnas 'I'
1630 AD	Furnas 'J'

Figure 9.3: The chronology of eruptions within the Furnas caldera over the last 5,000 years. (Derived from Booth *et al.* 1978; Guest *et al.*, 1996)

At Furnas sub-plinian, and subsequent column collapse activity, has produced small pyroclastic flows and surges (Cole *et al.,* 1995; Guest *et al.,* 1996). There have also been at least three major welded ignimbrite producing eruptions and evidence of one block and ash flow deposit. Associated with these eruptions are tephra fall deposits of various thicknesses. The Furnas 'C' eruption was probably the largest eruption within the last 5000 years. If it were to happen today it might produce an ash thicknesses of 0.5 metres up to a distance of 15-20 km from the vent, while around the vent itself more than 16 metres could be deposited (figure 9.4). It seems likely that remobilisation of the ash will have led to the formation of lahars while the loosely consolidated landforms created during these eruptions will have suffered collapse and land sliding.

Most of the eruptions that have taken place within the caldera in the last 5,000 years occurred in the last 2,000 years (ie. 8 of the 10 recognised eruptions). This represents an average of one eruption about every 220 years. Considering that the last eruption within the Furnas caldera was in 1630 it would appear that an eruption is now due but when the pattern of eruptions is scrutinised there appears to be no systematic pattern in the frequency of eruptions. It is therefore possible to treat the sequence as a random or Poisson process (Shooshtarian *et al.*, 1999) and argue that an eruption is not overdue because the absence of an eruption in any one year does not affect the likelihood of one in another year. Shooshtarian *et al.* (1999) calculated the probability of an eruption occurring in a 100 year period to be about 30%. This figure remained stable when different starting points for the sequence of eruptions were taken (ie. either 1000 BC or 3000 BC).

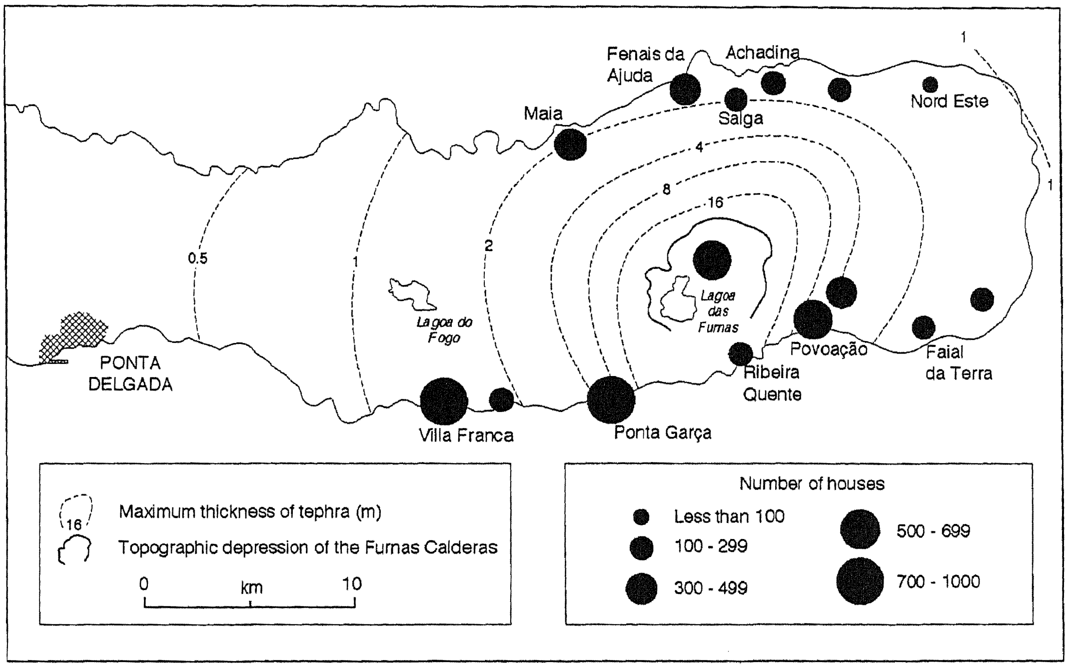


Figure 9.4: Maximum possible tephra fall following a Furnas 'C' size eruption from a vent located in the caldera (from Guest *et al.*, 1996, p. 18).

9.2.3 Historic activity

Five eruptions have occurred on land on San Miguel since the settlement of the island in the 15th century AD: two at Fogo in 1563 (Wallenstein *et al.,* 1998); in 1652 in the so called 'Waist Zone' between Sete Cidades and Fogo (Booth *et al.,* 1978) and at Furnas in 1439-1443 (Queiroz *et al.*, 1995) and 1630 AD. Of the two historical eruptions at Furnas the first, according to early records, appeared to have been taking place at the time of the original settlement of San Miguel by the Portuguese (Queiroz *et al.,* 1995).

Accounts from survivors of the eruption of 1630, indicate that earthquakes were felt for around 18 hours before the eruption (Dias, 1936). This provided a warning and caused some destruction in the towns of Povoação and Ponta Garça (figure 9.2). The explosive phase of the 1630 eruption lasted three days and covered the surrounding area with ash and lapilli, pyroclastic surges devastating the area between the caldera and Ponta Garça killing 80 people, over half the population. In addition, dense pyroclastic flows swept down the valleys to Riberia Quente on the coast. Landslides, mudflows and water floods also occurred and fine ash probably affected the whole island (Cole *et al.,* 1995). Nearly 30 people, who were residing within the caldera area, were also killed in the initial explosions. It is not clear what proportion of those within the caldera this represented but historical sources only record the escape of friars from a hermitage that had been built within the caldera. It seems possible that almost all those within the caldera at the time of the initial explosions were killed.

9.2.4. Volcanic hazards at Furnas

Guest *et al.* (1996, p. 26) argue that six aspects of an eruption need to be known if its nature and effect on various areas of the island are to be predicted (figure 9.5). They consider it likely that the next eruption will not be any bigger than that which has occurred in the last 5,000 years and is most likely to be sub-plinian. The amount of water, at present stored within the caldera, makes phreatomagmatic activity likely. The wind direction is highly variable in the Furnas area but the annual mean does suggest a slight prevalence of north and north-easterly winds. The climate of the Azores means that rainfall is likely at some stage during an eruption, the eruption itself may encourage it. A vent is likely to be located within the caldera of the volcano though it is possible that it might be situated just outside it. Using these parameters it is possible to suggest how different areas on the island might be affected by an eruption.

Hazard assessment of a future eruption
• location of the vent • composition of the material erupted • magnitude of the eruption (ie. amount of material erupted) • height of the explosive column • position with respect to topography and other features such as lakes • wind direction and other weather conditions.

Figure 9.5: Six factors that need to be known in order to assess hazard from a future eruption (Guest *et al,* 1996, p. 26).

The 1630 eruption was preceded by at least eighteen hours of seismic activity of a magnitude that if it took place today the earthquakes would not only be felt by the local inhabitants, but would also cause damage to buildings up to 10 km from the eruption site (Cole *et al.,* 1995). Landslides would also be highly probable and, if these transported large volumes of material into the Lagoa das Furnas, then water could be forced over the eastern lip of the lake causing flooding in the valleys of Furnas and Riberia Quente (figure 9.6). During an eruption the area within the caldera is likely to be devastated by pyroclastic surges and, depending on the location of the eruption, pyroclastic flows could reach Povoação and Ponta Garça. The high walls to the east and north of Furnas will probably prevent surges spreading outside the caldera in these directions, but this would be dependent on vent location. If a vent was located just to the north of the caldera wall then the towns on the northern coastline of the island would be threatened.

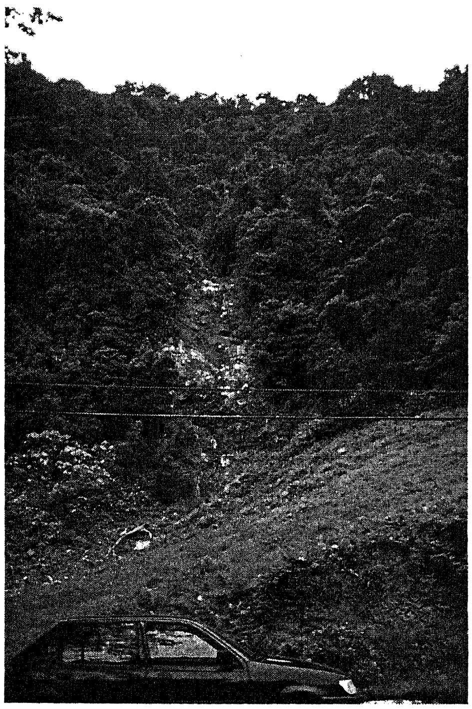


Figure 9.6: The scar left by a recent, small scale, landslide.

Depending on wind directions, it is likely that virtually the whole island will suffer some tephra fall but if the next eruption is larger than that of 1630 then tephra fall will be more extensive. Based on the 1630 fall deposits, areas of up to 5 km away from the vent could receive at least half a metre of tephra fall (Guest *et al.*, 1996) (figure 9.7). If the eruption were to be similar to the Furnas 'C' then areas up to 20 km from the vent could receive that amount. These deposits, given the climate of the area, could be remobilized in the form of lahars which might threaten areas in the drainage basin.

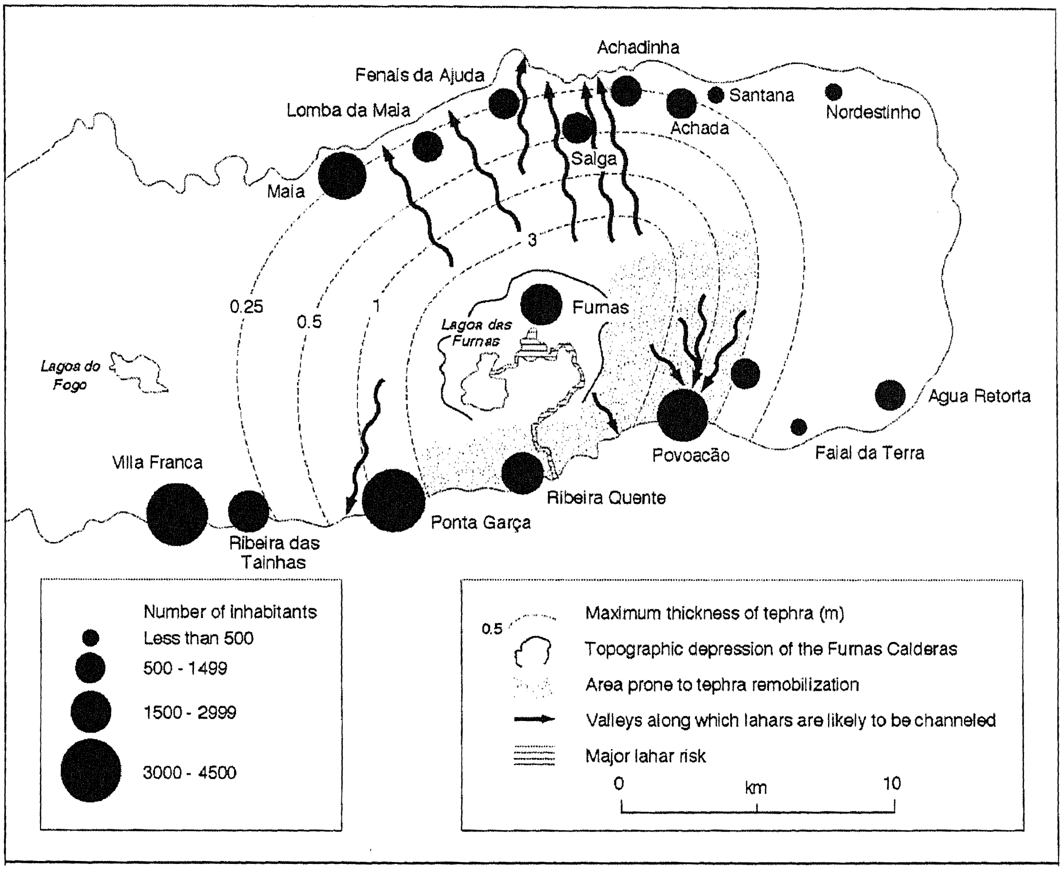


Figure 9.7: Maximum possible tephra fall following a 1630 size eruption from a vent located in the caldera (from Guest *et al.,* 1996, p. 25).

Areas within the caldera complex are also affected by fumarolic activity which releases high volumes of CO_2 in and around the caldera (Ferreira *et al.,* 1995; Óskarsson, 1999). High levels of CO_2 have been recorded in houses, pits, trenches, depressions or confined spaces which fill up with potentially asphyxiating levels of CO_2 (Baxter *et al.*, 1994). Baubron *et al.* (1994) mapped CO_2 soil emissions in Furnas village and identified four zones of medium to high risk of asphyxiation and one large area of low risk. Approximately a third of the village is affected by at least a low level of risk. The CO_2 also acts as a carrier for radon, which has been linked to lung cancer (Baxter, 1994). Fumarolic activity is prevalent throughout the caldera, including a large number of springs within Furnas (Carvalho *et al.,* in press). Although the springs providing drinking water in Furnas are free of toxic metals (eg. aluminium, manganese, arsenic), relatively high levels of fluoride have been found in some of the water supplying the village of Ribeira Quente. This water source has now been abandoned, but there is evidence, in the form of stained teeth, that previously it did lead to fluorosis (Baxter *et al.*, 1994) (figure 9.8).

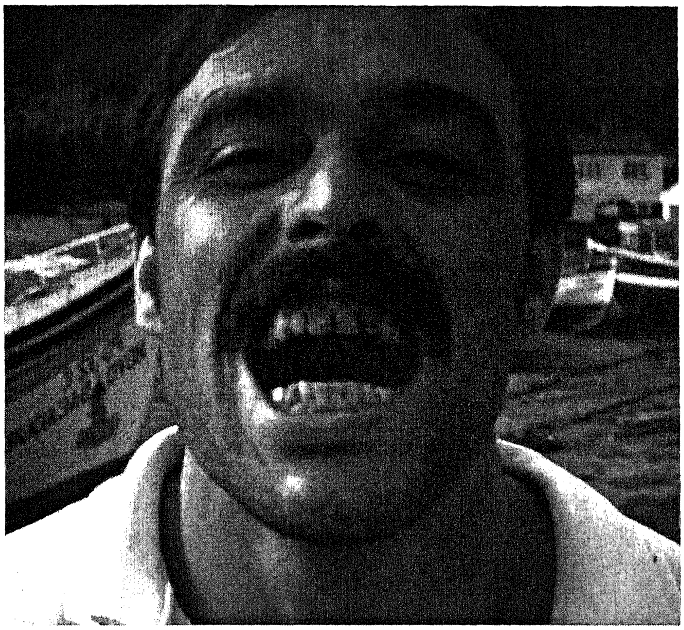


Figure 9.8: Fisherman from Riberia Quente with discoloured teeth, evidence of fluorosis.

Using a 1630 eruption as a minimum scenario it is possible to summarise the hazards that are likely to affect the town of Furnas (figure 9.9).

During periods of activity	During periods of inactivity and activity
Sub-plinian activity Pyroclastic flows (small and large) Phreatomagmatic explosions Domes Lava flows Debris flows	Hydrothermal explosions Gas emissions Floods Rockfalls and landslides Seismic activity

Figure 9.9: Volcanic hazards that may affect the town.

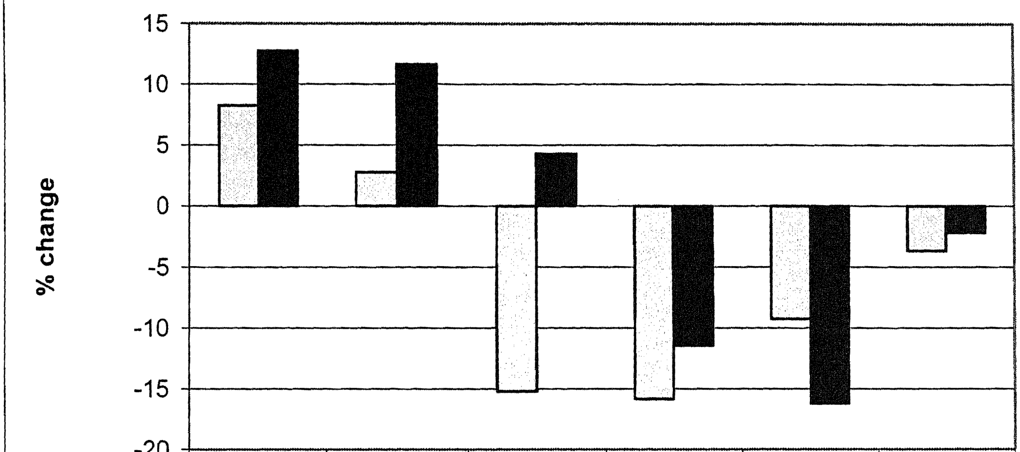
The direction and distance from the site of an eruption will control the impact of the eruptive processes. These factors will be meditated by other characteristics of an eruption in particular topography. For example, the lower lip of southern edge of the main caldera and the valley leading away from it directed the pyroclastic flows and surges of the 1630 eruption towards Ponta Garça and Riberia Quente. Generally villages at a greater distance from the Furnas caldera are under less threat than those that are closer. Villages within valleys or which are downslope of areas where volcanic ash is likely to accumulate may be threatened by lahars. The high north wall of the Furnas caldera may well protect villages along the northern coastline from pyroclastic flows and surges.

9.3 PREDICTING THE EFFECT OF AN ERUPTION

Predicting the likely effect of another eruption at Furnas is difficult, first, because the precise nature of a future eruption is unknown and, second, because there have been no recent events at the site and therefore no indication of how the present community might react to a volcanic event. The 1630 eruption, though useful in providing a likely volcanic scenario, offers no insight into the possible reaction of the present day population. Instead, more recent volcanic eruptions and earthquakes, that took place in similar areas, need to be examined to inform an assessment of likely community response and impact. Two particular events in the Azores are useful in this regard: these are the 1957 eruption of Capelinhos, on Faial, and the 1980 earthquake that affected the central islands and in particular Terceria, San Jorge and Graciosa.

The eruption of Capelinhos, on Faial, was the longest eruption since the settlement of Azores (Scarth, 1994). Lasting from 27th September 1957 to 24th October 1958 it was characterised by an interplay between magma and shallow sea water, a type of phreatomagmatic activity to become known as Surtseyan after the Icelandic eruption of 1963. Although no one was killed in the eruption there was considerable damage to villages and crops. The village of Praia do Norte was badly damaged, though much of this was the result of the associated seismic activity originating on the crest of the Caldeira of Faial and at Praia do Norte and not a result of volcanic activity at Capelinhos. The United States had, after the Second World War, developed a tradition of allowing refugees from particular situations in their home countries to enter the country above and beyond the normal quota amounts (Williams, 1981). In 1958 Congress enacted the Azorean Refugee act which helped to create 1,500 special non-quota visas. A further 2,000 visas were created in 1960 and in all 4,811 Azoreans emigrated to the United States. The effect of this migration on the population of Faial during the 1960's can be seen in figure 9.10.

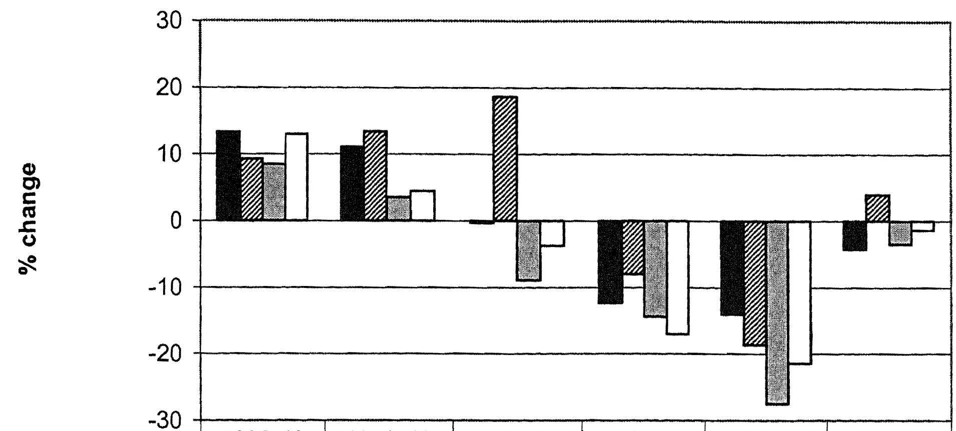
The earthquake that affected the islands of Terceria, San Jorge and Graciosa struck on January 1st 1980. It measured 7.0 on the Richter scale and of the population living on the islands at that time (~80,000) 59 were killed, hundreds were left injured and more than 21,000 people were left homeless (Instituto Açoriano de Cultura, 1983). The death toll from the earthquake might have been much higher if the earthquake had not struck during the afternoon on a holiday with good weather when many islanders were outside. Even so the damage done to buildings was considerable and on the island of Terceria over a third of the population were left without shelter.



	1930-40	1940-50	1950-60	1960-70	1970-81	1981-91
□ Faial	8	3	-15	-16	-9	-4
■ Azores	13	12	4	-11	-16	-2

Figure 9.10: Percentage population increase and decline on the islands of Faial and for the whole of the Azores (without Faial) (SREA, 1993).

In the aftermath of the earthquake, it was feared that there would be another large scale migration as had happened after the Capelinhos eruption (Instituto Açoriano de Cultura, 1983). In the event there was no noticeable increase in migration as a result of the earthquake. The population in Terceira actually increased in the decade after the event and there was a lower decline in the population of San Jorge and Graciosa than there was amongst the islands not affected by the earthquake (excluding Terceira) (figure 9.11). This is probably a good measure of the success of the emergency relief programme that followed. The success of the programme was in spite of the fact that there was no major emergency plan in existence before the 1980 earthquake. It was based instead on an effective *ad hoc* emergency programme.



	1930-40	1940-50	1950-60	1960-70	1970-81	1981-91
■ Azores	13	11	0	-12	-14	-4
▨ Terceira	9	13	19	-8	-19	4
▩ Graciosa	9	4	-9	-14	-28	-3
□ São Jorge	13	4	-4	-17	-21	-1

Figure 9.11: Percentage population increase and decline on the islands of Terceira, San Jorge, Graciosa and for the other islands in the Azores as a whole (SREA, 1993).

The success of the programme of relief has been attributed to a number of factors which are listed in figure 9.12 (Instituto Açoriano de Cultura, 1983). This programme provided temporary and then permanent shelter for the people of the islands affected by the earthquake. Much of the permanent shelter represented an improvement on what had existed before. It also helped businesses that were suffering by providing temporary office facilities and bridging loans.

The migration that had taken place after the Capelinhos eruption was blamed for the slow economic recovery of the island. The length of the eruption may also have made the reconstruction process difficult. The earthquake at Terceria was a one off event, while the Capelinhos eruption continued for a year. For both disasters it seems that the observed increase in migration rate was probably due to individuals who had already decided to leave. They were able to because of a relaxation of the US immigration laws (Williams, 1982). Disasters in the Azores seem to facilitate rather than cause migrations.

Main reasons for success of the reconstruction programme
• The overall management of the disaster response was co-ordinated by a single government entity (Gabinete de Apoio e Reconstrução - GAR) with little interference from the Regional Government of the Azores (RGA). • The GAR encouraged local participation by empowering village councils within the decision making process. This allowed individual needs to be taken into account during the reconstruction process. • All relief funds were pooled within one single account. This simplified accounting but may have made it difficult for non-governmental organisations to gain access to funds. • The willingness of neighbours to help each other by providing temporary accommodation and help with rebuilding. • The presence of the Lajes US military air base and Portuguese army and navy meant that there was a ready supply of labour, resources and air transport. • Making subsidised credit, cheap materials and work brigades available allowed people to rebuild their own homes.

Figure 9.12: Summary of main reasons for success as stated in the report into the reconstruction programme (Instituto Açoriano de Cultura, 1983).

9.4 VULNERABILITY

9.4.1 Location

The distribution of people in the area of Furnas volcano both determines whether they are vulnerable *per se* and also affects the nature of their vulnerability. This is because areas around the volcano are likely to be differentially affected by volcanic products and beyond a certain distance from the volcano there is little or no hazard. It was possible to identify three distinctive groups, who though all located in the Furnas area, spend different amounts of time in the area. These are permanent residents, temporary residents and tourists. The temporary residents are first, residents of Ponta Delgada who maintain a second home in the area and second migrants who retained their family home despite now living away from the island.

Residents of the area spend a large proportion of their time in the area of high hazard, though some might have a time-space path that leads them to be regularly outside the area of hazard. A person, for example, might work during week days in another town outside the area of hazard. The reverse situation exists for people who own a second home in the Furnas area. They will tend to spend a majority of their time outside the area of hazard but will be resident at specific times. Tourists spend a tiny proportion of their time in the Furnas area.

A large majority of the residents of towns and villages close to Furnas volcano are locally employed. The main source of employment is agriculture and fishing or related industries and this means that residents are likely to spend a large proportion of their time within or near their homes. The siting of a number of towns in and around the Furnas caldera is therefore a highly significant factor in the generation of vulnerability within the resident community. Their continued economic and social viability is central to the process that maintains a vulnerable population. The towns, especially Furnas, also draw both second home owners and tourists. Second home owners are attracted because of available housing and family ties with the towns. Many of the towns are also set in attractive landscapes and Furnas has, for a number centuries, developed a reputation as a spa town.

9.4.2 Self-protection

9.4.2.1 Self-protection during periods of inactivity

The health of the residents of Furnas is threatened by both geothermal and seismic processes during periods of volcanic inactivity. Geothermal activity is also an important economic resource, Furnas being an important health spa with many tourists visiting the thermal springs and a bottled mineral water plant. The threat from CO_2 exists most acutely if an individual enters a low enclosed area (eg. a pit, a cellar or hollow in the ground), or breathes assuming a position where their head is close to the ground (eg. crawling, lying on the floor, falling over) in areas where seepage is high. Such behaviour may lead to exposure to dangerously high levels of CO_2. It is the interplay of psychological and social factors that defines whether hazardous behaviour will take place. Risk perception will play an important role in this interplay. Though there is often a weak relationship between attitudes and behaviour (Wicker, 1969), an absence of perceived risk means that an individual will not specifically avoid hazardous behaviour.

Attitudes towards, gas, activity in the village	N	%
It is medicinal	24	48
Use to it, lived with it for a long time	9	18
Don't know if there is a problem	4	8
Worried about the hot springs	3	6
Causes dampness in houses - cold sulphur	3	6
It is a pressure release for the volcano	1	2
People who live near the springs are ok	1	2
Warms house	1	2

Figure 9.13: Content analysis of discussion about gas emissions in the village.

In-depth interviews were carried out with a systematic sample of Furnas residents (n=50). These interviews revealed that not one respondent knew that there was a problem of hazardous gas emission in Furnas (figure 9.13). The respondents instead associated it with a number of benign processes. Many of the respondents believed that the only gas being released in and around the village was the clearly visible steam produced by hydrothermal processes (figure 9.14). A large group of respondents (48%), therefore, believed that gases released in the valley were actually good for their health because the steam help clear colds or was associated with curative mineral waters.

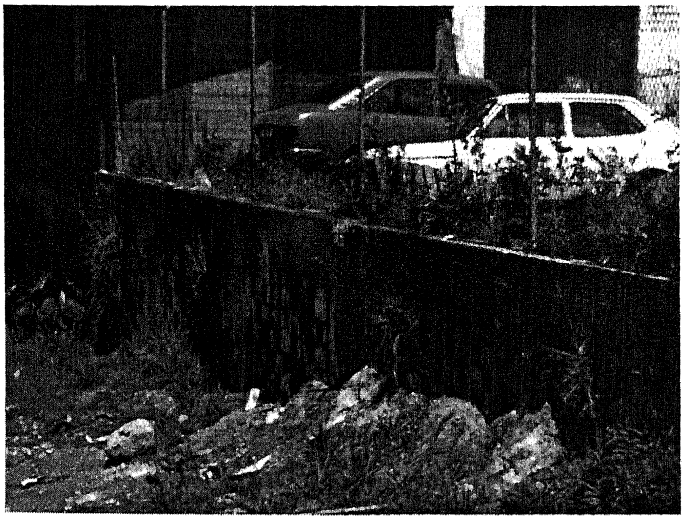


Figure 9.14: Seepage of gas beside a garage. The garage has an inspection pit that fills with high levels of CO_2.

> ..it is good for your health. Many years ago, mothers, when the children have coughs took their children to the springs and because of the steam they got better. There is a water in the springs and because - people take an egg and break it and put it and sugar in the water and

> drink it. This land has so many minerals - I drink many of them (Respondent 35)

18% felt that because they had lived all their life in the area they were 'use to it'. Some respondents (6%) commented on the fact that it caused dampness in their home.

> No, I've been here for 57 years and the only thing that we have here is damp but it is not bad for the health - we don't have steam on the walls in my house. Some scientists from America put some equipment in my house, to do some experiments- it seems ok (Respondent 37)

It seems likely that what they were actually observing in their home was the release of moisture trapped in the cracked, clay, coating of the walls (Personnel communication - Dr Rui Coutinho). These houses tended to be the ones that also had a high of level of CO_2 seepage, presumably, because the cracks were also allowing the gas into the house. Interestingly, although these residents recognised a problem, the dampness that they termed 'cold sulphur', they were not aware of the serious hazard associated with the construction of their home. Other respondents were not aware of any problems (8%). A few (6%) were nervous about it but only because they associated it with the fumaroles and their occasional violent behaviour (figure 9.15).

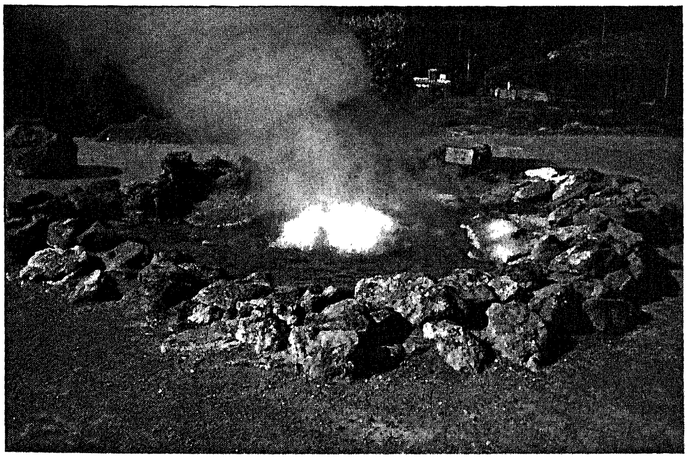


Figure 9.15: A hot spring within the village of Furnas.

Although the author was aware of a number of people in authority, mainly civil defence and medical workers, who had been informed about the CO_2 hazard, the vast majority of the residents of Furnas were not aware of the hazard. Some residents expose themselves to the CO_2 hazard more often than others. Individuals living in houses that are in zones of high seepage, with non-sealed floors (eg. wooden or cracked) and poor ventilation will be more vulnerable than others.

Similarly anybody whose employment involves working in hollows or holes in the ground will be more vulnerable (eg. garage mechanics, building workers etc.) (figure 9.14). Small children are particularly vulnerable because of their limited height and patterns of play.

The relatively high levels of radon found in houses means that residents, especially smokers, are at risk of developing lung cancer (Baxter, 1994). Men will be more vulnerable than woman because of the very low levels of female tobacco use, which were revealed in the survey. In this 'conservative' rural area smoking by women, especially amongst the older generation, is not the social norm.

9.4.2.2 Self-protection during periods of activity

During eruptions the health of all people resident in Furnas will be threatened by volcanic activity. The immediate susceptibility of individuals during an eruption, will principally be a function of their location and their ability to escape the town and caldera. The site of the town is likely to be one of total destruction from which, and assuming there had been no evacuation, there would be few survivors (Guest *et al.*, 1996).

The health of individuals may also be threatened by pre-eruptive seismic activity. Pomonis *et al.* (1999) surveyed housing types in Furnas and pointed to the low resilience of the rubble masonry construction which predominates within the village. Assuming that pre-eruptive seismic activity does not have a Mercali intensity of greater than 5.5, an epicentre towards the centre of the caldera and a focal depth of not less than 10 km, then it is estimated that ~34% of the buildings in Furnas village will suffer at least partial collapse. If collapse occurred during the night, they estimate ~80 individuals would be trapped under debris and ~47 people would die either immediately, or as a result of injuries. If house collapse occurred during the day they estimate ~43 individuals would be caught under debris and ~26 people would die immediately or as a result of injuries. The low resilience of rubble masonry construction is illustrated by their estimate that 40% of this type of building in Furnas is likely to suffer at least partial collapse, compared with 12% of concrete masonry and 4% of non-seismic reinforced concrete frame (Pomonis *et al.*, 1999). The particularities of the model used by Pomonis *et al.* produces a worst case scenario, thus less damage might be expected. Because streets in Furnas are narrow, with housing of up to two storeys backing directly on roads, any collapse is potentially very serious and would greatly impede evacuation.

Potential for escape depends on many factors. Human behaviour during disasters may be adaptive in such situations (Sime, 1990). Contrary to popular imagination it is generally devoid of panic and usually continues to follow social roles and norms until a very late stage, when conditions become extremely severe (Donald and Canter, 1990). An individual who has a good knowledge of what to expect in an eruption, knows how to behave and if helped by the authorities, can often escape (Drabek, 1986).

Of the residents surveyed by the authors none had made any preparations - either mental or physical - for a volcanic eruption. Respondents were generally shocked by the question and most commonly replied that they did not know what they would do or else stated that they would 'run away'. The nature of their responses and reaction to the question seemed to indicate that this was a proposition that they had not given much thought to. It will be argued below that the processes of coping with the threat induced by location, in a majority of cases, involved defending the belief that there was no danger.

Most respondents did not believe that they would have any warning. When discussing whether they could gain information on volcanic hazard, many (50%) felt that there was nobody in the town who could give them advice (figure 9.16). The television was seen as the only source of volcanic information by 44% of respondents and, in particular, Professor Victor Hugo Forjaz of the University of the Azores, who appeared regularly, to talk about volcanic and seismic activity. Other sources of information were through the children or members of the Civil Defence. Clearly, there seemed to be no easy accessible source of information for the villagers.

Where would you get information	N	%
There is nobody in Furnas	25	50
TV or radio	22	44
Through the children	2	4
Civil defense	2	4

Figure 9.16: Content analysis of discussion on where an individual would get information on volcanic hazard from.

It is not surprising that few preparations had been made because few respondents were worried about a future volcanic eruption (figure 9.17). When asked about volcanic hazard all respondents were, however, aware that the Furnas valley was a volcanic area. No individuals thought that there was zero possibility of a future eruption, but all respondents held beliefs that minimised concern. For instance, 34% of respondents indicated that they believed that the presence of fumaroles in the town meant that eruptions were unlikely and earthquakes would be weaker in Furnas.

Views about an eruption	N	%
Less dangerous here, because of springs	17	34
Not happen yet, it is very rare	16	32
Yes, worried when people talk about it	12	24
It is in the hands of God	12	24
It could happen anywhere, so it might happen here	3	6
The hot springs are worrying	3	6
Every one must die sometime	2	4

Figure 9.17: Content analysis of discussion about the threat of an eruption.

Respondent 28 is typical

> The volcano can breath through the hot springs, there have been eruptions in other places but not here. When an earthquake takes place they are not as strong here as they are in other places

Hot springs were believed to act as a release valve, ensuring that the volcano did not reach dangerous levels of pressure and 32% of respondents stated that an eruption had not happened in their lifetime, the implication of this belief being that an event was unlikely.

> This is very rare. Many years ago an eruption took place but until now nothing has happened (Respondent 26)

A number of respondents (28%) seemed to believe that they had little control over future events and held fatalistic beliefs.

> We are always waiting here for this, we live here on a volcano, people ask God not to let the volcano explode - but it may explode at any time (Respondent 23)

> We can die at any time so I am not worried about the volcano (Respondent 11)

Others respondents had a religious view, though still professing a lack of control over future events.

> If the volcano explodes it is God who has caused it. I am not afraid, we should embrace the things God gives us (Respondent 40)

28% of respondents deliberately avoided thinking about an eruption. Respondents who used this strategy reacted with considerable discomfort to the issue when it was raised in interview.

> I never think about it. When an earthquake takes place I am worried but I don't think about volcanic eruptions - they will never take place (Respondent 10)

The ability to avoid thinking about danger was determined to some extent by social interaction (ie. whether the chance of an eruption was being discussed within the community).

> Sometimes when people start talking about this I get worried - but then we forget about it (Respondent 22)

The belief that Furnas is safer than other places because of the hot springs has important behavioural implications. It is part of the process by which residents discount the need to reduce the risks they face. The belief that Furnas is safer is held by people outside the town itself. When Riberia Quente (figure 9.2) suffered from two seismic crises in 1952, people with relatives in Furnas moved there because they believe that the hot springs reduced the likelihood of a damaging event. Since seismic activity will be a probable precursor of an eruption, it is possible that people will move into Furnas during the pre-eruption period and people within the town will decide to stay. This will serve to increase the number of people in Furnas during an eruption. It is also likely that residents will interpret any precursory seismic activity as just seismic activity, rather than being the initial phases of a volcanic eruption. Between 1960 and 1985 San Miguel suffered 12 seismic episodes equal to or greater than 5 on the Mercalli scale, while there have been no eruptions on San Miguel for over 367 years. When asked about what they did during these seismic events, respondents indicated a number of behaviours ranging from 'curling up in a corner' to 'staying in bed'. None suggested they would or had tried to leave the building or remove themselves from the town. Their reasons for this behaviour were related both to fears that 'the ground would open up' and civil defence guidelines which advised people to stay indoors and shelter under door frames. In view of this pre-existing and long-standing pattern of behaviour, it seems likely that vital evacuation time will be lost and the transfer of reliable information made all the more difficult.

The typical reaction to a warning of an impending hazard is disbelief (Drabek, 1969; Drabek, 1986). This process is exacerbated if the hazard is unexpected and the level of preparedness low (Perry *et al.,* 1980). Disbelief results typically in a warning being ignored until the individual receives further confirmatory information (Quarantelli, 1980; Donald and Canter, 1990). The belief amongst the residents of Furnas that an eruption is unlikely, means that they are likely to ignore early warning signs and so delay the start of an evacuation.

Escaping may be delayed if individuals do not know that others are escaping. In the 1973 Summerland fire on the Isle of Man (UK), parents tried to collect their children rather than evacuate the building and this delayed their escape and caused blockages (Sime, 1983). Furnas district has a dependency rate of 40% (ie. population under 15 and over 65 - SREA, 1993) and there would be the potential for a delayed evacuation if individuals responsible for dependants were not confident that they were being evacuated to safety. The dependent group might also find it difficult to evacuate, not being able to move long distances on foot or rapidly. There has also been a commonly observed inverse relationship between age and propensity to evacuate (Mileti *et al.,* 1975). This has been attributed to a decreasing level of contact with both the community and with sources of warning with age (Perry, 1985). In a small nucleated settlement such as Furnas this effect is likely to be less pronounced than in an area of dispersed settlement because of the high levels of contact between residents.

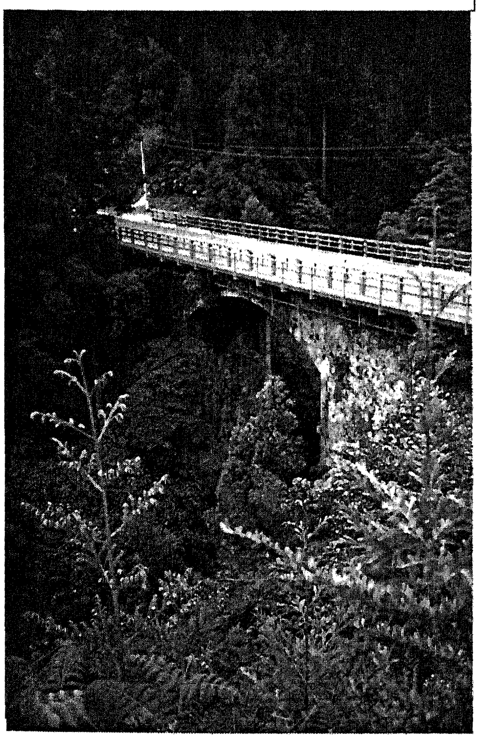


Figure 9.18: Masonry bridge

The potential for escape will also be determined by a number of factors beyond individual control or action. These include: slope stability; building design; vehicle availability; weather conditions and organisational responses. Seismic activity could also seriously disrupt the evacuation process. All the roads out of the caldera have a number of points at which they are likely to become blocked if seismic activity were to precede an eruption (Chester *et al.*, 1995). These include masonry bridges, unstable slopes and stretches of road in forested areas (figure 9.18). Lines of communication might be broken by the release of the large quantity of water held within the caldera (figure 9.19). Although 27% of people in the Azores own a car, the rate for agricultural workers is only 4%, which is more typical of the Furnas District (SREA, 1991).

Figure 9.19: Map of main lines of communication out of the caldera. Each reporting locality represents a point where the road might be broken in the event of seismic activity (from Chester *et al.*, 1999).

9.4.3 Physiological and psychological resilience

Extreme psychological and physiological stress will be placed on individuals during an eruption. This is especially true of individuals who live in and around the Furnas caldera, as they are likely to experience the stress as a result of having to evacuate, see the destruction of their homes and community and possibly, depending on how successful the evacuation is, the death of family, friends and neighbours. Individuals living further away from the Furnas caldera are likely to have a less stressful experience although this will be mediated by their own personal situation. They may, for example, have friends or family in the area of high destruction.

The ability of individuals to cope with different levels of stress seems to vary as do the negative consequences of such an experience. It is not possible to predict who will be able to cope with highly stressful events. The only way, therefore, to reduce the number of very bad cases is to ensure that no one experiences very high levels of stress.

Although climatic conditions on San Miguel are relatively mild, if evacuees were outside for a long period without adequate protection they could suffer from exposure, especially at higher altitudes (Chester *et al.*, 1996). This would be the case if the evacuation took place in the winter, at night or periods of high rainfall. Children, the sick and the old would be the most at risk although the problem is clearly not as acute as that experienced in areas with a harsher climate (eg. Iceland). Problems would also occur if the evacuated had nowhere to shelter once they were outside the devastated area and the severity of this problem would be determined by availability of shelter. If Ponta Delgada had to be evacuated, which seems unlikely in the event of a 1630 type eruption, then there would be an acute shortage of accommodation on the island. Otherwise a very large number of people could probably be accommodated in the town. The speed at which emergency shelter could be moved to the island would also affect the chances of the physically frail suffering exposure.

9.4.4 Livelihood and resources

Some people, including second home owners and those that only work in Furnas will suffer some economic losses while for others, whose sole home and livelihoods are in Furnas, the effect will be devastating. Second home owners are generally from other parts of the island or live in America, Canada or on mainland Portugal. Although these people have economic and leisure interests within the town, they have a high proportion of their wealth and livelihoods away from the volcanic area. Tourists, commuting workers and visitors all have a majority of their livelihood outside the area of hazard. Chapin (1989) identified five main social groups within San Miguel society. *Trabalhadores* or manual workers who usually act as labourers for others, though many own or rent small plots of land which they cultivate. In a town like Furnas they are typically agricultural labourers - raising crops, picking fruit or tending cattle. The *proprietários* own land and do not work for others. In rural areas they own small scale village businesses (eg. bars or shops) or farms. The *established educated* are the professional class. They rarely live in rural villages and towns but many own second or summer homes. *New entrepreneurs* mainly live in Ponta Delgada. The *Nobreza* are the descendants of the original island settlers and still own large areas of land. They live mainly in Ponta Delgada. The permanent residents of Furnas are either *Trabalhadores* or *proprietários*.

A volcanic eruption within the caldera would probably result in the destruction of a majority of buildings in the town. Crops would be destroyed and land sterilised. Livestock within or near the caldera would probably be killed by explosive activity and those surviving might die of starvation or poisoning from ingesting ash and loss of grazing opportunity. The structures supporting the tourist industry - such as hotels, gardens, springs, hospital and the landscape - would be largely destroyed, while the tourist trade to the island of San Miguel would be badly affected.

Basic insurance	N	%
No - no reason given	31	62
Yes	11	22
No - too expensive	5	10
No - rented house	3	6

Figure 9.20: Content analysis of discussion on house insurance.

Although diversity of trade, land and means of production is typical amongst rural dwellers (Chapin, 1989), this is unlikely to protect the residents of Furnas in the event of an eruption. The economic fabric of the town is likely to be destroyed; having two trades or non-contiguous land holdings or reciprocal relationships with neighbours would not protect an individual or family. Only a small percentage (22%) of respondents, in Furnas, had household insurance and for those that did it is likely that their policy would exclude damage caused by 'natural' disasters (figure 9.20). Having resources or access to a livelihood based away from Furnas might reduce vulnerability. *Proprietários* sometimes have bars, shops or market stalls in other towns (Chapin, 1989), but the towns would have to be in an area not adversely affected by an eruptive event. Savings and other resources, located away from Furnas, would also reduce the vulnerability of an individual. *Proprietários* are more likely than *Trabalhadores* to be in this position, while the *Nobrezza* often have resources overseas (Chapin, 1989).

On the whole quite a large group of respondents, 42%, felt that in the case of a catastrophe (eg. a house fire) befalling them, they would have to fend for themselves (figure 9.21). This seems quite a pessimistic and unrealistic view given the real experience of those who lost their homes in the 1980 earthquake. A sizeable group, 34%, believed that people in the village would offer non-financial help, such as accomodation or sustenance in the short term. Interestingly only 6% of respondents mentioned family help in the discussion. It seems possible that this may be because they were not prompted to confirm or deny whether the family would assist and took it for granted that they would.

After a catastrophe	N	%
People don't help, you would be on your own	21	42
Help, other than money	17	34
Government might help	9	18
Family would help	3	6

Figure 9.21: Content analysis of discussion on the type of assistance that would be available after a catastrophe.

9.4.5 Emergency organisation response

The organisational response to a volcanic crisis at Furnas will be vital in determining an individual's vulnerability. It will be necessary for the emergency and scientific organisations to interpret information and act quickly. Modern measuring instruments and a greater knowledge of volcanic processes allow scientists to interpret the warning signs of magma movement at an early stage. While the inhabitants of the area only had 18 hours of pre-seismic activity in 1630 to warn them of an immanent eruption, it is likely that today's inhabitants will have a greater amount of time.

Although monitoring systems provide the means by which a successful evacuation can be achieved, problems may arise from the emergency processes themselves. One problem lies in the difficulty of interpreting information provided by the monitoring instruments and then deciding when to order an evacuation. While the available instruments are good at identifying that a change within the volcanic system is taking place, the picture is not always clear. Forecasting exactly when it would be wise to evacuate or move back into an area is therefore difficult. This might not be a problem if evacuations did not cause such large scale individual and regional disruption. The decision makers within the emergency organisations, therefore, need to balance conflicting external pressures (eg. the economic cost of ordering an unnecessary evacuation) within a situation of great uncertainty. It is in this difficult situation that mistakes have been made that may have ultimately led to loss of life.

While the author was carrying out field work in 1994 there was no emergency plan for the villages around Furnas nor was there any permanent monitoring equipment. This has since changed with the establishment of a seismic network covering the Furnas edifice. Work carried out by the European scientists on Furnas, as a designated European laboratory volcano, during the early 1990's established baseline information. From this information it is now possible to recognise changes in gas composition and ground deformation that might be indicators of a future eruption (figure 9.22).

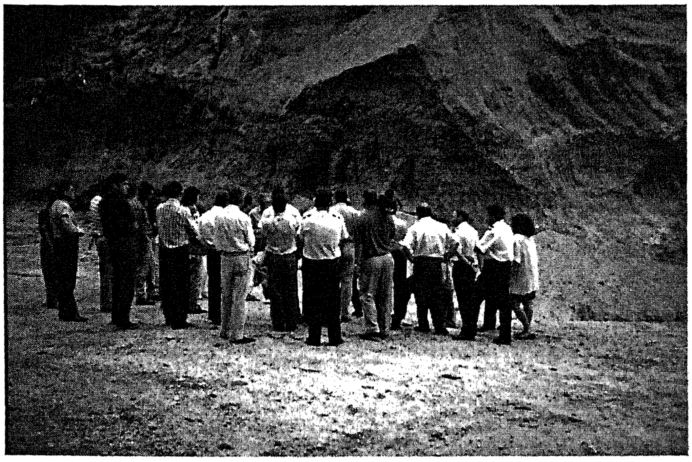


Figure 9.22: Civil defence and local government officials are informed, by British and Azorian scientists, of the volcanic hazards that exist in the Furnas area.

9.4.6 The reaction of family, communities and society.

The reaction within a society to an eruption can have a profound affect on an individual's situation. It is commonly believed that evacuations are dominated by anti-social behaviour such as looting (Wenger *et al.*, 1975). Although anti-social behaviour does occur during disasters it is typically a reflection on the situation that existed before the disaster rather something the disaster generated *per se*

(Drabek, 1986). The aftermath of the 1980 Azorian earthquake was epitomised by individual self sacrifice and group self-help (Instituto Açoriano de Cultura, 1983). Neighbours and relatives shared their homes; there were no incidences of looting or violence and there were no abuses of the reconstruction programmes. Although a post eruption situation would be different from that which existed after the 1980 earthquake, there is no reason to believe that Azorean society would not react in the same way.

For residents of Furnas, interviewed by the author, the community within the village is psychologically, socially and economically important. Its destruction and the potential dispersal of residents would represent a significant loss. After the relocation of towns forced by the 1941 eruption of Parícutin, Mexico, Nolan (1979) reported that some old people seem to loose the will to live and quickly died amongst the unfamiliar surroundings of their new homes. The position of the town would make reconstruction on the original site difficult if not impossible in the short term. Maintaining the town as a unit on a new site might help with recovery but this could only be a temporary measure. Research indicates that those who evacuate and do not return suffer higher levels of stress than those who opt to stay in a disaster hit area (Raphael, 1986).

The wider social effects of an eruption are harder to predict. It is clear that even a fairly small eruption would have profound 'knock-on' affects on the economy of San Miguel. Ash fall across the island would have a damaging affect on crops and livestock across the whole island, the tourist trade would be temporally suspended and industrial concerns disrupted. It is likely that the Satisfiers of basic needs such as medical provision, appropriate education and adequate shelter, that are typically provided through the government, will be set-back. On the other hand in the aftermath of a volcanic eruption it is likely that funds and aid would be made available from Portugal, the European Union and the United States, which have close ties with the islands. After the earthquake struck the island of Terceira, in 1980, the construction industry on the island boomed. The price for construction work increased 30-40% and construction workers salaries increased to two or three times their pre-earthquake level (Instituto Açoriano de Cultura, 1983). There was also an influx of workers from other islands and from the mainland which, it was reported, led to social problems such as prostitution and drug abuse. The new houses, provided for the homeless, were in many cases, however, of better quality than those they had lived in before and the standard of many people's living clearly improved after the earthquake. The rebuilding of Furnas, unlike that of the earthquake struck towns of Terceira, could not take place, certainly in the short term, on the towns original site. Difficult decisions would have to made as to where to relocate the residents in both the short and the long-term. As Nolan (1979) concluded from her study of the resettlement of the towns affected by the eruption of Parícutin, the success of the new towns was strongly linked to the resident's views being included in the resettlement process. There were serious conflicts between the relocated people and neighbouring towns and between those that had left the volcanic zone and those who had stayed behind. This conflict centred around land and economic interests. Any relocation will be fraught with problems, especially on a fairly densely populated island like San Miguel where a majority of land is already being exploited and there is not a large industrial or service sector to absorb surplus labour.

9.5 CHANGE IN VULNERABILITY

Vulnerability is principally a function of the social, environmental and economic context within which an individual or group exists. The siting of towns and villages around the Furnas caldera is one of the principal elements in the resident's vulnerability. Secondary causes stem from the development of the economy, social structure, culture of the communities and individual psychological processes. These aspects are linked to the settlement and development of the island of San Miguel and the political, social, economic and cultural factors that have influenced it. This can be seen as the *root cause* of the inhabitants' vulnerability.

9.5.1 Historical development of the settlements around Furnas volcano

The development of San Miguel began with the settlement of coastal sites, with suitable anchorages, and the exploitation of resources proximal to these sites. Other settlements were started and developed under the influence of opportunity, land ownership, pressure from population growth, government decision making and, more generally, changes in the world economic and political scene. Furnas and the other villages around the Furnas caldera seem to have developed under these influences, little affected by the volcanic hazard inherent in its location. The two volcanic eruptions, during the period of the island's settlement, have only halted the growth of these villages in the short term.

The exact date in which the Azores were discovered is uncertain. Some sources argue that maps such as the Angelino Dulcert of 1339 and the Mediceu atlas of 1351 show the Azores (Bento, 1994). The first Portuguese landings on the archipelago seemed to have taken place in the late 1420's or early 1430's, the islands were uninhabited before this time (Chapin, 1989; Bento, 1994; Guest *et al.*, 1996). The strategic importance of the islands lay in their location on the return leg of the trade routes from Europe to the 'New World' (Chapin, 1989). It was an importance that was to be maintained in the following centuries and one that was to see them come under the influence of different dominant maritime powers at various points in history.

The initial landing, by an expedition led by Gonçalo Velho Cabral, was on the island of Santa Maria (Chapin, 1989). San Miguel was the next island within the archipelago to be settled, this probably took place around 1444. Power within the islands was located with various local governors who were appointed by the Portuguese crown as hereditary captaincies. This initial distribution of power was to have an important effect on the economic, social and political development of the islands in the coming centuries. As well as the authoritative resources presented to some families in the form of colonial administrative positions, allocative resources were given to other politically significant families. The recipient of land was then expected to finance the exploitation of the land by moving workers at their own expense to the island (Williams, 1982). This lead to the domination of a few cash crops within the agriculture system and, indeed, the economy of the islands as a whole as landowners attempted to rapidly recoup their investments. The descendants of these original nobles were to dominate the polity and economy of the islands to the present day. The workers brought over to the Azores were not only Portuguese but also came from a wide variety of European states.

The first settlement of San Miguel took place during an eruptive phase in the Furnas caldera. Cabral had landed at Povoação (figure 9.2) and left slaves to clear and prepare land for cultivation (Guest *et al.*, 1996). When he returned in 1445 he was given reports describing loud noises, lightning and tongues of fire coming from the Furnas valley (Dias, 1936). This initial phase is likely to have coincided with the late dome forming stage of an eruption that had begun in the early 1440's (Queiroz *et al.*, 1995; Guest *et al.*, 1996). The process of settlement does not seem to have been disturbed by the active volcanism taking place at the same time in an area neighbouring the first settlement. This, therefore, was evidence at the very beginning of the settlement of the island that the exploitation of opportunity and the constraints of structure were to override the hazard presented by volcanism.

The settlement of the area around the Furnas caldera was to continue over time with a number of important events affecting it. Because of the lack of a suitable anchorage at Povoação, Vila Franca do Campo had become, in the late fifteenth and early sixteenth centuries, the main port and town in San Miguel and indeed the whole of the Azores (Dias, 1936; Bento, 1994) (figure 9.2). Although the town was some distance from the Furnas caldera, it was within range of volcanic activity. In 1522 an earthquake and associated debris flow destroyed the town, killing ~5,000 people. The town never recovered its prominence after this event and the administration of the island was moved to Ponta Delgada which in turn flourished. The town of Povoação had been established at the original landing site and other towns had grown up close to the Furnas caldera, these included Ponta Garça, Maia and Porto Formoso. All these towns exist today and represent the location of a large majority of the population vulnerable to the effects of the volcano.

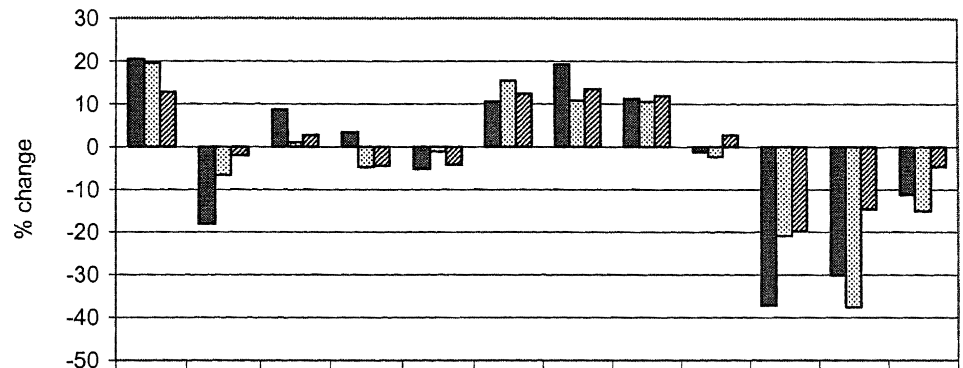
The earthquake that struck Vila Franca do Campo was to have important consequences in terms of increasing future vulnerable population because it encouraged the settlement of the Furnas caldera. Settlement of the caldera had started at the end of the 15th century, probably only 50-60 years after the cessation of eruptive volcanic activity (Martins, 1990; Cole *et al.,* 1995). The initial settlers of the caldera or valley were foresters and herders who were exploiting the valley for wood and grazing land for goats. Exploitation of wood from the valley was encouraged by the need to find building materials after the destruction of Villa Franca da Campo in 1522 and so temporary settlements were created in the caldera. A more permanent settlement of the valley began with the establishment of a hermitage by the friars. The eruption of the volcano in 1630 brought a sudden end to this first phase of settlement (Cole *et al.,* 1995). Although the friars at the hermitage were to escape, 30 people located in the caldera and closer to the eruptive centre were killed in the eruption. The village of Ponta Garça was very badly affected by south and south-west flowing pyroclastic flows and surges from the eruption. Over half the population was killed (~90-115) and almost all buildings in the town were destroyed (~100), many affected by the associated seismic activity. The other villages around the Furnas caldera were less seriously affected. They mainly suffered pyroclastic fall rather than surges and flows.

Despite the eruption, the village of Ponta Garça was rebuilt and the settlement of the Furnas caldera continued fairly soon after 1630. Jesuits, who had been given the land within the caldera, encouraged settlement by renting plots of land to inhabitants of neighbouring towns and people began to resettle the valley after 1665 (Dias, 1936). By 1706 there were 74 people living in the valley in 22 houses (Martins, 1990). The Jesuits as well as encouraging settlement of the valley also started to identify and record the different 'mineral waters' that could be found within the caldera (Martins, 1990). These mineral waters were to play a very important role in the development of the area. In 1760 the Jesuits were forced out of the Azores on the order of the Marquis of Pombal and the land in the valley was auctioned (Bento, 1994). By the end of the 18th century the population had grown and the parish of Furnas was established in 1792 (Martins, 1990). In 1790 Felix De Valois E Silva came from Lisbon in search of a medical treatments. He believed that the mineral waters of Furnas had medicinal qualities and spread the news of their healing powers (Anon, 1993). At around this time a doctor from Madeira, Dr Guilherme Gourlay, carried out the first comprehensive survey of the mineral waters (Anon, 1993). These two events were important because they established the village of Furnas as a therapeutic spa town. In the 18th century the orange trade was developing on the island and trade links with Europe and America were increasing (Chapin, 1989). Wealthy Azoreans, mainland Portuguese and foreigners started to visit and to build homes and gardens in the town and around the Lagoa das Furnas (Anon, 1993). Bath houses were constructed to collect water from the springs and fumaroles and by 1839 there were four (Bullard and Bullard, 1841) (figure 9.23). In the 19th and 20th Century this resource was to play an important role in the development of Furnas. It was to act as an important base for the tourist trade complementing other attractions such as the areas dramatic and beautiful landscape.

Figure 9.23: Bathmen and bath houses in 1839. (from Bullard and Bullard, 1841, p. 160).

The island's polity and economy, throughout its history, was strongly affected by events beyond its own coastline. The villages in and around the Furnas caldera were also subject to these forces but their location near the volcano did not seem to be influenced, except in the special case of Furnas village where the by-products of volcanism were to provide a recreational and medical resource. The economic history of the island up to the present day has been dominated by the rise and fall of specific cash crops. The reason for this lies in the large estates that were established on the island when it was first settled (Williams, 1982). Landowners, often absentee, were interested in producing cash crops for export rather than trying to establish agricultural self-sufficiency. Because of the dominance of a single crop within the economy the island tended to follow a boom and bust cycle as new markets were found and exploited and then lost. For example woad was grown in the fifteenth and sixteenth century providing a blue dye to the European market, it was overtaken by indigo from America in the mid-seventeenth century. In the eighteenth century citrus fruit and wine grapes became very important to the islands economy. Much of the citrus trade was with England, in 1870 500,000 boxes of 300-400 oranges were shipped to England from San Miguel. The isolation of the islands meant that in times of crisis, when supplies of products needed in their staple industries were cut off, their economies could be thrown into crisis. When, in the late 1830's, the supply of wood was cut off, the island was virtually deforested in the search for wood to crate fruit.

Dependence on a few major cash crops meant that when a number of diseases and pests invaded the island in the mid-nineteenth century the economy was devastated. These diseases and pests included: in 1835 the *Aspidiota conchiformis* bug which was imported from America and attacked the orange tree, in 1850 potato rot which struck at the islanders stable diet and in 1853 the fungus *Oidium tuckeri* which attacked the grape vine (Walker, 1886). The combination of failing crops, improving communications and opportunities overseas meant that San Miguel, as with the other islands on the Azores, experienced a great deal of out-migration in the latter part of the twentieth and early nineteenth century (Chapin, 1989). This included migration to Brazil, in the 1870s and 80s to Hawaii, America, Bermuda and Canada. Restrictions on migration to America and the return migration, due to economic depression in America, led to a rise in the population on San Miguel in the 1920's and 30's (figure 9.24) (Williams, 1982). The Second World War further restricted migration and by 1960 the island had reached a new population high. The size of the San Miguel's population in 1960 was taxing its resources and as a result of this and changes in the American and Canadian immigration policy in the 1950s and 1960s, there was a renewal of out-migration (Chapin, 1989; Williams, 1982).



	1864-78	1878-90	1890-1900	1900-11	1911-20	1920-30	1930-40	1940-50	1950-60	1960-70	1970-81	1981-91
Furnas	20	-18	9	3	-5	11	19	11	-1	-37	-30	-11
Povoação (RQ)	20	-7	1	-5	-1	15	11	11	-2	-21	-38	-15
São Miguel	13	-2	3	-4	-4	12	13	12	3	-20	-15	-5

Figure 9.24: The percentage increase or decrease in population between censuses for the Freguesia of Furnas, Povoação (including Ribeira Quente) and the whole of San Miguel excluding Furnas and Povoação.

The villages in and around the Furnas caldera generally experienced similar levels of migration as the whole island. To take Povoação as an example (figure 9.24). It is clear that, apart from 1950-60, the village has followed the general trend for in and out migration. The fact that the town is built on the edge of the Furnas caldera does not seem to have affected the movement of people in and out of the community. Instead the migration pattern reflects the internal and external economic and political context of the village.

In the 1930's trans-Atlantic flights would stop to refuel on San Miguel and for a time flying boats landed on the Lagoa das Furnas. Accommodation for visitors had originally been in private homes then in small hotels, by the 1920's there were a number of hotels in the town and a casino (Almeida and Rego, 1990). The Second World War and long distance jet transport put an end to this trade (Sayers, 1994). The population of Furnas has fallen and risen with the various periods of migration that have been common to the island as a whole (figure 9.24). It has reflected the specific economy of the town, in particular the tourist, mineral water and spa trade, and the more general trends within the economy of the island. There is no evidence that the development of the town has been hindered by volcanic risk. Indeed, volcanic eruptions only seem to have affected the development of the location for a short period after they have occurred.

9.5.2 Contemporary decision making

It is possible to gain some insight into why the villages around the Furnas volcano could develop into a site of potentially catastrophic volcanic activity despite there being two historic eruptions, by analysing contemporary beliefs and constructions of risk of the residents of Furnas. For the respondents, volcanic hazards did not appear to be a major issue of concern. Of the sample of Furnas residents most had either been born in Furnas and had lived all their lives in the town or had moved to the town as a result of marriage. A small number of the sample, originally from Furnas, had lived in Canada or America but had returned to the town. One woman had move to Furnas because she liked the town. In all cases the reasons for living in Furnas were grounded in a complex social history within which no apparent assessment of the volcanic risk had been made.

The majority of sampled residents seemed to feel an intense psychological attachment to the town and community. Place attachment is defined in the literature as the interplay of emotion, cognition and practice in a local environment (Low and Altman, 1992). Place attachment generally reflects stability and the long-term bond between people, their homes and their communities (Fried, 1963; Cochrane, 1987; Rivlin, 1987). In order to try and find out what the individual's feeling towards the town was, respondents were invited to discuss what the positive aspects of living in Furnas were (figure 9.25).

Positive aspects of life in Furnas	N	%
The natural beauty of the area, the closeness of nature, economic prosperity that comes from it	29	58
Everything is good	12	24
Don't appreciate it, it is an under utilised resource, could be used more in the future	8	16
Feel at home, land of our ancestors, always be good	8	16
I have nothing to compare it with	1	2
Social life, feeling of community	1	2

Figure 9.25: Content analysis of discussion on the positive aspects of life in Furnas.

When respondents were asked to discuss the positive aspects of life in Furnas, 58% singled out the natural environment, the natural beauties and wonders of the valley. Many respondents seemed to be expressing a genuine awe of their natural environment.

> I like everything about the town especially natural landscape (Respondent 38)

> Nature is the thing I most like, nature and greenery (Respondent 21)

For one respondent, what the residents in Furnas had was quite fundamental.

> Every one should have a link with nature. People from the big cities they live in apartments and the people from the fifth floor don't know those on the first. The world will end suddenly because people don't know each other, they don't say good morning, we live in a community (Respondent 39)

Respondents talked in terms of the natural landscape as 'their land' (16%) and there seemed to be an emotional attachment to the natural environment around Furnas (figure 9.26). This emotional attachment was associated with it being their 'home'. It meant that they could only feel positively towards such a place.

> People like their lands and I shall never leave here (Respondent 1)

> I like the nature, the mineral waters, everything that belongs to Furnas.
> I feel good in Furnas (Respondent 23)

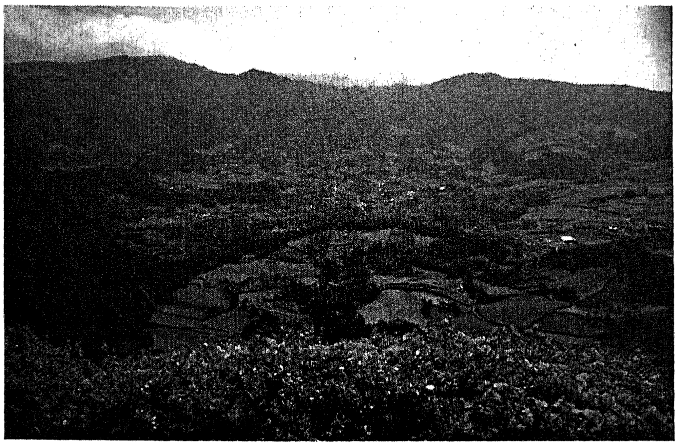


Figure 9.26: Looking from the western lip of the Furnas caldera down towards the village of Furnas.

A number of respondents (16%) commented that they, as residents, did not really appreciate the benefits of living where they did. It was also felt that this lack of awareness probably meant that the area was not fully exploited. It was possible that tourism could bring far more money into the village if were better managed.

> Here we have many things to attract tourists - in other places in the world they make something from nothing - they make very beautiful things to attract tourists and yet we do not take advantage of these things. Here we have many natural beauties and yet here we do not use them. The hot springs with their beauty and steam are not used enough. In the other places waters are artificial. The problem is with the farmers and lake....I am not from here but I know the other Islands of the archipelago and for me the most beautiful places in the Azores is the lake. There is a campsite that needs improving , with bathrooms . Many people go there and the government must do something - they say they will...The government say they will buy land but they do nothing (Respondent 4)

Negative aspects of life in Furnas	N	%
No problems	30	60
No jobs for the young	6	12
Tourists and other outsiders	5	10
Change in the community	5	10
Natural hazards	4	8
Prices of things	4	8
Drugs, music and aggressive behavior	4	8

Figure 9.27: Content analysis of discussion of the negative aspects of living in Furnas.

While the positive aspects of life in Furnas were generally stated in terms of the natural environment, problems were related to the social and economic environment. Sixty percent of respondents felt that there were no problems in Furnas (figure 9.27). For a proportion of those who felt there were, the influx of 'outsiders' was seen as a root cause of a number of problems. 'Outsiders' not only included tourists but also residents of other towns, especially the island's capital Ponta Delgada, who had purchased second homes in Furnas. The perceived effect of this in-migration was higher prices especially in the housing market. This meant that young people could not buy homes and long-term residents were finding it expensive to live.

> One problem is that young people here can not afford houses because other people can offer more money. People from Germany, America and Canada buy houses here. The house there belongs to other people (indicates house across road). A lot of the houses belong to people who come to spend the weekend. Were you here in August? The only people here were people from elsewhere (Respondent 5)

The presence of outsiders also seemed to be unbalancing the social fabric of the town. By not behaving in the way a resident of the town would behave they were undermining the expected norms or social rules. This might manifest itself simply in not greeting someone in the street

> They come a lot in the summer and don't come in the winter. We are very alone in the winter. Here many homes are owned by people from outside , my neighbours are very distant (Respondent 21)

The influence of education was another outside force that the respondents saw as problematic. It was perceived that the changing vocational aspirations and educational levels of the young people meant that Furnas could no longer support them. The lifestyles that the respondents had accepted were being rejected by the young.

> More people should be used to other types of work - that are needed here. Young people do not want to work, there are jobs but the people do not want to work (Respondent 4)

> They (the government) cannot do everything, they clean the street - they can not do more because they don't have the money. The young people don't want to work. They only want to study. The government doesn't have money to employ all these people (Respondent 11)

A number of respondents mentioned that anti-social behaviour was also rising including drug use, drunkenness, fighting and littering. Frequently this type of behaviour was linked to the 'outsiders'.

> We know that there is corruption in our land - no its not like corruption, I don't know how to say, it is like our customs and habits are being brought in by people from all different places. They have a lot of freedom and our young people are developing bad habits and customs (Respondent 39)

When talking about the problems and benefits of life in Furnas all respondents seemed to define them within the context of their own attachment to place; the emotional, cognitive and behaviour embeddedness of an individual in a specific socio-physical setting (Brown and Perkins, 1992). The positive aspects of life in Furnas centre around a strong emotional feeling for the 'natural beauty' and 'wonders' of the valley and in a sense that it is their home. The problems were all related to a disruption of the social environment of the town, an intrinsic part of an individual's attachment to a place. This disruption was perceived to be caused by elements external to the town, second home buyers, visitors, the education system and modern culture. The manifestations of this disruption were unemployed young people, empty houses, neighbours who did not understand the social rules of the town, high prices and increasing levels of violence and anti social behaviour.

The residents seem, at least at a discursive level, to be unaware of the threat they face from volcanic activity. Other problems, as demonstrated above, seem to hold a far more significant place in their minds. Only one of the respondents mentioned the threat of an eruption when discussing the problems of living in Furnas. When the respondents were forced to discuss the possibility, their reasoning and discussion seemed to reflect an active process of mental risk reduction. While, when respondents were questioned about the potential of a volcanic eruption all their responses indicated that they knew that one could happen, almost all gave some reason why this was not likely.

It is possible to suggest that they suppress this cognition, that there is a substantial volcanic threat in Furnas, because it is psychologically inconsistent with others or is a situation of *cognitive dissonance* - a negative drive state or an uncomfortable feeling that requires action. (Festinger, 1957). In the case of the resident of Furnas it contradicts the belief that Furnas is a good place to live or that they have made the right decision, in the past, to stay in the town (Dibben and Chester, 1997). Cognitive dissonance could be removed by actually changing the risk they face but purposeful or deliberate risk reduction generally involves a cost (eg. in time, money, loss of community, loss of production etc.). In the case of Furnas it would probably mean leaving the town. In some cases this cost may be too much for the individual, family or social group to bear for others it may just be highly undesirable. Understanding volcanic hazard was in most cases partial, probably because of the psychological need to avoid the subject, while the benefits associated with staying in Furnas were very clear. The consequence is that psychological risk reduction is by the far the preference of the inhabitants over the alternative of physical risk reduction. The various cognitive strategies used for reducing the perception of risk have been discussed above. When risk reduction, through relocation has been partially forced on communities, the perceived costs have lead to a reversal of the process. This happened after the evacuation of the 264 inhabitants of Tristan da Cunha in 1961. Within 18 months of being in Britain the islanders elected to return to Tristan da Cunha (Blair, 1964). Aspects of alternative locations may be perceived as more threatening than those that migrants leave behind.

9.6 CONCLUSIONS AND IMPLICATIONS FOR VULNERABILITY MITIGATION

The villages around the Furnas caldera have grown and developed despite volcanic eruptions taking place during their history. Destructive volcanic activity has had only a slight influence on the development of the villages, limited to periods of activity and immediately afterwards, while the volcanic landscape created has become an exploitable resource. The economic and social structure of the villages is typical of the rural towns and villages of the island and its growth has been consistent with its position and various resources. The vulnerability of the residents has stemmed from the socio-economic development of the island, affected only slightly by actual volcanic activity. The result is a situation in which a large proportion of the population is vulnerable to volcanic activity (figure 9.28).

Vulnerability in the area is not primarily related to marginality (Susman et al., 1983). For example there was no evidence that the affluent and powerful had a more accurate knowledge of hazards such as the CO_2 seepage. This conclusion finds support in recent work on vulnerability. Cannon (1994, p. 27) states that 'vulnerability should not be simply equated with poverty'. Those that are relatively wealthy may cope less well than the poor during a disaster period. During the 1941-52 eruption of Parícutin, Mexico, the first to permanently leave the area that was to be destroyed by lava flows were people who had relatives in other villages, possessed skills that would allow them to gain employment or had flexible assets that could be moved (Nolan, 1979). Though many of these individuals and groups were from the wealthier section of society, some of the affluent did not leave because their wealth was tied up in land and property. As has been noted above some shop, farm and bar owners will lose their source of income and may be less able or willing to exploit new sources of income in a post eruption situation than those who though poorer have more transferable skills. Those that had been thinking about migrating will have made preparations and may be in a situation where they can easily leave the island. It is less likely that those with successful businesses will have made such preparations.

Hazards	Vulnerable groups
Periods of inactivity	
CO_2	• Owners of houses or business in areas of seepage - especially those with wooden, cracked floors and poor ventilation • Anyone working near or below ground level in an area of significant seepage • Children • People with no knowledge of hazard
Radon	• Owners of houses or business in areas of high CO_2 seepage - especially those with wooden, cracked floors, poor ventilation • Smokers in areas of CO_2 seepage
Fluoride	• Residents who consumed drinking water from the now superseded supply.
Period of activity	
Precursory Seismic activity	• People in rubble masonry buildings • People who would interpret seismic activity as tectonic and not prepare for evacuation
Volcanic eruption	• People without access to transport • The old and young • Individuals with dependants in the village • People with inadequate knowledge of evacuation procedures • The socially isolated • Those with an inaccurate understanding of the volcanic activity within the valley
Generally	• Those closer to the eruptive centre
After activity	• People and groups (eg families, dependants) with high proportion of their resources in Furnas or in nearby areas • People and groups with their livelihood dependent on the village and the surrounding environment • Long-term residents who feel a strong bond with Furnas as a place • People who have an extreme reaction to the stress of a disaster • People and groups without potential post-evacuation support or opportunities

Figure 9.28: Summary of vulnerable individuals in the village of Furnas. Vulnerable groups identified through their susceptibility to different volcanic conditions.

To take the village of Furnas as an example, there is no indication that any changes that do occur in its economy, society or environment will substantially change the existing situation of vulnerability. Vulnerability in Furnas is therefore not likely to decrease in the foreseeable future without external intervention. Great care will need to be taken in organising any intervention because the roots of vulnerability lie in the very nature of the village and its people. Intervention, to be effective, would involve fundamental change. This is unlikely to be achieved without resistance. Changing people's attitudes to the likelihood of an eruption would involve engendering a feeling of unease about the future. This could, if not carried out carefully, produce feelings of extreme discomfort amongst the residents or possibly the kind of mechanism of risk denial already noted above. The imposition of vulnerability mitigation measures also needs to take into account the way they will interact with the existing social situation. Building regulations, for example, might be harder for the poor to comply with, leading to regulation avoidance, or might be easier for the powerful to avoid and so be similarly ignored. Any programme would need to deal with issues of economic loss and compensation. Educating people about the CO_2 hazard, for example, could adversely affect the value of houses in areas of high seepage. Monitoring and warning systems, the main thrust of many countries volcanic risk reduction programmes, may be affected by factors such as knowledge/ skill gaps, politics, individual research interests, fluctuations in funding or interpersonal relationships and so be rendered less than effective. Monitoring and warning systems will probably be used by a population as evidence that they are not threatened and therefore do not need to alter their present behaviour, if the systems are ineffective then the threat may not have been reduced at all. As people come to rely more on structures created by modern societies to increase public safety, the greater the chances that the catalyst for a disaster will actually lie within these structures. Importantly, because the population in question do not perceive a need for action, any vulnerability mitigation measures might, if not combined with a programme of dialogue with the local population, become more a form of oppression rather than an exercise in relief.

While noting the problems mentioned above, it is vital that the vulnerability of the residents of Furnas and surrounding villages is tackled. The approach should, though, attempt to be inclusive and sensitive both to the psychological and economic impact that vulnerability reducing measures may have on the various communities. Various recommendations might be made:

- Evacuation plans should be rehearsed with the population of Riberia Quente, Furnas and other neighbouring towns and villages. It is perfectly possible to evacuate these towns in a number of hours as long as everyone knows what to do, adequate transport is provided and the evacuees are confident dependants are also being evacuated. Without a rehearsals it is likely that considerable delays will be experienced.

- The main evacuation route out of Furnas would be along the En2-1a road. There are two principal areas of weaknesses on that route. First, on the stretch of road out of the caldera (C1-C5 figure 9.16) and second over a bridge at C7 (figure 9.16). Where possible it would be wise to try and protect these stretches of road. The road from Riberia Quente to Furnas has numerous points along its length where breaks could occur. It is therefore vital that Riberia Quente is evacuated very early in the event of an eruption.

- An effective programme of monitoring should be started. This might involve using local people to act as 'bare-foot' volcanologists. They might be responsible for monitoring fumarolic activity on a daily basis and rough ground levelling calling in scientists if they notice changes. Similar low tech monitoring programmes have been used in Indonesia. Such a programme might help introduce the community to the concept that Furnas may well erupt in the near future but that this hazard can be made manageable.

- At a regional level it would be worth establishing plans to deal with an evacuated populations of tens of thousands. The chance that there will be an eruption on one of the islands of the Azores in the near future is relatively high. The ability to protect a large displaced population is likely to be vital.

- A programme of meetings should be arranged in Furnas at which the specific problem of CO_2 and radon seepage could be explained and discussed with residents. Information and funds should be provided to help all residents to seal their floors or adequately vent their rooms. This interaction with the local population might be extended into a fuller discussion of hazards in Furnas. The aim would be both to increase awareness of the hazard and also to seek further solutions to this problem from within the threaten communities.

- This programme could be expanded to deal with the broader issues of vulnerability in Furnas and other towns and villages near the volcano. The aim of such a programme would be to increase the vulnerable's knowledge of their own situation and enable them to make decisions about their own future. The process would probably have to be empowered to stop its decisions being ignore by existing interest groups. This might be achieve by allocating it resources whether the decisions reached are those hoped for by existing interest groups.

CHAPTER TEN: DISCUSSION

10.1 INTRODUCTION

A number of major themes emerge from the two case studies. These are now considered with reference to other situations of volcanic hazard. The themes discussed include: [1] behaviour and risk perception, [2] the importance of routine, [3] place and space, [4] the importance of specific spatial forms: islands, valleys and the city, [5] opportunity and constraint, [6] time-space distanciation, [7] the significance of scale, [8] a European disaster context and, lastly, [9] technology as a source of volcanic threat. The implications for vulnerability mitigation of these and other findings will also be considered.

10.2 MAJOR THEMES

10.2.1 Behaviour and volcanic risk perception

The case studies seem to support the contention that behaviour, which tends to increase susceptibility to volcanic hazard, precedes and then directs risk perception. This is the result of a number of factors including: the risk increasing aspect of the behaviour not being obvious or important within the context of that behaviour, or the uniqueness or unfamiliarity of the activity meaning that effective evaluation of risk is impossible, difficult or, apparently, unimportant. Susceptibility increasing behaviour may also be unavoidable or at least difficult to avoid in terms of the amount of control an individual has over that aspect of their lives.

Relocating to a hazardous area is often the most fundamental way an individual increases his or her vulnerability to volcanic hazard. Moving as a child with parents, getting married or changing jobs might all be volcanic susceptibility increasing behaviours. In each case it is likely that the reason for the behaviour will tend to dominate the decision making process and the specific risk increasing aspect will be suppressed by the importance of the reason or the complexity of the whole decision making structure. In the case of the child, they will have little control over the decision making process.

The theory of cognitive dissonance was presented as the possible psychological mechanism at work within this process. Although it is a latent process, and is therefore difficult to prove or disprove, some support was found within the case studies for it. The theory predicts that it is the individual's own sense of culpability within the process that has put them in a situation of vulnerability that invigorates the cognitive risk reduction process. Those that have freely chosen a course of action that results in higher vulnerability have greater need to believe that their actions are not maladaptive. The reverse is true for those who have not had control over the events that have led to their vulnerability. This is an important finding for hazard mitigation programmes. It emphasises the need for social change to go along side safety information campaigns because those that can but do not change their behaviour are not likely to believe it is necessary and those that do believe it is necessary but do nothing are likely to be unable to do so. The mechanism of cognitive dissonance reduction does not work in isolation. It is complicated by other psychological and social processes such as social representations, feelings of place attachment and cultural traditions. Indeed, it is the interaction of these factors within a hazardous location, that presents much of the inertia within vulnerable communities.

10.2.2 The importance of daily routine

Behaviour, that increases susceptibility to volcanic hazard, can be of a routine nature, going to work at a specific location, for example, or continuing with a particular form of agriculture. Within the repetition of the activity and in its social context the risk aspect, if known, is likely to be suppressed or forgotten. An individual will tend to suppress any discomfort he or she feels through various cognitive strategies as will other people in the same situation. Groups sharing similar situations will, through a process of active discourse, develop similar representations. Social representations of a volcano will therefore be related to membership of various social groups. The spatial focus of volcanic hazard means that physical closeness will be an important factor in the development of social representations. Representations of the volcano are similar, therefore, within communities (eg. villages, towns etc.). This was found to be true both in Furnas and Trecastagni. People living in areas of volcanic hazard will tend to bolster each others confidence in their own personal decision making.

Routine behaviour can, itself, increase susceptibility to volcanic hazard. The predictable and understood nature of behaviour in familiar environments mitigates against the identification of impending threat and therefore often slows reactions to it. During the Kings Cross fire (London) in 1987 a majority of people, in the early stages of the fire, continued with routine patterns of behaviour despite there being cues to the presence of a fire in the station (Donald and Canter, 1990). In the context of the fire that was to follow, this continuance of routine behaviour was maladaptive and probably led to a number of people losing their lives or being injured.

The routine nature of life, within which individual vulnerability is produced and reproduced, can be contrasted with the extraordinary nature of a volcanic eruption. Its scale, erratic and rare occurrence leave it virtually unimaginable within a day-to-day existence. The elements that influence the reproduction of vulnerability may occur very regularly (eg. every day) while a volcanic eruption, or a reminder of its potential, may only take place very occasionally (eg. once every 300-400 years). It is therefore not surprising that individuals do not attempt to modify vulnerability through action but, rather, attempt to cope with it through the use of various received representations and cognitive strategies.

10.2.3 Place and space

The relationship between volcanic hazard and location means that often what is threatened is not just a single aspect of a person's life but many facets of it. It may be their home, family and community that could be destroyed. Linked together through proximity, location may have a special significance for the individual. This has been referred to as place attachment. The bonding an individual feels with an environment is significant in a number of ways. It may, for example, stop an individual relocating to a safer area thus maintaining vulnerability. It might increase the stress associated with a forced move because it would be a dislocation from a significant place. It also creates an inertia that acts against changes that might reduce vulnerability. If people value a particular situation they are unlikely to attempt or accept changes.

Space will also be important in the reproduction of individual volcanic vulnerability. This is because space organises social practise, through environmental roles and rules. Because of the located nature of volcanic hazard, space is both the reason for an individual's vulnerability and a defining aspect of it. It is why someone is there but also defines in what condition they are there in.

10.2.4 The importance of particular environmental forms: islands, valleys and the city

It is within the interaction between the physical environment and human presence that vulnerability is produced. Particular forms of the environment seem to have an important influence on the development of vulnerability. Three forms of the environment, significant within the context of the two case studies, were islands, valleys and the city. It is not argued that these environmental forms determine vulnerability, rather they make certain socio-economic conditions probable and therefore vulnerability likely.

The nature of volcanic islands is significant within the process of vulnerability change in a number of ways. Often, though not in the case of Sicily, an island is completely dominated by one or a number of volcanoes. A majority of the land mass of a volcanic island is typically threatened by volcanic activity. There is, as a result, no opportunity to exploit the resources contained within the island without generating a situation of vulnerability. It is often the case that once the island is settled, the only method of significantly reducing vulnerability is to abandon it. It is difficult to move people from a volcanically hazardous area, outside a crisis period, even for continental volcanoes where a move might be to a culturally and economically similar area. For a volcanic island this process is far more significant. Typically it would mean a move over a great distance to an area that is likely to be culturally, economically and climatically different to a migrant's home. Even during periods of crisis it may be difficult to encourage people to leave an island. In the case of Tristan de Cunha an evacuation was forced on the residents but a large number of islanders returned once the initial crisis was over (Blair, 1964). In the case of Furnas volcano, the residents of the villages closest to the volcano could not be moved to a location on the Azores that would not also be threatened by volcanic activity. In the past, this isolated location, would have meant that islanders had no chance of escaping the after effects of a volcanic eruption. The location of many volcanic islands on mid-ocean ridges historically made them strategically very important. From their waters it was possible to dominate various trade routes. This long history of settlement and their continued strategic value makes wholesale resettlement, to avoid volcanic hazard, very unlikely.

Valleys are significant within the production and reproduction of vulnerability because they have certain heightened hazard characteristics while at the same time being attractive to settlement. Valleys, around volcanoes, act as a channel for many of the products of eruptions including lava flows, pyroclastic flows, releases of CO_2 and lahars. In some mountain areas the damming of rivers can cause a secondary hazard, as they increase the amount of stored water that may be released down stream in the event of an eruption. Settlements within valleys, even tens of Kilometres away, can be reached rapidly by these very destructive and deadly volcanic products. Valleys are attractive to settlement for a large number of reasons: they often represent the main lines of communication, they may be the only suitable area for building, have an easily accessible supply of water, be the best agricultural land and offer shelter. Settlements located at the mouth of valleys are similarly threatened by volcanic products. This was the position of the town of Armero (Colombia) during the 1985 eruption of Nevado del Ruiz when a lahar swept down the Lagunillas Canyon (Fisher *et al.,* 1997). The town was largely destroyed and ~25,000 people were killed. In the Furnas area the village of Riberia Quente is in a particularly hazardous location. It is at the end of a valley that is likely to have flood waters, lahar and pyroclastic surge and flow channelled down it in the event of an eruption.

The location of a city within an area of volcanic hazard is significant in a number of ways. Urbanisation involves the concentration of a large number of people in space. If this point is close to a volcano then a large number of people could be affected by an eruption. In a slightly more complex way the morphological and demographic nature of a city makes residents relatively more vulnerable. A high population density, for example, may make a speedy evacuation difficult. Similarly, its importance within a region may mean that vulnerability is extended outside the area of immediate volcanic impact. More fundamentally a city's economic and social character along with its relationship with the region within which it is located and with the outside world tends to give it momentum that means it may be little affected by economic change around it and certainly not by volcanic risk. A diversity of commercial activities mean, for example, that fluctuations in specific industrial sectors will not impact the city as much as towns dominated by the specific trade. Once a city is established it is likely that its size, importance, diversity and significance will carry it forward through periods of political and economic change. Collective feelings of security mean that little may be done to reduce vulnerability, while a city's high profile mean that in the case of an eruption aid is likely to arrive early and in large quantities. Reconstruction is therefore relatively easy. The chance that the size of the vulnerable population will decrease over time is significantly reduced by the existence of a city.

10.2.5 Opportunity and constraint

While behaviour that increases susceptibility to volcanic hazard often seems to take place free of concerns about volcanic risk, it is strongly affected by the social socio-physical conditions that exist across a volcanic area. These conditions offer opportunities and constraints to individuals and thus condition situations of vulnerability. Many vulnerable individuals would not deliberately try and reduce their vulnerability but this might indirectly result from an individual's response to changing constraints and opportunities.

Vulnerability in Furnas is maintained through the continuing existence of economic and social opportunity in the villages around Furnas. The twentieth century saw a decline in economic opportunity and a reduction in the constraints on migration. The result was a fall in the number of people living in the area and therefore the number of vulnerable individuals. Sufficient opportunity still exists within the villages, or constraint on leaving, to maintain populations of thousands. It seems likely that these socio-economic conditions will endure and therefore a potentially vulnerable population will continue to exist. It is also apparent that opportunities to increase allocative resources, for those still living in the villages around Furnas, have been minimal. The local economic growth is stifled because of its economic reliance on agriculture. The ability to build up financial reserves that might mitigate the impact of losing home and livelihood in an eruption have therefore been limited. At the same time EU aid props up the Azorian economy to such an extent that the islands continue to be economically viable despite their lack of major industries.

On Etna the situation is varied with individuals living in towns on the northern and western flanks of the volcano having experienced opportunities to live and work abroad and elsewhere in Italy and have an ability to advance themselves economically within their existing communities. In contrast towns on the southern flanks of the volcano and Catania have provided opportunities for making a livelihood that has not only maintained the existing population but has also attracted people to move to the area. Within this southern area land rental prices, the attraction of the 'hill towns' and the push of city crime has moved large numbers of people higher up on the volcano. This has had a profound affect on the number of people who will be affected by an eruption.

The opportunities and constraints, that affect vulnerability, exist as an aspect of the social system or established social practises of society. Social practises are established through the action of individuals (re)producing social structure. Vulnerability is therefore reproduced through individual agency. This finding has a very important implication for hazard mitigation. It suggests that programmes attempting to change risk behaviour solely through the communication of 'risk information' are very unlikely to be successful. A more fundamental change in the nature of social systems as they operate in the area would be needed instead.

10.2.6 Time-space Distanciation

A high level of time-space distanciation or the stretching of social systems across space is a feature of modernity (Giddens, 1984). This stretching or integration across space means that despite a local threat or disaster the reproduction of the conditions that generate vulnerability can continue largely unaffected by the local event. Social systems may not be overly affected by a disaster, even less the threat of disaster, because they stretch across time and space and therefore change in one area will be acted against by the weight of practise elsewhere.

Individuals, in a threatened area, may attempt to change the specific aspects of the social system that generates vulnerability. They will probably be hindered in doing this by their inability to affect aspects that are socially and spatially distant from themselves and their own power within the social system. Social systems, especially in the late Twentieth century, stretch through space and across national borders. Political bodies that exist within national boundaries may have limited influence over other social systems (eg. the world economy) as they affect a specific region. The incentives for migration, significant in terms of vulnerability in both the Azores and Sicily, were to a large extent out of the control of the Portuguese or Italian governments.

Powerful individuals and groups can influence the individual through manipulations of parts of the social system. Thus an enforcement of planning law may, for example, stop the location of housing in high hazard areas. The chances that they might try to manipulate existing social systems in order to reduce vulnerability in a specific region will be affected by vested interests of individuals and groups. It is very unlikely that any one group will have it in their interest to push through measures that will reduce vulnerability across a society simply because it is unlikely their interests will be so widely spread. It is possible that democratically elected parties might attempt to do this but they may be influenced by electoral interests. This will be explored further in section 10.5.4.

The scale, complexity and globalised nature of modern social systems makes them very difficult to be changed, although they are, of course, dynamic and changing in themselves. Many governments, for example, believe in the free flow of capital and this has, as a result, become the dominant factor in economic and social change. More generally, Giddens (1990) has likened modernity to a runaway juggernaut, emphasising that it does not take one path and is not of one piece. He argues that modernity as a juggernaut can be driven to some extent but always threatens to rush out of control. As long as the present institutions of modernity endure then the direction or pace it takes can never be entirely controlled. A lack of control over social systems is significant for vulnerability reduction because, as has been discussed above, they lie at the root of individual vulnerability. If social systems cannot be easily manipulated, then the ability to reduce vulnerability is severely reduced.

It is the case, though, that some of the general goals of political organisations and the products of modern mixed economies will result in the reduction of vulnerability. The provision, for example, of greater financial resources, democracy, education and the insurance of basic human needs (state and private insurance) will generally reduce vulnerability. Unfortunately even in countries where the mean level of these resources are increasing there appears to be a disproportional distribution of them and many countries are not able to increase individual resources at all. But the push for a universal provision of these resources will, if successful, also decrease certain aspects of vulnerability.

10.2.7 A European disaster context

On average people living around Furnas volcano are susceptible to volcanic hazard in more ways than those living on Etna. Their susceptibility to volcanic hazard also more directly impacts basic needs namely their physical health and autonomy of agency. The type of explosive activity likely to be experienced in the Furnas area will be highly destructive in the area close to the volcano. While scientific and technological advances make early warnings possible, a successful evacuation can not be guaranteed. It might fail because of the nature of organisations charged with providing this service, for example a lack of funding, in-fighting, changing interests, political conflicts, lack of knowledge or technological failure, or because people will not move out of the area in sufficient time having been given a warning.

Societal differences are a fundamental part of what differentiates vulnerability between regions. Within any one socio-economic region, therefore, differences in volcanic activity has a more significant impact on vulnerability than would normally be the case. What differentiates the Furnas from the Etna situation, in terms of vulnerability, is not so much the character of society but rather the nature of volcanic activity. This finding seems to contradict the main thrust of recent work on vulnerability, that it is the nature of society that transforms the natural environment into a 'natural' hazard. However this would be a misreading of the results. Both Etna and Furnas exist within a fairly similar European context. This means that a loss of livelihood or resources, as a result of a natural disaster, will affect physical health and autonomy of agency (Basic needs) but not be catastrophic. Once the initial crisis has passed it is possible that those affected may be in a slightly better situation than they were before. This seems to have been the case in Mascali (after the 1928 eruption) and on Terceria (after the earthquake in 1980). The direct threat to physical health and autonomy of agency, from an eruption becomes a more pertinent aspect of vulnerability when the indirect affect, through the suppression of Satisfiers of basic needs, has less of an impact. In a European context the Satisfiers of basic needs are unlikely to be suppressed for any length of time. This will not be the case in countries without the ability or willingness to re-establish the societal pre-conditions for the Satisfiers of basic needs. To take a historical example, after the death of livestock during the 1783 eruption of Laki (Iceland) about 10,500 people died in the famine that followed (Krafft, 1991). The ability of Icelanders to recover after the eruption was severely hampered by their isolation and self dependency. It is likely that a volcanic event occurring in a Less Developed Country today would have a similar impact.

There are groups around both Etna and Furnas who, despite the influx of capital and resources that will occur after an eruption, will still not have their basic needs satisfied. In Catania, for example illegal immigrants may find it very difficult to gain compensation for lost resources. These groups are a very small proportion of the affected population compared to disasters in other areas of the world. During flooding in Bangladesh, for example, a very large proportion of those affected by the flooding will find that the Satisfiers for their basic needs suppressed for a considerable time after the event. In some cases, if there is a recurrence of the natural hazard, those affected may experience a downward spiral of worsening conditions as their basic needs are less and less well satisfied. Again in a European context this is unlikely to happen.

The influx of capital that occurs after a European disaster may have beneficial consequences for a region. The need to rebuild will, for example, boost the building sector creating both skilled and unskilled jobs. After the 1980 Azorian earthquake, the local Tercerian construction sector boomed with labour having to be imported from the mainland (Instituto Açoriano de Cultura, 1983). Where people are living in poor quality accommodation, the newly provided housing may be better than they had previously. This was the case in Mascali (post 1928) and Terceria (post 1980).

Vulnerability has been reduced more in terms of disaster recovery than in any other aspect. This is principally due to the European states acceptance of the role of guarantor of recovery in the case of disasters. This means that people threatened by effusive rather than explosive eruptions have seen a greater reduction in their vulnerability. People are still likely to be killed and injured in explosive eruptions despite, and in the future possibly because of, monitoring technologies and emergency planning. While few people on Etna are vulnerable, the same can not be said for Furnas. Within a broader European perspective this finding is highly significant because more people, living in volcanic areas, are threatened by explosive rather than effusive activity (eg. the Naples area of Italy, etc.). Although volcanic vulnerability has decreased in Europe it is still significant.

On Etna, development, as well as reducing vulnerability, has led to an increase in the total number of people who are living on the volcano. With the historic shifting of the scale of responsibility for recovery from the individual to the nation this puts an increasing burden upon others in the country. The number of vulnerable people around Furnas is half the figure it was in the 1940-1950's. It is now lower than it is was at the end of the nineteenth century because of immigration but this is atypical for many of the areas vulnerable to explosive eruptions in Europe (eg. Tenerife, Vesuvius etc.). In these locations the vulnerable population has tended to increase because of favourable socio-economic conditions. On Tenerife an expanding tourist sector has led to considerable development on the island. The vulnerable population has increased and now includes both tourists and those employed in the tourist sector. Although the development of Catania has different implications within the context of Etnean volcanism, it is an example of the effect that an expanding urban centre can have within a volcanic area. In the case of the Naples region, the consequences are far more serious because of the explosive volcanism experienced historically in the area.

10.2.8 Technology as a source of volcanic threat

In the case of explosive volcanism, economic development will not necessarily have reduced the vulnerability of those who are threatened (ie. if individuals cannot protect themselves or an emergency organisation protect the individual, then no other aspects of coping are important). It also true that scientific and technological development may not reduce vulnerability but simply change it. The monitoring systems that are designed to warn of an immanent eruption are fallible in a number of ways. They may be faulty themselves and if not cross checked with other instrumentation give misleading information. This might lead to someone ignoring correct information because it has been wrong before or believing incorrect information because that is what the instrument is showing. A second way in which monitoring systems are fallible is through the people and organisations that run them. Organisations are susceptible to problems such as in-fighting, funding crises, skill shortages, poor flows of information, leadership problems and may have an agendas of their own that is not directly related to the safety of the people living in a monitored area. People are fallible in similar ways. As a population comes to rely more heavily on a monitoring system and adjust their lifestyles in reference to it, then the extent to which a failure of that system can cause a crisis increases. The scientific system can never achieve a completely socially, economically or politically neutral position when it functions in a society. This is increasingly true as it moves away from the laboratory out into the social world as it inevitably does when it tackles volcanic activity.

10.3 A COMMENT ON STRATEGIES FOR REDUCING VULNERABILITY

Taking into account the findings from the two case studies it is possible to comment on possible strategies for reducing vulnerability to volcanic hazards. The first stage of any assessment of vulnerability, as outlined in chapter 3, is ideally an investigation of volcanic hazard. Geological and geophysical research in a volcanic area should be part of any vulnerability mitigation strategy. This initial work should include the identification of potentially active volcanoes, an investigation of their volcanic character and the mapping of areas of hazard. There is a considerable amount of variation in the amount of continuing and completed scientific research between volcanic areas. On some volcanoes, such as Etna (Italy) or Kilauea (Hawaii, USA), a considerable amount of research has been carried out and a fairly deep understanding of the volcanic hazards achieved, on other volcanoes the reverse is true. Factors such as the intensive nature of volcanic research, the high level of required skills, limited funds, the number of available scientists, the personal interests of scientists, all make it a difficult situation to rectify. However an increasing general understanding of volcanological processes means that likely hazard scenarios can be proposed, with some accuracy, even for volcanoes that have not been extensively studied but this is only a step towards a true analysis of vulnerability.

Though a wider understanding of volcanic hazards across a greater number of volcanoes would be an important step in the process, on its own it may do little to reduce vulnerability. There is the added danger that the relevant authorities will use the existence of ongoing scientific work as evidence that they are dealing with the problem without having to enact any policy that might prove unpopular or harm their own interests. This may also happen with monitoring systems. They require very little actual change within affected societies while demonstrating a commitment to hazard reduction. The presence of scientists and volcanic monitoring systems may also be used by a vulnerable population as evidence of no threat. Unless the monitoring system has actually substantially reduced vulnerability it may be causing as much harm as good. Decision makers need to be made to see that 'hazard' exists at the interface between 'hard' natural science and 'soft' social science. Focusing on one aspect, to the exclusion of the other, will have disastrous consequences.

10.3.1 Scaling a volcanic disaster

The different scales at which a volcanic disaster can be viewed will be important in determining responsibility and decisions about response. Scaling a volcanic disaster at an individual level, it is seen as being experienced by people. This is actually how an eruption is encountered. Empathy may be felt for the victims because the individual is visible. Scaling it at this level may also tend to lead to the conclusion that it is an individual's fault, that they brought this crisis upon themselves, because the wider context is not visible. Scaling the disaster at a regional level allows individual behaviour to be seen in the context of wider social patterns and it also reveals that a volcanic eruption may have a regional impact. Scaling it at a national level exposes the fact that, in a European context, the cost of an eruption will be felt not only by individuals living in the affected area but also by the wider community. This is because a reconstruction programme will be funded by either regional government or, more likely, by central government. This may encourage a debate over whether it is right for everyone to pay for the costs of a few people's way of life. While the costs are minimal it is possible that this dilemma will be ignored but in the event of major disaster the issue may be forced. Smith (1992) argues that it is idealistic to believe in the privilege of the local, instead it is common for the local to be oppressed within a hierarchy of scale. In other words it often the case that power lies within a social system in such a way that the interests of the local are subordinate to the regional or national. It may be the case that residents of volcanic areas are forced to give up their homes in order to reduce the cost of their particular forms of living to the nation. It is also true that scaling a problem at a national or international level may allow national or international policies to be formulated to reduce vulnerability.

During the recent volcanic crisis on Montserrat, a dispute developed between the Department for International Development, dealing with the crisis, and the local government in Montserrat over the amount of aid and support being given to the islanders (The Montserrat Reporter, 7th November, 1997). The debate was ostensibly over the release of funds to improve the infrastructure of the north of the island but was fundamentally about the UK government's policy over the island's future. National scale decision making about efficient expenditure against the local scale survival of the island community. It is likely that this debate will continue when the crisis is over and the future of the island is considered. The amount of influence a group has within central government will determine the extent to which its way of life is either defended or re-established after a disaster.

Smith (1993) argues that the role of radical geographers should be to instigate the politics of 'jumping scale' or the combining of two scales into one politically significant entity. The Big Issue[11] in the UK combines, in their sellers, the individual and national level (personal communication - Dr Mike Kesby). The seller represents the individual, the visible face of homelessness. The seller is not only able to find a solution to their homelessness through an income from the magazine but also represents the national through their presence as a *Big Issue seller* on the streets of most cities in the UK and in the articles of the magazine. The effect of this positioning of homelessness may lead to a national solution. This type of political lobbying may be harder to achieve within the spatially concentrated context of volcanic hazard. The Azores, for example, is physically a long way from mainland Europe. On the other hand the presence of a large Azorian immigrant population, in the USA, meant that the 1980 earthquake was scaled at both a national and individual level through the immigrants collecting

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[11] A magazine sold by the homeless in the UK. The homeless person buys the magazine from the organisation for half its cover price and then sells it on the street for profit. The Magazine combines both general interest articles with those on homelessness and other social problems.

donations for the disaster appeal. This made fund raising easier and American aid likely.

10.3.2 Vulnerability reduction through compulsion

One of the main findings of this thesis is that the construction of risk perception seems to follow, rather than direct, behaviour that increases susceptibility to volcanic hazards. Instead representations of risk develop within a situation of higher than wanted risk, that drives a process of cognitive dissonance and existing social representations. It may, as a result, be very difficult to change behaviour through an individual's own attitudes. Instead it may be necessary to attempt to more directly influence behaviour through changes in the legal and economic elements of a social system.

Location has been highlighted as a basic aspect of vulnerability. Its integration with broad social trends and, at the same time, its significance as a fundamental aspect of an individual's life means that it is extremely difficult to manipulate in order to reduce vulnerability. It is likely that any attempt to change people's location will be met with resistance. It is therefore necessary to make ethical decisions about whether it is right or wrong to force relocation. The parameters of the ethical debate may include situations where the wider population may suffer as a result of the location of a few or where only the few will suffer. One of the choices will be between the greater good of the wider population versus the freedom of choice of the few. Given these problems one approach to relocation would be a gradual discouragement of in-migration and an encouragement of out-migration. This might be achieved through restrictive planning laws within the area of high hazard and incentives outside it. Overall this would lead to the decline of communities but this process would take place gradually and therefore might not be as ethically, socially, economically or politically insupportable as sudden forced change. The residents of Trecastagni were broadly supportive of stopping development in areas of volcanic hazard on Etna. They viewed it as a way of conserving the environment and the character of their town. A compromise solution might therefore be to leave existing communities as they are but to limit, as much as possible, future developments. In a region where the hazard can be mapped (ie. the probability of an area being affected by a volcanic product), it might be possible to stop development in some higher hazard areas. When a city is located in an area of volcanic hazard the problem of location is more intractable. The number of people affected, the economic importance of the city and its regional significance would all make a change of location extremely difficult if not impossible. The only opportunity that might exist would be after an eruption, when widespread destruction would make rebuilding a necessity and this could be allowed only in safer locations.

Location is not solely an outcome of individual decision making but rather individual choice within a complex socio-economic context. The macro scale forces that create constraint and opportunities for individual location decision making are therefore implicated in the generation of vulnerability. Unfortunately, in terms of vulnerability reduction, there is a trend within many countries of the world and supra-nation organisations (eg. International Monetary Fund, World Bank etc.) away from planned economies. The ability of governments to affect the socio-economic forces that create situations of constraint and opportunity are, therefore, increasingly limited.

If location can not be changed, then other aspects of an individual's susceptibility to volcanic hazard need to be modified in order to reduce vulnerability. An individual's ability to protect themselves, within the eruptive period of a volcanic episode, is imperative. It is closely linked to the emergency organisational response, self-protection working within the envelope of safety provided (or not provided) by emergency organisations. Self-protection is also important outside eruptive periods, in areas where chronic hazards such as CO_2 seepage exist. Knowledge of hazards and how to avoid them, combined with the ability to do so, are central to self-protection in areas of volcanic hazard. Unfortunately, as the case studies demonstrated, there is not a simple relationship between level of hazard and an individual's awareness and ability to protect themselves. Perversely, my research results show that the greater the threat to the individual, when it is the result of their own actions, the more likely they are to try to cognitively diminish it. Their attitude then affects their emergency planning. Individuals are, therefore, unlikely to make mental plans for an emergency scenario or to prepare physically for such an eventuality if they live in an area threatened by volcanic hazard.

Attempts to increase the chances of self protective behaviour in the event of an eruption must take into account this factor. Ironically it is likely that any attempts to communicate the levels of hazard in an area or potential emergency plans will be ignored because they challenge an individual's confidence in their own safety. It is necessary, therefore, to compel inhabitants of vulnerable areas to learn safety procedures (eg. evacuation routes) or to behave in a safe manner (eg. replace wooden floors with a non gas permeable material in areas of CO_2 seepage) through legal processes. Though procedures might be resented, they would be learnt and followed if compliance was rigorously enforced.

As well as tending not to plan how to escape a threatened area, vulnerable individuals also tend not to make plans for how they will cope with the destruction of their property and source of livelihood. Resources that will be available to individuals after an eruption should be developed. This might be achieved, for example by encouraging the siting of new businesses outside the area of volcanic hazard employing people within the area. The development of saving or insurance schemes for those living in the high hazard area might have the joint affect of discouraging settlement and also creating resources for the individual in the case of an eruption. Compulsory insurance schemes might be unpopular whilst optional schemes might be ignored. This might particularly be the case if an insurance culture does not exist in an area (eg. around Etna). There was the expectation, within the Etna area, that recovery after a disaster was the responsibility of the state, taxes already paid were the individuals contribution to emergency response. The individual was scaling the problem at a national level. This will be fine only as long as government does not scale the problem at the level of the individual and expect them to have a solution to their own problems.

10.3.3 Effective disaster management

It has been demonstrated in recent years that volcanic emergency strategies can reduce the number of people killed and injured in volcanic eruptions. This has generally been achieved through an early evacuation of the threatened area. The emergency response at Mount Pinatubo (Philippines - 1991), Rabaul (1994) and Montserrat (1995-8) meant that the evacuations were achieved ahead of destructive volcanic activity and few people were killed in the eruptions themselves.

A successful emergency response to a volcanic eruption depends, first on an accurate interpretation of warning indicators, secondly an efficient evacuation of those threatened and thirdly the maintenance of an evacuated zone during the period of the crisis. Modern technology and scientific progress allow those monitoring a volcano a greater understanding of its likely future behaviour. Unfortunately there is still a great deal of uncertainty within this process of prediction. This exacerbates the problems associated with moving information from a relatively value free, scientific, environment into a social system where it immediately becomes value laden. During the recent Montserrat volcanic crisis a system that calibrated expert judgements was used (personal correspondence - Willy Aspinall). This system allowed judgements to be pooled with each participant's opinion being weighted depending on an *a priori* assessment of its informativeness and impartiality (Aspinall and Woo, 1994). The system was used to aid decisions over what level of alert should apply to designated zones around the volcano. These levels of alert would determine the type of access members of the public should have to the zones. Possibly a measure of this system's success was that the only people to be killed, to date, were individuals working and living in zones which the volcanic observatory had identified as an exclusion zone.

A key point, as the above example illustrates, is that even if the information provided is largely accurate, the way it is interpreted and translated into action within a social system will determine whether it is useful in reducing casualties. Individuals will interpreted information in terms of their own existing representations. This may lead to it being accepted, modified or ignored. Unless there is evidence to support the message that the volcano is now highly dangerous (eg. visible activity, actual casualties etc.), individuals who have representations of the volcano as not threatening are likely initially to ignore the information. Organisations may use the information selectively to support their own political and economic interests or they may be not be able to translate them into effective measures. Their ability to direct behaviour, for example, will be related to their effectiveness prior to the volcanic emergency. Some of these problems may be overcome if a single, politically strong, body exists charged with both monitoring and organising the emergency. The negative side of this is that if this one body was not operating effectively the result would be catastrophic because there would be no authority to check its decisions.

The psychological and physiological susceptibility of individuals can be reduced through carefully emergency planning. Although psychological susceptibility can not be easily predicted, the extent to which a traumatic event will affect an individual seems to be independent of any easily measurable indicators. Effective emergency planning reduces the stress of an eruption for all those involved including those who are more susceptible to the trauma of the event than others. The physiologically vulnerable should be especially catered for in any plans. Emergency organisations might, for example, ensure that they had access to motorised transport, shelter after an evacuation and support in the post-eruption period. By ensuring the welfare of dependent individuals, emergency organisations would also protect carers who might endanger their own health trying to protect their wards.

10.3.4 Dialogue

The conflict between vulnerable individuals' representations of volcanic hazard and the representations that emergency organisations feel they require, needs to be addressed in a sensitive manner. It is likely that direct, one-way, communications on the threat vulnerable individuals face will be dismissed because it contradicts firmly held beliefs and agitates an individual's sense of ontological security. Instead a more long-term, immersed approach, needs to be pioneered involving an active dialogue within vulnerable communities and a gradual subversion of beliefs about volcanoes. This would involve a long-term programme of meetings between the community and a facilitator whose job it would be to gradually persuade the community to face the threat they are under while at the same time learning about and developing with them ways of reducing vulnerability.

Care would have to be taken in developing such a method. It would be easy for disputes to tear the group apart and difficult for it to achieve a general consensus. In the 1950's in Riberia Quente (San Miguel) a parish priest decided that the location of the town was highly dangerous (source - interviews with resident of Riberia Quente). The town had suffered a series of earthquakes and the priest was particularly worried about the loose volcanic ash deposits that towered over the town. His plan was to try and get the villagers to move to neighbouring communities. Despite a concerted effort and his position at the centre of the community, he was unable to convince them to move.

The final decision reached through such a process might not be the one originally envisaged by the emergency authorities. A group, for example, might decide that no action should be taken. They might choose a course of action that actively threatens the interests of another group. At the start of such a process, authorities, would have to decide the parameters of such an exercise and whether they would be willing to accept decisions arrived at that varied or were contrary to those originally planned.

10.3.5 Equity and democracy

The unequal distribution of resources within a social system has some important implications for volcanic vulnerability. This is especially true for areas where there is no social contract between the state and the citizen guaranteeing that a basic set of needs are satisfied. Within the Furnas and Etna areas, the distribution of resources though not having a great influence on vulnerability would have an affect on the level of recovery after a volcanic eruption. It is likely that those with a high level of access to allocative and authoritative resources, before an eruption, would be able to access them after it and therefore rapidly re-establish a comfortable standard of living.

In less developed countries it is likely that access to low level of resources would have a significant affect on vulnerability. Poverty, with its lack of opportunity and constraining nature, may mean that people have little choice but to live in more hazardous areas. Lack of resources may also affect evacuation and recovery after an eruption. During the recent Montserrat crisis, the ability to leave the island was strongly related to resources and power. The expatriate settlers left very early on in the crisis followed by those who had friends and relatives in neighbouring islands, the UK or USA. This stratification of islanders meant that many vital community functions had collapsed with the absence of key people. During an eclipse, concern was expressed that the mentally ill who had been left on the island might damage their eyesight by looking directly at the sun because they were now unsupervised (personal communication - Dr Paul Cole). A key point is that the same physical event can have very different impacts in different regions and on different groups of people. This is as much the case for volcanic eruptions as it is for other 'natural' disasters such as famines.

The alleviation of poverty and reduction of inequalities in a society, as well as relieving other problems, will also have a significant affect on vulnerability. A more general goal of encouraging democracy may be more controversial. It has been argued that famines do not happen in democratic countries with a free press (Sen, 1993). When political parties rely on the support of vulnerable communities it is more likely that the needs of these communities will be reflected in policy. Sen (1993) argues that famines can be avoided fairly easily because they are rarely the result of absolute food shortages. They are the product of an uneven distribution of food within a country with only a small proportion (<5%) of a population actually threatened. On the other hand, as the case of Mascali demonstrated, a strong central leadership can, in bypassing debate, rapidly concentrate resources in an area and democratic parties can ignore areas if they are not electorally significant.

The cases studies of Furnas and Etna volcanoes suggest the growing importance of conflicting interests within the process of vulnerability generation and mitigation within the European context. This conflict may centre around the rights of people to decided how to live their lives, social movements' confidence that vulnerable individuals are making 'free choices' or that the natural environment is being protected and the possible costs involved in 'life-style' choices for the wider community. On Etna, for example, this conflict involves groups as diverse as present residents, the Mafia, potential migrants, conservationists, political parties in Sicily, the Italian people and, more broadly, the people of Europe. The importance of conflicting interest is growing partly because of the increased role politically and economically significant bodies play in the organisation of societies to reduce risk but also because such organisation may not reduce risk but rather create new forms of it. The organisation of society being the aim of modern political thinking and the transformation and generation of new risks being the consequence. It is, therefore, necessary to address the issue of conflicting interests because the active organisation of society is now possible and practised, while at the same time the process of organisation is affecting different interests to varying extents.

A mechanism is needed to reconcile interests that lie within a context wider than the particular case of volcanic vulnerability reduction. This wider context of risk has been discussed by Beck (1992, 1998) and Giddens (1998). Both come to a similar conclusion, that a revitalised (parliamentary) democracy is the solution to the modern situation of risk. Beck (1998) argues that:

> technical (or ecological) democracy is the utopia of a responsible modernity, a vision of society in which the consequences of technological development and economic change are debated before key decisions are taken...what is needed is nothing less than a *second enlightenment* which opens our minds, eyes and institutions to the self-afflicted endangerment of industrial civilization (Beck, 1998, p. 21).

While Gidden (1998) states that:

> Social movements and special interests groups cannot supply what parliamentary politics offers - the means of reconciling different interests with one another...[the issue of manufactured risk] demands to be brought more directly into the political arena (Giddens, 1998, p. 34).

These visions of a parliamentary arena, debating and directing the development of technologies and futures, while treating interests with equal weight, may be idealistic. However it would be more equitable than allowing the debate to be driven and risk discourses to be constructed purely by industrial and commercial interests as is often the case today. *There is a clear need for new mediums to enable negotiations of risks within which the vulnerable are empowered and knowledgeable.*

10.4 CRITIQUE OF THE VULNERABILITY APPROACH

The approach, to volcanic disaster, set out in this thesis has allowed a thorough inspection of vulnerability in two case study areas. However a number of difficulties have become apparent during the project.

The approach demands extensive cross disciplinary work. A vulnerability project needs to be based on a precise understanding of the volcanic hazards in an area. This may involve work in a variety of different geoscience areas. To progress the project, work needs to be carried out within the areas of history, economics, geography, sociology and psychology. All these areas then need to be brought together in a final assessment of vulnerability. Vulnerability analysis is therefore both time consuming and difficult to organise. In areas where research has already been carried out a vulnerability project may be easier but for many volcanoes little or no work has been carried out. It may therefore be necessary to modify the methodology in areas where volcanic knowledge is low and unlikely to be improved in the near future. This would involve the use of likely volcanic scenarios from similar geological areas. The movement of the work into the arena of policy and change would be harder if no estimation of the probability of an eruption could be given.

Vulnerability analysis, as set out in this thesis, is necessarily complex. It involves exploring both the natural and the human domains, at different levels, across space and through time. This means that there is no simple answer to the question, of how vulnerability can be reduced. This is not the fault of the method, rather it is a fact of the situation. Ways of reducing vulnerability will always be complex.

The mix of methods used in volcanic vulnerability analysis will not be supported by some methodological purists. However the advantage of the method is that it allows quite disparate areas of research to be tackled. The use of different methods can be seen as a strength in that it permits a certain amount of cross-validation or triangulation to take place. The case studies of Furnas and Etna suggest the importance of persevering with this approach because it highlights how a population can be differentiated in terms of the type and quantity of threat faced and how this situation may be the result of unique historical, environmental, social and cultural conditions.

CHAPTER ELEVEN: CONCLUSION

The main aim of this thesis as outlined in chapter 1 was to produce a more comprehensive framework within which to explain volcanic disasters. In order to do this two objectives were identified. These were first, to develop an approach that was capable of identifying what antecedent conditions tend to precipitate volcanic disasters and secondly, to develop a theory capable of explaining the production of these conditions. These were the main objectives for Part One of this thesis. The objective for Part Two was: to test the approach and theory in the context of two case studies; to examine whether vulnerability, as earlier defined, is increasing or decreasing in these areas and to suggest how vulnerability in these regions might be reduced. How each of these objectives has been satisfied will now be discussed.

An approach that is capable of identifying what antecedent conditions tend to precipitate volcanic disasters has been developed. This approach revolves around the interface between physical and human systems. It identifies, precisely, how a volcanic event is harmful by suggesting ways in which an individual's basic needs are susceptible. This approach is sensitive to both different types of volcanic activity and societies. It does not, for example, limit the way basic human needs may be expressed or satisfied within different cultures. Different social systems will therefore react differently to the same physical event.

A theory capable of explaining the production of these conditions has been developed. Within this theory, volcanic vulnerability is seen principally as a function of historically given dynamic social conditions as they exist within and across various hierarchies of space. The potential effect of volcanic activity over this space is not likely to influence these conditions. Though the actual effect of a volcanic eruption may be profound, it will be rare in terms of socially significant periods of time and therefore will only have limited significance. Individuals in reproducing these conditions and space also reproduce their own vulnerability. This theory links individual psychological theory with macro social theory and provides a plausible theory of vulnerability.

The approach and theory have been tested in the context of two case studies. The approach reveals the nature of personal vulnerability in these areas and the theory provides a credible explanation why this should be. The case studies show that in European countries individual vulnerability to volcanism has tended to decrease in the last hundred years but that this rate of reduction is now levelling off. The reduction in the last hundred years has been the result of the development of state insurance, better emergency and medical techniques and a growing understanding of volcanic activity. For effusive eruptions individual vulnerability is now rare but this is not true for explosive eruptions where it is still common.

The case studies have more to tell us about the general problem of vulnerability in volcanic environments. It has shed light on the relationship between factors such as technology, international economics, democracy, welfare polices, urbanisation, economic growth, regional geography and vulnerability. It has demonstrated the significance of scaling in conceptualising the problem and emphasised the extreme situation that exists in some less developed world areas subject to volcanic hazard.

The final issue, how can vulnerability be reduced, is the most problematic. A framework for identifying vulnerability can be produced, an assessment of vulnerability can be made and proposals as to the causes can be put forward, but can vulnerability be reduced? The work carried out in this thesis points towards a solution which extends beyond the typical technological response. A number of significant problems, with the use of technology in isolation to reduce vulnerability, have been identified. An equitable and effective programme of vulnerability reduction can only be achieved by recognising its complex nature and incorporating an empowered vulnerable and others in a debate on what technological, political and economic measures should be used to reduce it. The end product would be an inclusive programme prepared for a hazard conscious population. Even if the programme could not remove all vulnerability, the remaining threat would have been agreed upon by the vulnerable from a position of knowledge and power.

GLOSSARY

Many of these terms are more fully described within the text.

Bounded rationality – a model of decision making in which the actor does not necessarily aim to maximise gain but rather to satisfy some broad objectives.

Caldera – often circular depression, with steep sided walls, that results from the collapse of a MAGMA chamber. It can be many miles wide.

Cognitive dissonance – a theory which deals with the effect of an inconsistency between beliefs, attitudes and behaviour. It is argued that such inconsistency causes a feeling of discomfort and therefore encourages individuals to either cognitively or behaviourally modify their situation.

Cultural biases - deeply held beliefs and worldviews whose value lie in the defence of particular patterns of social relations. The patterns of social relations in cultural theory are summarised under four, sometimes five, archetypes. These are differentiated depending on the extent to which they involve membership of bounded groups or the extent to which interactions are governed by rules or are negotiated ad hoc. The main four cultural biases are: *egalitarians*, *individualists*, *hierarchists* and *fatalists*.

Expected Utility - rational decision making which assumes that it is possible to have a concept such as 'gain' - which is a composite of the advantages and disadvantages of different choices - secondly, that people try to maximise gain and, thirdly, that in attempting to maximise gain, people have perfect knowledge. They need to have perfect knowledge to judge each potential choice in terms of two factors; value and probability. Value is the affective or emotional weight given to an outcome by an individual and the probability being the chance that an expected outcome would happen.

Fumarole – a vent giving off gases or steam. Can appear on active or dormant volcanoes.

Heuristics - a cognitive procedure or shortcut whose function is to reduce the number of possible outcomes or solutions to a problem and, therefore, make a problem more manageable.

Hydrothermal activity - occurs when water is able to drain into the ground, is heated by shallow magma and returns to the surface under hydrostatic pressure. The resulting features include hot springs, FUMAROLES, geysers and mud-pots. If there is a slow circulation of water, chemical reactions between the water and the surrounding rock can take place. The result is waters with differing mineral and gas contents.

Lahar - are water lubricated flows made up of any type of material from a volcanic edifice for example: trees, pyroclastic material, or large boulders. Lahars flow down slope under the force of gravity, following topographic depressions such as river valleys. They represent a serious hazard to humans.

Lava – molten rock and MAGMA which solidifies when erupted. Typically they are categorised, depending on their flow morphology, as being of one of three main types: pahoehoe, aa or block type. The flow itself may be simple (ie. a single flow unit) or compound (ie. made up of several flow fields) depending on the effusion rate and viscosity of the lava. Usually slow moving and therefore not a great hazard to human life.

Magma – hot mobile molten rock originating from the partial melting of the mantle at depths of ~70-200 km. Magma composition is a continuum arbitrarily divided into three main types, defined by silica content (SiO_2): these are basaltic (silica-poor - not particularly explosive), andesitic/ trachytic (intermediate in composition - explosive) and rhyolitic (silica rich - explosive).

Ontological security - a feeling that the natural and social worlds are predictable and are as they appear to be.

Pyroclastic flow - are clouds of hot gas and particles that, driven principally by gravity, move across a landscape as a density cloud. They are highly hazardous.

Social Representations - systems of values, ideas and practises which allow the establishment of an order which will enable an individual to orient and master their material and social worlds. They also allow communication to take place by providing a code or a naming and classifying system in order to allow social exchange.

Social System – the patterning of social relations across space and time, through the reproduction of social practises.

Structuralism - generally, any approach which argues the priority of social structure over individual action.

Structuration – the organisation of social relations across space and time due to the dual nature of structure.

Subjective expected utility – a theory similar to EXPECTED UTILITY but which recognises that an individual might subjectively rather than objectively value different elements within the process.

Time-space distanciation – the stretching of social systems across time and space. Is a function of the process of social and systems integration.

Tsunami – a large rapidly moving sea wave generated by seismic activity or a volcanic eruption.

APPENDIX A

The interview schedule used in Trecastagni - secondary questions, prompts and response sets are in brackets.

q1. Have you lived all your life in Trecastagni? (yes/ no) (Why did you decide to move to Trecastagni?)
q2. What are the advantages of living in this town?
- A) What services are there?
- B) What are the advantages of the town's environment?
- C) What problems are there with the town's environment?
- D) Are you satisfied with the towns social environment?
- E) Is the town lacking in any services?
- F) Are there any social problems in the town?

q3. Have you thought of moving to another town? (yes/ no) (Why?)
q4. What do you think are the main problems faced by the people of this town?
q5. Generally, what are your feelings towards the volcano?
q6. Do you think your land or property is at risk? (yes/ no) (In what way is it at risk?)
q7. Do you think the health of the inhabitants of this town is at risk? (yes/ no) (In what way is it at risk?)
q8a. I do not believe there is a real danger that the town will be destroyed by lava. (Strongly agree/ Agree/ Neither agree nor disagree/ Disagree/ Strongly disagree)
q8b. The chance of lava coming close to the town is very high. (Strongly agree/ Agree/ Neither agree nor disagree/ Disagree/ Strongly disagree)
q8c. I would suffer great financial hardship if the town was destroyed by lava. (Strongly agree/ Agree/ Neither agree nor disagree/ Disagree/ Strongly disagree)
q8d. It would be a great loss for me if this town was destroyed by lava. (Strongly agree/ Agree/ Neither agree nor disagree/ Disagree/ Strongly disagree)
q8e. I have taken precautions to limit the extent of the damage if the town was destroyed by lava. (Strongly agree/ Agree/ Neither agree nor disagree/ Disagree/ Strongly disagree)
q8f. I do not believe the volcano represents a danger to the inhabitants of this town. (Strongly agree/ Agree/ Neither agree nor disagree/ Disagree/ Strongly disagree)
q8g. The chance of me or a member of my family being close to a dangerous eruption is high. (Strongly agree/ Agree/ Neither agree nor disagree/ Disagree/ Strongly disagree)
q8h. Being close to a lava flow is not dangerous. (Strongly agree/ Agree/ Neither agree nor disagree/ Disagree/ Strongly disagree)
q8i. I avoid areas of volcanic activity. (Strongly agree/ Agree/ Neither agree nor disagree/ Disagree/ Strongly disagree)

q9. Is there a greater danger to property, from an eruption, in this town compared to other towns? (yes/ no) (Why is this?)

q10. Do you have insurance against damage done by a volcanic eruption? (yes/ no)

q10b. If not why not? ? (It is not worth it/ I am not able to buy it/ I didn't know it existed/ Other)

q11. Do any of your friends or family have insurance against damage done by volcanic eruptions? (yes/ no)

q12. Do you have insurance against earthquakes? (yes/ no)

q12b. Do you have insurance against fire? (yes/ no)

q13. Have you used other methods to protect your property? (yes/ no) (What are these)

q14. Do you believe that reconstruction after a natural catastrophe is the responsibility of the state or the individual citizen? (The State/ The citizen) (Why do you believe this?)

q15. Do you believe that restricting building in the area of high risk is a good or bad idea? (good/ bad) (Why?)

q16. Do you think the way of life on Etna is very different to that in the rest of Sicily? (yes/ no) (why do you think this?)

q17. Do you believe it is possible to control a lava flow? (yes/ no) (To what extent?)

q18. Do you think the construction of permanent barriers to protect towns on Etna is a good or a bad idea? (good/ bad) (Why do you think this?)

Could you tell me your age? Gender? (Male/ Female)
What is the occupation of the main wage earner in your household?

Topics for discussion - in-depth interviews in Furnas.

- Do you live permanently in Furnas?
- Length of residence, Why did you move here?
- Family living in area, how long have they lived in the area
- Have you thought about moving away? (Why is this?)
- The advantages of living in this village
- Problems faced by the people of this village
- Gases being released in the town/ the waters/ a future eruption/ an earthquake. (Why is this?)
- Do you think you would have a warning before an eruption? What would you do if you realised an eruption was taking place?
- Do you have insurance - for fire/ earthquakes/ volcanic eruptions (why is this?)
- How do people cope if they lost their house in a fire or had some other sudden catastrophe? (social support/ savings/ sources of income)
- How do you find out information about the volcano? where would you go for information?

Occupation of main wage earner
Gender
Age
Smoker
Finished schooling at what age

APPENDIX B

Appendix B tabulates the data derived from the Italian census. It shows only data used in the analysis and all figures have been rounded to whole numbers. The source and calculation of these variables is shown after the tables.

Comune	%Unemploy 91	%Unemploy 81	%Hol. homes 91	%Comuter 91	%Pasture 61	%MI 51-61	%MI 61-71	%MI 71-81	%MI 81-91	1861-1991	pop 1991	Sector	Relief prot	Hazard
1 Aci Bonaccorsi	21	8	11	55	0	9	1	3	4	1138	2360	4	1	3
2 Aci Castello	9	7	16	49	2	6	0	21	16	15911	17927	4	1	1
3 Aci Catena	14	13	3	48	0	-9	-6	14	30	16163	20760	4	1	1
4 Acireale	21	9	12	84	0	-3	-5	-5	-9	15414	46199	4	1	1
5 Aci Sant'Antonio	12	6	10	116	5	-13	-4	8	53	18695	12459	4	2	5
6 Adrano	10	12	11	45	21	3	-12	-8	-12	19556	32717	6	1	1
7 Belpasso	16	8	6	158	3	2	-5	7	23	11821	19183	5	2	1
8 Biancavilla	16	7	13	62	9	-3	-21	-3	3	12838	22226	6	2	1
9 Bronte	21	14	5	57	37	-10	-35	-27	-1	7837	18689	7	2	3
10 Calatabiano	20	16	20	47	13	-12	-18	-7	0	3002	5713	3	1	1
12 Camporotondo Etneo	18	11	5	101	4	8	-3	32	31	1335	2066	5	2	3
14 Castiglione	11	13	11	41	23	-21	-31	-10	-10	-469	4551	2	2	1
15 Catania	16	9	4	101	7	-1	-6	-16	-18	262467	333075	5	2	1
16 Fiumefreddo di Sicilia	18	17	8	76	0	-5	-10	10	10	7620	9408	3	1	1
17 Giarre	14	12	5	81	1	-3	3	8	-4	13465	26732	3	1	1
19 Gravina Catania	15	6	1	32	0	6	88	81	0	25254	26627	5	2	3
21 Linguaglossa	25	24	8	65	33	-14	-16	-4	-4	-2684	5393	2	2	1
22 Maletto	20	10	9	45	51	-12	-18	-6	-22	1657	4254	8	1	1
23 Mascali	13	14	31	51	1	-10	-11	-11	10	6161	9779	3	2	3
24 Mascalucia	18	7	19	62	0	12	15	73	47	15993	19286	5	2	3
26 Milo	24	22	27	77	0		-26	-12	-12	176	1126	3	1	3
29 Misterbianco	16	11	6	148	9	10	9	34	18	34506	40785	5	1	1
30 Motta Sant'Anastasia	21	11	4	65	7	4	-11	11	19	5492	8716	5	1	0
31 Nicolosi	18	6	38	78	6	3	-4	8	11	2572	5365	5	2	6
33 Paterno	20	21	3	65	6	4	-14	-8	-7	29065	44266	6	2	1
34 Pedara	12	9	44	77	2	-8	5	21	33	4688	8034	4	2	5
35 Piedimonte Etneo	21	12	19	65	23	-11	-25	-5	-4	-1096	3886	3	2	1
38 Randazzo	38	37	9	64	51	-19	-24	-2	2	4545	11550	1	2	1
39 Riposto	21	16	15	64	0	-11	-12	1	1	7629	14048	3	1	1
41 San Giovanni La Punta	12	9	7	87	1	20	28	46	22	17227	18858	4	2	3
42 San Gregorio di Catani	10	8	4	64	4	15	15	63	7	7496	9169	4	2	1
44 San Pietro Clarenza	24	8	9	60	0	2	-4	34	38	3035	4025	5	1	3
45 Sant'agata Li Battiati	11	5	1	56	0	3	115	59	9	10337	10856	5	1	4
46 Sant'Alfio	32	9	24	49	28	-8	-11	-16	-2	-5	1666	3	2	6
47 Santa Maria Licodia	17	18	15	60	3	4	-13	-4	3	4310	7096	6	1	0
48 Santa Venerina	19	12	10	89	4	-7	-7	-4	1	1412	6972	4	2	3
50 Trecastagni	12	9	34	120	5	-1	-4	7	30	3922	6960	4	2	5
51 Tremestieri Etneo	13	7	4	72	2	15	84	54	13	15556	16695	5	1	4
52 Valverde	16	11	10	116	1	28	33	34	11	4873	5717	4	1	1
53 Viagrande	17	6	21	74	0	-3	-9	11	10	2794	5688	4	1	5
55 Zafferana Etnea	25	7	24	58	10	1	-8	5	7	4003	7361	4	2	4
57 Maniace	54	56	1	39					-4	1768	3101	8	1	1

Comune	Rented51	Water inside 51	WC inside 51	Rented61	Vater insid 61	Bath61	WC inside 61	Rented71	Vater insid 71	Bath71	WC inside 71	Rented81	Bath81
1 Aci Bonaccorsi	22	0	8	26	49	7	54	21	83	43	91	20	72
2 Aci Castello	43	41	2	49	85	22	86	39	91	52	89	35	85
3 Aci Catena	43	11	7	43	53	5	63	37	76	38	76	31	80
4 Acireale	50	17	5	49	53	12	63	38	71	48	81	20	72
5 Aci Sant'Antonio	29	1	5	32	34	6	78	17	80	35	84	24	79
6 Adrano	32	9	60	35	45	5	59	25	86	24	92	20	63
7 Belpasso	28	6	15	24	46	6	73	18	86	40	91	19	79
8 Biancavilla	22	15	65	17	38	4	64	17	86	24	94	11	64
9 Bronte	21	19	30	18	70	5	80	13	84	22	90	12	98
10 Calatabiano	37	13	57	40	69	6	81	31	83	29	84	27	98
12 Camporotondo Etneo	16	1	31	25	48	9	71	16	85	13	92	28	99
14 Castiglione	16	15	13	15	60	4	79	13	83	25	90	12	67
15 Catania	74	60	2	71	91	31	92	58	95	67	97	52	87
16 Fiumefreddo di Sicilia	40	30	9	38	87	14	83	33	90	51	87	27	85
17 Giarre	47	26	3	45	78	18	73	39	84	56	84	35	83
19 Gravina Catania	32	10	5	38	71	14	90	41	98	79	97	38	95
21 Linguaglossa	23	22	22	23	83	9	81	18	96	37	89	16	79
22 Maletto	9	0	65	9	32	3	91	-7	92	17	96	7	53
23 Mascali	36	27	6	36	55	5	64	28	77	36	82	30	78
24 Mascalucia	34	13	4	38	75	19	92	27	94	58	93	31	92
26 Milo				17	52	7	58	12	75	34	76	15	67
29 Misterbianco	35	3	43	40	24	6	62	34	69	43	83	32	84
30 Motta Sant'Anastasia	23	15	59	27	64	10	80	18	89	41	93	0	75
31 Nicolosi	20	0	6	19	32	12	69	10	88	59	96	19	85
33 Paterno	40	17	42	43	52	6	81	38	86	32	93	31	71
34 Pedara	25	0	7	26	29	7	85	12	91	72	94	22	85
35 Piedimonte Etneo	25	21	17	28	61	6	86	24	92	34	90	20	73
38 Randazzo	22	13	47	25	55	6	77	18	87	25	88	17	77
39 Riposto	48	36	5	48	79	18	67	36	83	52	83	32	83
41 San Giovanni La Punte	32	8	2	36	66	15	87	28	93	34	94	6	91
42 San Gregorio di Catani	28	1	2	34	60	12	91	25	86	63	92	31	92
44 San Pietro Clarenza	21	0	19	19	65	4	85	20	89	50	88	26	89
45 Sant'agata Li Battiati	35	4	6	32	71	20	93	36	97	82	98	35	98
46 Sant'Alfio	18	0	6	23	43	2	64	16	69	28	76	18	58
47 Santa Maria Licodia	25	4	38	23	44	3	64	15	72	23	88	16	69
48 Santa Venerina	21	1	5	25	22	9	57	18	71	30	84	19	79
50 Trecastagni	32	6	3	31	54	12	83	16	92	60	94	25	83
51 Tremestieri Etneo	24	6	5	34	57	12	78	32	94	76	96	32	94
52 Valverde				26	45	12	62	29	88	66	93	33	93
53 Viagrande	28	7	3	31	57	12	83	19	77	39	85	24	79
55 Zafferana Etnea	17	25	7	19	27	13	76	12	85	47	86	16	78
57 Maniace												1	40

Comune	%AGR51	%IND51	%SER51	%AGR61	%IND61	%SER61	AG51_61	IND51_61	SER51_61	%AGR71	%IND71	%SER71	AG61_71
1 Aci Bonaccorsi	44	19	37	33	37	30	-10	18	-8	28	36	35	-5
2 Aci Castello	57	21	22	45	25	30	-12	4	8	33	29	39	-12
3 Aci Catena	52	14	33	48	21	31	-4	6	-2	41	29	31	-7
4 Acireale	44	24	32	41	26	32	-3	2	1	29	31	40	-12
5 Aci Sant'Antonio	53	26	20	47	29	25	-7	2	4	35	35	29	-11
6 Adrano	71	16	14	67	19	14	-4	3	0	54	29	17	-12
7 Belpasso	69	15	16	57	23	20	-12	8	4	34	39	27	-23
8 Biancavilla	77	11	12	67	19	14	-9	8	2	57	22	20	-10
9 Bronte	74	15	11	62	25	13	-12	9	3	49	32	19	-12
10 Calatabiano	80	7	13	76	12	12	-4	5	-1	58	24	18	-18
12 Camporotondo Etneo	61	22	17	41	27	32	-20	5	15	23	41	36	-18
14 Castiglione	76	18	6	73	16	11	-3	-2	5	58	25	17	-15
15 Catania	10	35	55	8	40	52	-2	5	-3	5	37	58	-3
16 Fiumefreddo di Sicilia	63	12	25	63	17	21	0	4	-4	45	31	24	-18
17 Giarre	51	23	26	49	25	26	-3	2	1	36	25	39	-13
19 Gravina Catania	25	57	18	18	57	25	-7	0	7	5	47	48	-13
21 Linguaglossa	68	17	16	63	21	16	-5	5	0	51	28	22	-12
22 Maletto	81	10	9	73	18	10	-9	7	1	53	32	15	-20
23 Mascali	79	8	12	74	13	13	-5	5	1	65	17	18	-9
24 Mascalucia	42	29	29	29	44	27	-13	15	-2	16	44	39	-12
26 Milo				83	9	8				54	26	20	-29
29 Misterbianco	63	22	15	47	34	19	-16	12	4	58	26	16	11
30 Motta Sant'Anastasia	81	10	10	63	22	16	-18	12	6	23	49	28	-39
31 Nicolosi	58	16	27	48	25	27	-10	10	0	37	38	25	-11
33 Paterno	70	14	17	67	17	17	-3	3	0	71	15	14	4
34 Pedara	67	14	19	50	31	19	-17	17	0	54	22	23	5
35 Piedimonte Etneo	73	13	14	68	19	13	-5	6	-1	33	38	29	-35
38 Randazzo	68	18	14	70	17	13	2	-1	-1	54	27	20	-16
39 Riposto	45	22	33	47	22	32	2	0	-2	35	23	42	-11
41 San Giovanni La Punta	39	36	25	36	42	22	-3	6	-3	19	44	37	-18
42 San Gregorio di Catani	47	32	22	40	37	23	-6	5	1	21	42	38	-20
44 San Pietro Clarenza	48	28	24	33	35	33	-16	7	9	13	45	42	-20
45 Sant'agata Li Battiati	23	41	36	16	50	35	-7	8	-1	6	36	58	-10
46 Sant'Alfio	84	7	9	75	13	12	-9	6	3	62	22	17	-14
47 Santa Maria Licodia	76	10	14	73	12	15	-4	2	2	55	23	22	-18
48 Santa Venerina	66	18	16	58	26	15	-8	8	-1	45	34	22	-14
50 Trecastagni	62	16	22	42	33	25	-20	16	3	33	39	29	-10
51 Tremestieri Etneo	57	22	21	43	35	22	-14	14	1	11	34	55	-32
52 Valverde				50	36	14				27	48	25	-23
53 Viagrande	49	16	35	44	27	29	-5	11	-6	28	35	38	-17
55 Zafferana Etnea	64	15	21	55	24	21	-9	9	0	42	28	30	-13
57 Maniace													

Comune	IND61_71	SER61_71	%AGR81	%IND81	%SER81	AG71_81	IND71_81	SER71_81	%AGR91	%IND91	%SER91	AG81_91	IND81_91	SER81_91
1 Aci Bonaccorsi	-1	6	18	29	53	-10	-7	17	15	26	60	-4	-3	7
2 Aci Castello	4	9	16	22	62	-17	-7	23	8	17	75	-8	-5	13
3 Aci Catena	8	0	25	27	48	-15	-2	17	13	27	59	-12	1	11
4 Acireale	4	8	20	24	56	-9	-7	16	19	21	60	-2	-2	4
5 Aci Sant'Antonio	7	4	27	28	45	-9	-8	16	8	30	62	-19	3	16
6 Adrano	10	3	47	21	32	-7	-8	15	45	14	41	-2	-7	9
7 Belpasso	16	7	20	37	44	-14	-2	17	13	34	53	-7	-2	9
8 Biancavilla	3	6	49	19	33	-8	-4	12	44	16	40	-5	-3	8
9 Bronte	7	5	32	34	33	-17	2	15	25	35	39	-7	1	6
10 Calatabiano	12	6	42	23	34	-16	0	16	28	25	47	-15	2	13
12 Camporotondo Etneo	14	4	9	39	52	-14	-2	16	8	32	60	-1	-7	8
14 Castiglione	9	6	48	23	29	-10	-2	12	42	21	37	-6	-2	8
15 Catania	-3	6	4	27	69	-1	-10	11	5	22	73	2	-5	3
16 Fiumefreddo di Sicilia	15	3	30	30	40	-15	-1	16	22	26	52	-8	-4	12
17 Giarre	1	13	25	22	53	-11	-3	14	15	21	63	-9	-1	10
19 Gravina Catania	-10	23	3	31	66	-2	-16	18	6	24	70	4	-8	4
21 Linguaglossa	6	6	45	20	35	-6	-8	13	33	19	47	-11	-1	12
22 Maletto	15	5	35	41	24	-18	9	9	34	33	34	-1	-9	10
23 Mascali	4	5	46	23	32	-19	5	14	29	23	48	-17	1	16
24 Mascalucia	0	13	6	36	58	-10	-9	18	7	28	66	0	-8	8
26 Milo	18	11	46	23	31	-8	-4	11	37	22	41	-9	-1	10
29 Misterbianco	-8	-3	10	41	50	-48	14	34	6	36	59	-4	-5	9
30 Motta Sant'Anastasia	28	12	23	28	49	0	-21	22	18	22	60	-4	-6	10
31 Nicolosi	12	-1	24	28	47	-13	-9	22	14	24	62	-10	-4	15
33 Paterno	-2	-3	41	22	37	-30	7	23	32	21	47	-9	-1	10
34 Pedara	-9	4	19	32	49	-36	9	26	9	28	63	-10	-4	14
35 Piedimonte Etneo	19	16	33	31	36	0	-7	7	25	31	44	-9	0	8
38 Randazzo	9	7	50	22	28	-3	-5	8	44	18	38	-6	-4	10
39 Riposto	1	10	24	24	51	-11	2	9	19	20	61	-6	-4	10
41 San Giovanni La Punta	3	15	8	33	58	-11	-11	21	5	24	71	-4	-9	13
42 San Gregorio di Catani	5	15	9	26	65	-11	-16	27	6	20	74	-4	-6	10
44 San Pietro Clarenza	10	9	13	42	45	0	-3	3	12	31	57	-1	-10	11
45 Sant'agata Li Battiati	-14	24	3	22	75	-2	-14	17	5	17	79	1	-5	4
46 Sant'Alfio	9	5	53	21	26	-9	-1	10	37	21	42	-16	-1	16
47 Santa Maria Licodia	11	7	46	18	37	-9	-6	15	36	17	46	-9	0	10
48 Santa Venerina	7	6	35	31	34	-10	-2	12	22	32	47	-13	0	13
50 Trecastagni	6	4	21	30	49	-11	-9	20	11	26	63	-10	-4	15
51 Tremestieri Etneo	-1	33	5	23	72	-6	-11	17	5	21	74	0	-2	2
52 Valverde	12	11	13	38	49	-14	-9	24	6	30	64	-7	-8	15
53 Viagrande	8	8	22	29	49	-6	-6	12	9	29	62	-13	0	13
55 Zafferana Etnea	4	9	36	26	38	-6	-2	8	26	25	49	-10	-1	11
57 Maniace			76	6	18				43	25	32	-33	19	14

Variables	Calculation	Source
1861-1991	(population in 1991)-(population in 1861)	Italy. Istituto Nazionale di Statistica (1993) *13o censimento generale della popolazione e delle abitazione, 20 ottobre 1991. Fascicoli provinciali.* Rome : ISTAT, 1993.
pop 1991	population in 1991	Italy. Istituto Nazionale di Statistica (1993) *13o censimento generale della popolazione e delle abitazione, 20 ottobre 1991. Fascicoli provinciali.* Rome : ISTAT, 1993.
Sector	Etna region divided into eight sectors centred on summit	author
Relief prot	Comuni in relief shadow	Based on Cristofolini and Romano, 1980
Hazard	Location of main towns in reference to different zones of hazard	Based on Cristofolini and Romano, 1980
%Unemploy 91	((unemployed 91/active population 91) x 100)	Italy. Istituto Nazionale di Statistica (1993) *13o censimento generale della popolazione e delle abitazione, 20 ottobre 1991. Fascicoli provinciali.* Rome : ISTAT, 1993.
%Unemploy 81	((unemployed 81/active population 81) x 100)	Italy. Istituto Centrale di Statistica (1983) *12o censimento generale della popolazione 25 ottobre 1981. vol.2, Dati sulle caratteristiche strutturali della popolazione e della abitazioni. t.2, fascicoli regionali.* Roma : Istituto Centrale di Statistica.
%Hol. homes 91	((holiday homes/all homes) x 100)	Italy. Istituto Nazionale di Statistica (1993) *13o censimento generale della popolazione e delle abitazione, 20 ottobre 1991. Fascicoli provinciali.* Rome : ISTAT, 1993.
%Commuter 91	((comuni residents employed in industry/ total industrial workers in comuni) x 100)	Italy. Istituto Centrale di Statistica (1995) *7o censimento generale dell'industria, del commercio, dei servizi e dell'artigianato 26 ottobre 1991.* vol.2, Dati sulle caratteristiche strutturali delle imprese e delle unità locali. t.2, Fascicoli regionali. Roma : the Istituto.
%Pasture 61	((area pasture/area agriculture) x 100)	Italy, Istituto Centrale di Statistica (1966) *1 censimento generale dell' agricoltura 24 ottobre 1962. v.2, Caratteristiche strutturali delle aziende agricole. t.2, fascicoli regionali,* Roma : the Istituto.
%MI 51-61	((((population 61 - population 51)-natural increase)/((population 61 + population 51)/2)) x 100)	1951-1961 Italy. Istituto Centrale di Statistica, *Annuario di statistiche demografiche*, Roma: Istituto Centrale di Statistica.
%MI 61-71	((((population 71 - population 61)-natural increase)/((population 71 + population 61)/2)) x 100)	1961-1971 Italy. Istituto Centrale di Statistica, *Annuario di statistiche demografiche*, Roma: Istituto Centrale di Statistica.
%MI 71-81	((((population 81 - population 71)-natural increase)/((population 81 + population 71)/2)) x 100)	1971-1981 Italy. Istituto Centrale di Statistica, *Annuario di statistiche demografiche*, Roma: Istituto Centrale di Statistica.

%MI 81-91	((((population 91 - population 81)-natural increase)/((population 91 + population 81)/2)) x 100)	1981-1984 Italy. Istituto Centrale di Statistica, *Annuario di statistiche demografiche*, Roma: Istituto Centrale di Statistica. 1985-91 Italy. Istituto Centrale di Statistica. *Statistiche demografiche*. Roma: Istituto Centrale di Statistica.
Rented51	((rented home 51/all homes 51) x 100)	Italy. Istituto Centrale di Statistica (1955) *IX censimento generale della popolazione, 4 Novembre 1951. Popolazione legale dei comuni*. Roma: Istituto Poligrafico dello Stato.
Rented61	((rented home 61/all homes 61) x 100)	Italy. Istituto Centrale di Statistica (1963) *10o censimento generale della popolazione, 15 Ottobre 1961*. Roma : Soc. A.B.E.T.E.,
Rented71	((rented home 71/all homes 71) x 100)	Italy. Istituto Centrale di Statistica (1972) *11o censimento generale della popolazione, 24 ottobre 1971*. Roma : Tipolitografia F. Failli, 1972-1977.
Rented81	((rented home 81/all homes 81) x 100)	Italy. Istituto Centrale di Statistica (1983) *12 censimento generale della popolazione 25 ottobre 1981. vol.2, Dati sulle caratteristiche strutturali della popolazione e della abitazioni. t.2, fascicoli regionali*. Roma : Istituto Centrale di Statistica.
Water inside 51	((home with water 51/all homes 51) x 100)	Italy. Istituto Centrale di Statistica (1955) *IX censimento generale della popolazione, 4 Novembre 1951. Popolazione legale dei comuni*. Roma: Istituto Poligrafico dello Stato.
Water inside 61	((home with water 61/all homes 61) x 100)	Italy. Istituto Centrale di Statistica (1963) *10o censimento generale della popolazione, 15 Ottobre 1961*. Roma : Soc. A.B.E.T.E.,
Water inside 71	((home with water 71/all homes 71) x 100)	Italy. Istituto Centrale di Statistica (1972) *11o censimento generale della popolazione, 24 ottobre 1971*. Roma : Tipolitografia F. Failli, 1972-1977.
WC inside 51	((home with WC 51/all homes 51) x 100)	Italy. Istituto Centrale di Statistica (1955) *IX censimento generale della popolazione, 4 Novembre 1951. Popolazione legale dei comuni*. Roma: Istituto Poligrafico dello Stato.
WC inside 61	((home with WC 61/all homes 61) x 100)	Italy. Istituto Centrale di Statistica (1963) *10o censimento generale della popolazione, 15*

		Ottobre 1961. Roma : Soc. A.B.E.T.E.,
WC inside 71	((home with WC 71/all homes 71) x 100)	Italy. Istituto Centrale di Statistica (1972) *11o censimento generale della popolazione, 24 ottobre 1971*. Roma : Tipolitografia F. Failli, 1972-1977.
Bath61	((home with bath 61/all homes 61) x 100)	Italy. Istituto Centrale di Statistica (1963) *10o censimento generale della popolazione, 15 Ottobre 1961*. Roma : Soc. A.B.E.T.E.,
Bath71	((home with bath 71/all homes 71) x 100)	Italy. Istituto Centrale di Statistica (1972) *11o censimento generale della popolazione, 24 ottobre 1971*. Roma : Tipolitografia F. Failli, 1972-1977.
Bath81	((home with bath 81/all homes 81) x 100)	Italy. Istituto Centrale di Statistica (1983) *12 censimento generale della popolazione 25 ottobre 1981. vol.2, Dati sulle caratteristiche strutturali della popolazione e della abitazioni. t.2, fascicoli regionali*. Roma : Istituto Centrale di Statistica.
%AGR51	((active employed in agriculture 51/active population 51) x 100)	Italy. Istituto Centrale di Statistica (1955) *IX censimento generale della popolazione, 4 Novembre 1951. Popolazione legale dei comuni*. Roma: Istituto Poligrafico dello Stato.
%AGR61	((active employed in agriculture 61/active population 61) x 100)	Italy. Istituto Centrale di Statistica (1963) *10o censimento generale della popolazione, 15 Ottobre 1961*. Roma : Soc. A.B.E.T.E.,
%AGR71	((active employed in agriculture 71/active population 71) x 100)	Italy. Istituto Centrale di Statistica (1972) *11o censimento generale della popolazione, 24 ottobre 1971*. Roma : Tipolitografia F. Failli, 1972-1977.
%AGR81	((active employed in agriculture 81/active population 81) x 100)	Italy. Istituto Centrale di Statistica (1983) *12 censimento generale della popolazione 25 ottobre 1981. vol.2, Dati sulle caratteristiche strutturali della popolazione e della abitazioni. t.2, fascicoli regionali*. Roma : Istituto Centrale di Statistica.
%AGR91	((active employed in agriculture 91/active population 91) x 100)	Italy. Istituto Nazionale di Statistica (1993) *13o censimento generale della popolazione e delle abitazione, 20 ottobre 1991. Fascicoli provinciali*. Rome : ISTAT, 1993.
%IND51	((active employed in manufacturing industry 51/active population 51) x 100)	Italy. Istituto Centrale di Statistica (1955) *IX censimento generale della popolazione, 4 Novembre 1951. Popolazione legale dei comuni*. Roma: Istituto Poligrafico dello Stato.

%IND61	((active employed in manufacturing industry 61/active population 61) x 100)	Italy. Istituto Centrale di Statistica (1963) *10o censimento generale della popolazione, 15 Ottobre 1961*. Roma : Soc. A.B.E.T.E.,
%IND71	((active employed in manufacturing industry 71/active population 71) x 100)	Italy. Istituto Centrale di Statistica (1972) *11o censimento generale della popolazione, 24 ottobre 1971*. Roma : Tipolitografia F. Failli, 1972-1977.
%IND81	((active employed in manufacturing industry 81/active population 81) x 100)	Italy. Istituto Centrale di Statistica (1983) *12 censimento generale della popolazione 25 ottobre 1981. vol.2, Dati sulle caratteristiche strutturali della popolazione e della abitazioni. t.2, fascicoli regionali*. Roma : Istituto Centrale di Statistica.
%IND91	((active employed in manufacturing industry 91/active population 91) x 100)	Italy. Istituto Nazionale di Statistica (1993) *13o censimento generale della popolazione e delle abitazione, 20 ottobre 1991. Fascicoli provinciali*. Rome : ISTAT, 1993.
%SER51	((active employed in service industry 51/active population 51) x 100)	Italy. Istituto Centrale di Statistica (1955) *IX censimento generale della popolazione, 4 Novembre 1951. Popolazione legale dei comuni*. Roma: Istituto Poligrafico dello Stato.
%SER61	((active employed in service industry 61/active population 61) x 100)	Italy. Istituto Centrale di Statistica (1963) *10o censimento generale della popolazione, 15 Ottobre 1961*. Roma : Soc. A.B.E.T.E.,
%SER71	((active employed in service industry 71/active population 71) x 100)	Italy. Istituto Centrale di Statistica (1972) *11o censimento generale della popolazione, 24 ottobre 1971*. Roma : Tipolitografia F. Failli, 1972-1977.
%SER81	((active employed in service industry 81/active population 81) x 100)	Italy. Istituto Centrale di Statistica (1983) *12 censimento generale della popolazione 25 ottobre 1981. vol.2, Dati sulle caratteristiche strutturali della popolazione e della abitazioni. t.2, fascicoli regionali*. Roma : Istituto Centrale di Statistica.
%SER91	((active employed in service industry 91/active population 91) x 100)	Italy. Istituto Nazionale di Statistica (1993) *13o censimento generale della popolazione e delle abitazione, 20 ottobre 1991. Fascicoli provinciali*. Rome : ISTAT, 1993.
AG51_61	%AGR61 - %AGR51	above
AG61_71	%AGR71 - %AGR61	above
AG71_81	%AGR81 - %AGR71	above

AG81_91	%AGR91 - %AGR81	above
IND51_61	%IND61-%IND51	above
IND61_71	%IND71-%IND61	above
IND71_81	%IND81-%IND71	above
IND81_91	%IND91-%IND81	above
SER51_61	%SER61-%SER51	above
SER61_71	%SER71-%SER61	above
SER71_81	%SER81-%SER71	above
SER81_91	%SER91-%SER81	above

APPENDIX C

Tabulation of the responses to the questionnaire survey in Trecastagni.

		Count	Percentage
q1. Have you lived all your life in Trecastagni?	Yes	171	86%
	No	29	15%
q3. Have you thought of moving to another town?	Yes	42	21%
	No	158	79%
q6. Do you think your land or property is at risk?	Yes	66	33%
	No	134	67%
q7. Do you think the health of the inhabitants of this town is at risk?	Yes	29	15%
	No	171	86%
q9. Is there a greater danger to property, from an eruption, in this town compared to other towns?	Yes	57	29%
	No	143	72%
q10. Do you have insurance against damage done by an eruption?	Yes	9	5%
	No	180	90%
	Do not know	11	6%
q10b. If not why not?	It is not worth it	80	40%
	I am not able to buy it	44	22%
	I didn't know it existed	41	21%
	Other	33	17%
q11. Do any of your friends or family have insurance against damage done by volcanic eruptions	No	178	89%
	Do not know	22	11%
q12. Do you have insurance against earthquakes?	No	183	92%
	Do not know	17	9%
q12b. Do you have insurance against fire?	Yes	5	3%
	No	179	90%
	Do not know	16	8%
q13. Have you used other methods to protect your property?	Yes	4	2%
	No	196	98%
q14. Do you believe that reconstruction after a natural catastrophy is the responsibility of the state or the individual citizen?	The State	186	93%
	The citizen	14	7%
q15. Do you believe that restricting building in the area of high risk is a good or bad idea?	Yes	187	94%
	No	13	7%
q16. Do you think the way of life on Etna is very different to that in the rest of Sicily?	Yes	21	11%
	No	175	88%
	Do not know	4	2%
q17. Do you believe it is possible to control a lava flow ?	Yes	139	70%
	No	61	31%
Age	18-25	39	20%
	26-35	71	36%
	36-45	49	25%
	46-55	20	10%
	56-65	16	8%
	66+	5	3%
Gender	Male	115	58%
	Female	85	43%

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
q8a. I do not believe there is a real danger that the town will be destroyed by lava.	1	61	24	16	
q8b. The chance of lava coming close to the town is very high.		25	22	52	2
q8c. I would suffer great financial hardship if the town was destroyed by lava.		29	24	48	
q8d. It would be a great loss for me if this town was destroyed by lava.	16	73	11		
q8e. I have taken precautions to limit the extent of the damage if the town was destroyed by lava.		5	3	93	
q8f. I do not believe the volcano represents a danger to the inhabitants of this town.	3	80	7	12	
q8g. The chance of me or a member of my family being close to a dangerous eruption is high.		32	28	41	
q8h. Being close to a lava flow is not dangerous.		23	19	58	
q8i. I avoid areas of volcanic activity.	5	66	11	16	3

		q8a. I do not believe there is a real danger that the town will be destroyed by lava.						
		agree		neutral		disagree		Total
q1. Have you lived all your life in Trecastagni?	Yes	103	60%	42	25%	26	15%	171
	No	19	66%	5	17%	5	17%	29
q3. Have you thought of moving to another town?	Yes	20	48%	18	43%	4	10%	42
	No	102	65%	29	18%	27	17%	158
q6. Do you think your land or property is at risk?	Yes	18	27%	26	39%	22	33%	66
	No	104	78%	21	16%	9	7%	134
q7. Do you think the health of the inhabitants of this town is at risk?	Yes	12	41%	8	28%	9	31%	29
	No	110	64%	39	23%	22	13%	171
q9. Is there a greater danger to property, from an eruption, in this town compared to other towns?	Yes	39	68%	10	18%	8	14%	57
	No	83	58%	37	26%	23	16%	143
q10. Do you have insurance against damage done by an eruption?	Yes	4	44%	5	56%			9
	No	113	63%	38	21%	29	16%	180
	Do not know	5	45%	4	36%	2	18%	11
q10b. If not why not?	It is not worth it	50	63%	21	26%	9	11%	80
	I am not able to buy it	30	68%	10	23%	4	9%	44
	I didn't know it existed	30	73%	2	5%	9	22%	41
	Other	10	30%	14	42%	9	27%	33
q11. Do any of your friends or family have insurance against damage done by volcanic eruptions	No	117	66%	39	22%	22	12%	178
	Do not know	5	23%	8	36%	9	41%	22
q12. Do you have insurance against earthquakes?	No	117	64%	38	21%	28	15%	183
	Do not know	5	29%	9	53%	3	18%	17
q12b. Do you have insurance against fire?	Yes	5	100%					5
	No	113	63%	39	22%	27	15%	179
	Do not know	4	25%	8	50%	4	25%	16
q13. Have you used other methods to protect your property?	Yes	3	75%	1	25%			4
	No	119	61%	46	23%	31	16%	196
q14. Do you believe that reconstruction after a natural catastrophy is the responsibility of the state or the individual citizen?	The State	112	60%	47	25%	27	15%	186
	The citizen	10	71%			4	29%	14
q15. Do you believe that restricting building in the area of high risk is a good or bad idea?	Yes	115	61%	46	25%	26	14%	187
	No	7	54%	1	8%	5	38%	13
q16. Do you think the way of life on Etna is very different to that in the rest of Sicily?	Yes	9	43%	9	43%	3	14%	21
	No	109	62%	38	22%	28	16%	175
	Do not know	4	100%					4
q17. Do you believe it is possible to control a lava flow ?	Yes	74	53%	42	30%	23	17%	139
	No	48	79%	5	8%	8	13%	61
Age	under 46	103	65%	34	21%	22	14%	159
	Over 46	19	46%	13	32%	9	22%	41
Gender	Male	67	58%	29	25%	19	17%	115
	Female	55	65%	18	21%	12	14%	85
Total		122	61%	47	24%	31	16%	200

		q8d. It would be a great loss for me if this town was destroyed by lava.				
		agree		neutral		
						Total
q1. Have you lived all your life in Trecastagni?	Yes	159	93%	12	7%	171
	No	19	66%	10	34%	29
q3. Have you thought of moving to another town?	Yes	30	71%	12	29%	42
	No	148	94%	10	6%	158
q6. Do you think your land or property is at risk?	Yes	61	92%	5	8%	66
	No	117	87%	17	13%	134
q7. Do you think the health of the inhabitants of this town is at risk?	Yes	24	83%	5	17%	29
	No	154	90%	17	10%	171
q9. Is there a greater danger to property, from an eruption, in this town compared to other towns?	Yes	54	95%	3	5%	57
	No	124	87%	19	13%	143
q10. Do you have insurance against damage done by an eruption?	Yes	9	100%			9
	No	161	89%	19	11%	180
	Do not know	8	73%	3	27%	11
q10b. If not why not?	It is not worth it	73	91%	7	9%	80
	I am not able to buy it	43	98%	1	2%	44
	I didn't know it existed	31	76%	10	24%	41
	Other	29	88%	4	12%	33
q11. Do any of your friends or family have insurance against damage done by volcanic eruptions	No	160	90%	18	10%	178
	Do not know	18	82%	4	18%	22
q12. Do you have insurance against earthquakes?	No	164	90%	19	10%	183
	Do not know	14	82%	3	18%	17
q12b. Do you have insurance against fire?	Yes	5	100%			5
	No	160	89%	19	11%	179
	Do not know	13	81%	3	19%	16
q13. Have you used other methods to protect your property?	Yes	1	25%	3	75%	4
	No	177	90%	19	10%	196
q14. Do you believe that reconstruction after a natural catastrophy is the responsibility of the state or the individual citizen?	The State	168	90%	18	10%	186
	The citizen	10	71%	4	29%	14
q15. Do you believe that restricting building in the area of high risk is a good or bad idea?	Yes	170	91%	17	9%	187
	No	8	62%	5	38%	13
q16. Do you think the way of life on Etna is very different to that in the rest of Sicily?	Yes	17	81%	4	19%	21
	No	157	90%	18	10%	175
	Do not know	4	100%			4
q17. Do you believe it is possible to control a lava flow ?	Yes	122	88%	17	12%	139
	No	56	92%	5	8%	61
Age	under 46	141	89%	18	11%	159
	Over 46	37	90%	4	10%	41
Gender	Male	104	90%	11	10%	115
	Female	74	87%	11	13%	85
Total		178	89%	22	11%	200

		q8c. I would suffer great financial hardship if the town was destroyed by lava.						
		agree		neutral		disagree		Total
q1. Have you lived all your life in Trecastagni?	Yes	44	26%	44	26%	83	49%	171
	No	14	48%	3	10%	12	41%	29
q3. Have you thought of moving to another town?	Yes			13	31%	29	69%	42
	No	58	37%	34	22%	66	42%	158
q6 Do you think your land or property is at risk?	Yes	19	29%	9	14%	38	58%	66
	No	39	29%	38	28%	57	43%	134
q7 Do you think the health of the inhabitants of this town is at risk?	Yes	5	17%	3	10%	21	72%	29
	No	53	31%	44	26%	74	43%	171
q9 Is there a greater danger to property, from an eruption, in this town compared to other towns?	Yes	15	26%	22	39%	20	35%	57
	No	43	30%	25	17%	75	52%	143
q10 Do you have insurance against damage done by an eruption?	Yes			4	44%	5	56%	9
	No	57	32%	43	24%	80	44%	180
	Do not know	1	9%			10	91%	11
q10b If not why not?	It is not worth it	28	35%	18	23%	34	43%	80
	I am not able to buy it	10	23%	10	23%	24	55%	44
	I didn't know it existed	8	20%	9	22%	24	59%	41
	Other	11	33%	10	30%	12	36%	33
q11 Do any of your friends or family have insurance against damage done by volcanic eruptions	No	52	29%	47	26%	79	44%	178
	Do not know	6	27%			16	73%	22
q12 Do you have insurance against earthquakes?	No	58	32%	46	25%	79	43%	183
	Do not know			1	6%	16	94%	17
q12b Do you have insurance against fire?	Yes					5	100%	5
	No	57	32%	47	26%	75	42%	179
	Do not know	1	6%			15	94%	16
q13 Have you used other methods to protect your property?	Yes	3	75%	1	25%			4
	No	55	28%	46	23%	95	48%	196
q14 Do you believe that reconstruction after a natural catastrophy is the responsibility of the state or the individual citizen?	The State	53	28%	38	20%	95	51%	186
	The citizen	5	36%	9	64%			14
q15 Do you believe that restricting building in the area of high risk is a good or bad idea?	Yes	56	30%	44	24%	87	47%	187
	No	2	15%	3	23%	8	62%	13
q16 Do you think the way of life on Etna is very different to that in the rest of Sicily?	Yes	6	29%	2	10%	13	62%	21
	No	52	30%	41	23%	82	47%	175
	Do not know			4	100%			4
q17 Do you believe it is possible to control a lava flow ?	Yes	31	22%	39	28%	69	50%	139
	No	27	44%	8	13%	26	43%	61
Age	under 46	49	31%	43	27%	67	42%	159
	Over 46	9	22%	4	10%	28	68%	41
Gender	Male	37	32%	32	28%	46	40%	115
	Female	21	25%	15	18%	49	58%	85
Total		58	29%	47	24%	95	48%	200

		q6. Do you think your land or property is at risk?			
		Yes		No	
q1. Have you lived all your life in Trecastagni?	Yes	56	85%	115	86%
	No	10	15%	19	14%
q3. Have you thought of moving to another town?	Yes	17	26%	25	19%
	No	49	74%	109	81%
q7. Do you think the health of the inhabitants of this town is at risk?	Yes	24	12%	5	3%
	No	42	21%	129	65%
q9. Is there a greater danger to property, from an eruption, in this town compared to other towns?	Yes	19	29%	38	28%
	No	47	71%	96	72%
q10. Do you have insurance against damage done by an eruption?	Yes	5	8%	4	3%
	No	60	91%	120	90%
	Do not know	1	2%	10	7%
q10b. If not why not?	It is not worth it	21	32%	59	45%
	I am not able to buy it	16	24%	28	21%
	I didn't know it existed	11	17%	30	23%
	Other	18	27%	15	11%
q11. Do any of your friends or family have insurance against damage done by volcanic eruptions	No	56	85%	122	91%
	Do not know	10	15%	12	9%
q12. Do you have insurance against earthquakes?	No	62	94%	121	90%
	Do not know	4	6%	13	10%
q12b. Do you have insurance against fire?	Yes			5	4%
	No	61	92%	118	88%
	Do not know	5	8%	11	8%
q13. Have you used other methods to protect your property?	Yes			4	3%
	No	66	100%	130	97%
q14. Do you believe that reconstruction after a natural catastrophy is the responsibility of the state or the individual citizen?	The State	62	94%	124	93%
	The citizen	4	6%	10	7%
q15. Do you believe that restricting building in the area of high risk is a good or bad idea?	Yes	64	97%	123	92%
	No	2	3%	11	8%
q16. Do you think the way of life on Etna is very different to that in the rest of Sicily?	Yes	13	20%	8	6%
	No	53	80%	122	91%
	Do not know			4	3%
q17. Do you believe it is possible to control a lava flow ?	Yes	56	85%	83	62%
	No	10	15%	51	38%
Age	under 46	44	67%	115	86%
	Over 46	22	33%	19	14%
Gender	Male	39	59%	76	57%
	Female	27	41%	58	43%

		q1. Have you lived all your life in Trecastagni?			
		Yes		No	
q3. Have you thought of moving to another town?	Yes	37	22%	5	17%
	No	134	78%	24	83%
q6. Do you think your land or property is at risk?	Yes	56	33%	10	34%
	No	115	67%	19	66%
q7. Do you think the health of the inhabitants of this town is at risk?	Yes	24	14%	5	17%
	No	147	86%	24	83%
q9. Is there a greater danger to property, from an eruption, in this town compared to other towns?	Yes	56	33%	1	3%
	No	115	67%	28	97%
q10. Do you have insurance against damage done by an eruption?	Yes	9	5%		
	No	153	89%	27	93%
	Do not know	9	5%	2	7%
q10b. If not why not?	It is not worth it	73	43%	7	24%
	I am not able to buy it	36	21%	8	28%
	I didn't know it existed	32	19%	9	31%
	Other	28	17%	5	17%
q11. Do any of your friends or family have insurance against damage done by volcanic eruptions	No	151	88%	27	93%
	Do not know	20	12%	2	7%
q12. Do you have insurance against earthquakes?	No	155	91%	28	97%
	Do not know	16	9%	1	3%
q12b. Do you have insurance against fire?	Yes	5	3%		
	No	150	88%	29	100%
	Do not know	16	9%		
q13. Have you used other methods to protect your property?	Yes	4	2%		
	No	167	98%	29	100%
q14. Do you believe that reconstruction after a natural catastrophy is the responsibility of the state or the individual citizen?	The State	164	96%	22	76%
	The citizen	7	4%	7	24%
q15. Do you believe that restricting building in the area of high risk is a good or bad idea?	Yes	159	93%	28	97%
	No	12	7%	1	3%
q16. Do you think the way of life on Etna is very different to that in the rest of Sicily?	Yes	16	9%	5	17%
	No	151	88%	24	83%
	Do not know	4	2%		
q17. Do you believe it is possible to control a lava flow ?	Yes	119	70%	20	69%
	No	52	30%	9	31%
Age	under 46	139	81%	20	69%
	Over 46	32	19%	9	31%
Gender	Male	102	60%	13	45%
	Female	69	40%	16	55%

		q1. Have you lived all your life in Trecastagni?			
		Yes		No	
q8a. I do not believe there is a real danger that the town will be destroyed by lava.	agree	103	60%	19	66%
	neutral	42	25%	5	17%
	disagree	26	15%	5	17%
q8b. The chance of lava coming close to the town is very high.	agree	44	26%	5	17%
	neutral	44	26%		
	disagree	83	49%	24	83%
q8c. I would suffer great financial hardship if the town was destroyed by lava.	agree	44	26%	14	48%
	neutral	44	26%	3	10%
	disagree	83	49%	12	41%
q8d. It would be a great loss for me if this town was destroyed by lava.	agree	159	93%	19	66%
	neutral	12	7%	10	34%
q8e. I have taken precautions to limit the extent of the damage if the town was destroyed by lava.	agree	9	5%		
	neutral	5	3%		
	disagree	157	92%	29	100%
q8f. I do not believe the volcano represents a danger to the inhabitants of this town.	agree	139	81%	25	86%
	neutral	13	8%		
	disagree	19	11%	4	14%
q8g. The chance of me or a member of my family being close to a dangerous eruption is high.	agree	51	30%	12	41%
	neutral	50	29%	6	21%
	disagree	70	41%	11	38%
q8h. Being close to a lava flow is not dangerous.	agree	38	22%	8	28%
	neutral	38	22%		
	disagree	95	56%	21	72%
q8i. I avoid areas of volcanic activity.	agree	115	67%	26	90%
	neutral	22	13%		
	disagree	34	20%	3	10%

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