Hazard responses in the *pre-industrial era:* vulnerability and resilience of traditional societies to volcanic disasters

HEATHER SANGSTER

Thesis submitted in accordance with the requirement of the University of Liverpool for the degree of Doctor in Philosophy

2013

Department of Geography and Planning

School of Environmental Sciences

University of Liverpool

Liverpool, UK

CONTENTS

FIGURES

LIST OF FIGURES **Page**

TABLES

LIST OF TABLES **Page**

PREFACE

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

Sangster, H., Chester, D.K., Duncan, A.M. 2013. Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era. In: Reide, F. (Ed.). *Book Title TBC*. University of Aarhus, Denmark, Aarhus, pp. no page numbers.

Sangster, H., Duncan, A.M., Chester, D.K. 2013. Religions and Hazards. In: Bobrowsky, P. (Ed.) Encyclopedia of Natural Hazards. Springer, Heidelberg.

Chester, D.K., Duncan, A.M., **Sangster, H.** 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research*, 225-226, 65-80.

Macdonald, N., Chester, D.K., **Sangster, H.,** Todd, B., Hooke, J. 2012. The significance of Gilbert White's 1942 Paper 'Human Adjustments to floods' in the development of risk and hazard management. *Progress in Physical Geography*, 36, 1, 125-133.

Chester, D.K., Duncan, A.M., **Sangster, H.** 2010. Religious interpretations of disaster. In: Gaillard, J.C., Wisner, B. and Kelman, I (Eds.), Routledge Handbook of Natural Hazards and Management. Routledge, London, pp. 875.

Sangster, H., Chester, D.K., Duncan, A.M. 2013. Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era: presented at the *LaPaDiS Colloquium*, Aarhus, 14 – 16 January, 2013.

Sangster, H., Chester, D.K., Duncan, A.M. Human responses to historical eruptions of Etna (Sicily) from 1600 to present and their implications for present-day disaster planning: presented at the *European Geosciences Union Conference*, Vienna, 22 – 27 April, 2012.

Sangster, H., Chester, D.K., Duncan, A.M. Human Adjustments to the 1906 eruption of Vesuvius, Italy: presented at the *European Geosciences Union Conference*, Vienna, 3 – 8 April, 2011.

Sangster, H., Chester, D.K., Duncan, A.M. Human Adjustments to the 1906 eruption of Vesuvius, Italy, *BSG Annual Conference*, University of Liverpool, 28 – 30 June, 2011.

Sangster, H., Chester, D.K., Duncan, A.M. Pre-Industrial responses to volcanic eruptions in Western Europe and their role in Contemporary Civil Defence Plans: presented at the *Cities on Volcanoes 6th International Conference*, Tenerife, 31 May – 4 June, 2010.

Sangster, H., Chester, D.K., Duncan, A.M. Pre-Industrial responses to volcanic eruptions in Western Europe and their role in Contemporary Civil Defence Plans, *BSG 50th Anniversary Conference*, London, 31 August – 2 September, 2010.

Sangster, H., Chester, D.K., Duncan, A.M. Pre-Industrial responses to volcanic eruptions in Western Europe and their role in Contemporary Civil Defence Plans, *RGS-IBG Mid-Term Postgraduate Conference,* Aberystwyth University, 5 – 6 March, 2010.

ACKNOWLEDGEMENTS

First, I would like to thank my supervisors, Professor Angus Duncan and Dr. David Chester, for their time and effort over the last three and a half years. Professors Nicolau Wallenstein and Rui Coutinho from the *Departimento de Geociencias*, *Universeidade dos Açores*, must also be thanked for their kind help and hospitality in the field and in the provision of supplementary materials. Thanks are also extended to Sandra Mather and Suzanne Yee for expertly drafting the figures.

A special thanks must go to my family, especially my parents, Alison and Graeme, for their continued love and (financial!) support. Thanks must also be given for proof reading several(!) versions of the thesis at different stages in development, and for ticking off every reference and more importantly, identifying all those missing ones! Thanks to my brother John, and sister Catriona, for their continued support, not just throughout the Ph.D. but throughout my time at University. Finally, thanks must be given to Neil for his patience and support...not forgetting that promised trip to Disneyland!

DECLARATION

I hearby declare that the following thesis is based on the results of investigations conducted by myself, and that this thesis is of my own composition. This thesis has not, in whole or part, been previously presented for a higher degree. Work other than my own is clearly indicated in the text by reference to the relevant researcher or publications

Heather Sangster

The work presented in this thesis is the work of the candidate Heather Sangster. Conditions of the relevant ordinance and regulations have been fulfilled.

Dr David Chester

The research work was undertaken at the Department of Geography and Planning, School of Environmental Sciences, University of Liverpool.

ABSTRACT

This thesis has two aims to: a. assess the *vulnerability* and *resilience* of traditional societies and those on the threshold of modernisation to volcanic and volcano-related disasters; and b. evaluate the extent to which historical events and their associated responses may inform future policies of disaster management. In order to address these aims this thesis has three objectives, these being: a. to test the strengths and weaknesses of two methodologies, an historical approach based on archival and other information - applied to Etna and Vesuvius and a set of techniques focused around *vulnerability* and *resilience* – applied to the Azores; b. to identify traditional strategies of coping and survival during the *pre-industrial* period in the three case-study areas; and c. to evaluate the potential use of these data in the development of future disaster management plans.

During this research techniques from the earth sciences (i.e. field data collection) were combined with those more commonly seen in historical studies (i.e. archival data sources) to draw out the ways in which people have coped in the past to eruptions. Field visits were carried out on Etna, Sicily (Italy) and São Miguel Island, Azores (Portugal).

The principal conclusions of this research are:-

a. That the historical and *vulnerability* and *resilience* approach worked well, respectively for Etna and the Azores.
b. Less successful was the application of the historical approach to Vesuvius. In contrast to Etna this reflected amongst other things the fact that the last eruption occurred nearly seventy years ago (i.e. in 1944) and since that time the ‘*folk*’ memory of volcanic activity has been largely expunged because of rapid economic development combined with population growth.
c. In all three case study areas, volcanic earthquakes are an under-stated hazard; the process of development is increasing *vulnerability* and the practice of *popular Catholicism* does not prevent responses based on scientific understanding and civil defence planning.

The study identifies that future work would benefit from the application of a *vulnerability* and *resilience* based methodology grounded within both historical and contemporary contexts.

Chapter 1

INTRODUCTION

This Chapter introduces the research aim(s), objectives and structure of the thesis.

1.1 INTRODUCTION: VOLCANOES, SOCIETY AND PEOPLE

"*A volcano is not made on purpose to frighten superstitious people into fits of piety, nor to overwhelm devoted cities with destruction*"

James Hutton (1788)

Despite international efforts to reduce the loss of life, exposure to, and damage from so-called 'natural'[1] hazards, the number of recorded disasters has continued to rise. The last ten years of the twentieth-century were designated by the United Nations as the *International Decade for Natural Disaster Reduction* (*IDNDR* – 1990-1999). In the ten years of dedicated international research and activity, the *IDNDR* aimed to: improve the capacities of countries to mitigate the effects of natural hazards; better utilize and transfer scientific and technical information; and develop programmes of education and training (Lechat, 1990). By the end of the 'Decade' national and international agencies had become more focused on the particularities of the societies and cultures at risk from 'natural' disasters and how they have reacted in the past – and will respond in the future – to damaging events.

It is estimated that around *ca*. 10% of the world's population live near to, or on, active or potentially active volcanoes, and more than 500 million people could be at risk from volcano and volcano-related hazards in the twenty-first century (Tilling, 2004). If the figures for the numbers of people affected by, but not killed in, natural disasters for the most recent decade are examined (Table 1.1), then the impact of eruptions appears to be minimal in comparison to floods, droughts, storms and earthquakes. From these figures it would be easy to conclude that volcanic eruptions pose less of a threat than is commonly thought, and relative to other 'natural' hazards, occur infrequently and affect few people (Wijkman and Timberlake, 1984).

---

[1] The term *natural* in natural hazards, although etymologically doubtful – because in a sense all hazards are *natural*, it is sanctioned by long-term use in disaster research.

Chester *et al.* (2001) have shown from a more detailed examination of losses from volcano and volcano-related disasters that the reasons why the estimated number of people affected, but not killed by these events, underestimates the actual impact: firstly, there are differences in magnitude, frequency and recurrence intervals of individual volcanoes – which means that in some decades losses are inevitably much higher than in others; secondly, it is only a matter of chance that major eruptions in the twentieth century occurred in areas of low population density (e.g. Katmai, Alaska – 1912; and Bezymianny, Kamchatka, Russia – 1955/6); and thirdly, the reporting and recording of events has improved. Russell Blong estimated that from 1600 A.D. to 1982 just under 240,000 people had been killed due to the direct and indirect effects of eruptions (Blong, 1984), however, the powerful impact of four major volcano disaster of the 1980s (Mount St. Helens (U.S.A.) in 1980 – 57 people killed; El Chinchón (Mexico) in 1982 – *ca.* 2,000 people killed; Galunggung (Indonesia) in 1982/3 – more than 600,000 people affected; and Nevado del Ruíz (Columbia) in 1985 – *ca.* 23,000 people killed) demonstrated the increased *vulnerability* of modern societies to volcanic eruptions; whilst the recent 2010 Eyjafjallajökull eruption (Iceland) has shown that even moderate-scale eruptions can have serious local, national and international economic effects (e.g. on transport – especially aviation; farming practices and communications).

Table 1.1: Estimated number of people affected, but not killed, by natural disasters in the twentieth and twenty-first centuries. (Based on information from: EM-DAT[2]).

Disaster type	Numbers affected 2000-2010 (thousands)	Numbers affected 2000-2010 (% of total)	Numbers affected 1900-1999 (thousands)	Numbers affected 1900-1999 (% of total)
Floods	1,123,679	45.13	2,110,793	53.96
Droughts	880,343	35.36	1,310,103	33.49
Storms	400,838	16.10	410,523	10.49
Earthquakes	76,227	3.06	67,823	1.73
Landslides	3,605	0.14	5,828	0.15
Wildfires	2,139	0.09	3,621	0.09
Volcanic eruptions	1,511	0.06	3,334	0.09
Tsunami	2,561	0.06	50	0.001
Total	2,489,781		3,912,076	

---

[2] For the inclusion of a disaster in EM-DAT (Emergency Events Database - http://www.emdat.be) the following criteria must be fulfilled: 10 or more people reported killed; 100 or more people reported affected; declaration of a state of emergency; and call for international assistance.

Despite the hazards posed by many volcanoes, people in the past, and today, have continued to find not just the agricultural and resource potential of these regions attractive, but also the deep-seated economic, social and cultural features; as such this has resulted in the increase in population and in-migration within these potentially hazardous environments (Burton *et al*., 1993; Chester *et al*., 2001).

1.2 THE AIMS AND OBJECTIVES OF THE RESEARCH

A major research frontier in the study of *natural hazard* research involves unravelling the ways in which societies have reacted historically to disasters, and how such responses influence current policies of disaster reduction. In volcanic hazard research historical studies have been undertaken by a small number of research teams. Examples of publications where historical data has been used to reconstruct past responses include, the works of: Russell Blong in Papua New Guinea (1982, 1984) – where oral and written evidence have been important; more recently Carmen Solana and her colleagues in Tenerife, the Canary Islands (2012); and David Chester and Angus Duncan and their colleagues who have pioneered studies in Italy and the Azores (Chester *et al*., 1985, 1999, 2005, 2007a, 2007b, 2009, 2011, 2012; Dibben and Chester, 1999; Duncan *et al*., 1996, 2005; Coutinho *et al*., 2010).

In the past decade research of this type has been facilitated by a ‘revolution’ in the availability of source materials across a range of languages and in a variety of electronic formats (e.g. official archives – especially letters, manuscripts, maps, paintings, reports and telegrams; major contemporary and historical publications – which are now often available either electronically or as reprints; newspapers of record; newsreel-films and still-photography). Whilst the present author is not a fluent Italian or Portuguese speaker the introduction of more reliable translation software (e.g. *Systrans* and *Google Translate*) also provides far more scope to the researcher in the study of *natural hazards* than was the case even a few years ago. It is upon these sources of information that this thesis is based.

The main aims of this thesis are reflective of this research frontier and are two-fold:-

1. To assess the *vulnerability* and *resilience* of traditional societies and those on the threshold of modernisation to volcanic and volcano-related disasters.

2. To evaluate whether historical events and their associated responses may inform future policies of disaster management.

In order to address these aims three objectives need to be achieved. These are:-

1. To test the strengths and weaknesses of two methodologies that have the potential to reveal how traditional societies and those on the threshold of modernisation have coped in the past with volcanic and volcano-related disasters. The first approach is historically-based and uses archival data, major contemporary and historical publications and newspapers of record to draw out the ways in which people have coped in the past. The second focuses on *vulnerability* and *resilience* and is tailored to situations where there are fewer eruptions, but many other extreme events.

2. To identify traditional strategies of coping and survival in *pre-industrial* or *folk* societies in three case-study areas.

3. To assess the potential use of the information collected in Objectives 1 and 2 in the development of future disaster management plans.

These research aims and objectives are examined across three case-study areas: Mount Etna (Sicily, Italy); Mount Vesuvius (Italy) and the Islands of São Miguel and Faial (the Azores, Portugal). These case studies are comparable as they all present a 'Southern-European' culture (i.e. similar religious practices and socio-economic conditions), and until recently could be characterised as *pre-industrial*. They differ, however, both in their styles of volcanic activity and the historical source materials available to the researcher.

1.3 STRUCTURE OF THE THESIS

This thesis is presented in seven Chapters and each addresses the research aims and objectives identified in section 1.2.

In **Chapter 2** the histories and philosophes of natural hazard management are examined, from the pioneering work of Gilbert F. White and his colleagues in the 1940s (i.e. the *dominant* approach); through the work of the *radical* critics of the 1980s; to the period from 1990 and encompassing the United Nations *International Decade for Natural Disaster Reduction* (*IDNDR* – of the last ten years of the twentieth century) and the subsequent *International Strategy for Disaster Reduction* (*ISDR*).

Chapter 3 considers the use of the two different methodologies applied in this thesis: historical reconstruction and *vulnerability* and *resilience* analysis.

Chapters 4, 5 and 6 are detailed case studies of Mount Etna (Sicily, Italy), Mount Vesuvius (Italy) and the Islands of São Miguel and Faial (the Azores, Portugal), respectively. The historical methodology is used in **Chapters 4 and 5**, and the *vulnerability* and *resilience* methodology in **Chapter 6**.

The conclusion to the thesis in **Chapter 7**, not only reviews how and to what extent the research aims and objectives have been fulfilled, but also briefly sketches out the possible future projects that follow on from this study.

Chapter 2

DISASTER AND HAZARD RESEARCH

The focus of this Chapter is two-fold: firstly, to review the major characteristics of the ***historical*** perspectives used as frameworks for the study of volcanoes and society (i.e. the *dominant* approach and its several *radical* alternatives); and, secondly, to review the major characteristics of the ***contemporary*** perspectives used as frameworks for the study of volcanoes and society (i.e. the *IDNDR* and the *ISDR*).

2.1 SOCIAL THEORY AND VOLCANIC ERUPTIONS: DEFINING A FRAMEWORK

"The concept of hazards as external events impinging on unsuspecting people has been shed in favour of the interpretation that they emerge from interactions between people and environments"

J.K. Mitchell *et al*. (1989)

Since the 1940s hazard and disaster research has developed within three domains: *natural hazard research*, *disaster research* and *risk analysis* (Mitchell, 1990). *Disaster* studies, generally carried out by sociologists, were derived from efforts to support U.S. civil defence authorities. *Disaster* research sought to understand how people reacted to peacetime disasters and the implications this might have on wartime emergencies (Quarantelli, 1988). Research into *risk analysis* focuses on more technological sources and in particular on the development of techniques used both to quantify risk and inform policy (Starr, 1969). In *natural hazard* research, the first area to be developed and the focus of this Chapter, a number of perspectives have been used as frameworks within which to study volcanoes and society. These include: the *dominant* approach, also known as the *Chicago School,* and the *radical* approach (see Barrows, 1923; White, 1942, 1945, 1973; O'Keefe *et al*., 1976; Johnston, 1979, 1989; Hewitt, 1983a; Stoddart, 1987; Whittow, 1987; Palm, 1990). From the middle of the first decade of the twenty-first century, research into *natural hazards* and *disasters* has been cast within a framework defined by the polarities (or opposites) of *vulnerability* and *resilience*, elements of which either increase or decrease the impact of extreme events on a given society (see Pelling, 2001, 2003; Bankoff, 2001, 2012; García-Acosta, 2002; Wisner *et al*., 2004; Cutter, 2006; Galliard *et al*., 2010). These themes are discussed in sections 2.2 (2.2.1 and 2.2.2) and 2.3 (2.3.1).

2.2 DOMINANTS AND RADICALS: FROM GILBERT F. WHITE TO KENNETH HEWITT

2.2.1 Human ecology and the dominant paradigm

Before the 1980s, research on disasters was mainly carried out under the banner of what has been termed the *dominant* approach or paradigm. The *dominant* approach is characterised by five main research objectives which are summarised in Table 2.1, however as John Whittow (1987, pp. 308) points out, there is probably a sixth to: "evaluate the hazard's dimensions in order to predict the degree of impact and spatial dimensions of the risk zone". The extent and nature of human occupancy (Objective 1 – Table 2.1) is the foundation upon which the approach is based. The *dominant* approach developed from ideas first outlined by Harlan H. Barrows[3] (1923) in a paper entitled '*Geography as Human Ecology*'. Human ecology, the first research approach to be applied in the field of natural hazard research, is concerned with people "reacting and adjusting to environments while at the same time attempting to adjust the environment to [their] own needs" (Johnston, 1979, pp. 39 – see Fig. 2.1). Barrows' views were later taken up and applied to natural hazards by the American Scholar Gilbert F. White as he considered the range of possible policies that could be introduced to reduce flood losses in the U.S.A. (White, 1942, 1945).

Table 2.1: The research objectives of the *dominant* approach. (From Chester, 1993, pp. 229).

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K. 1993. *Volcanoes and Society*. Edward Arnold, London, pp. 351.

Understanding the impacts of White's (1945) paper, '*Human Adjustments to Floods*' which began as a University of Chicago Ph.D. in 1942, requires a consideration of both its motivation and its philosophical and political contexts (see Macdonald *et al*., 2012 –

---

[3] The long professional career of Professor Harlan Harland Barrows (1877-1960) was marked by major efforts to develop the fields of historical geography and the conservation of natural resources.

Appendix 1). In the U.S.A. the late 1920s and 1930s were notable for a series of environmental extremes i.e. the Mississippi flood in 1927 (Barry, 1998) and severe droughts in the 1930s (Hurt, 1981). Within this framework of environmental catastrophes and subsequent social hardship, the latter being not only a consequence of the extreme physical processes but also of the Great Depression, a new approach to managing the environment emerged. In order to overcome the Great Depression, government policy became more interventionist and involved a series of policies that became known as President Roosevelt's New Deal (Reisner, 1993). This change in political philosophy altered the ways in which many individual scientists/engineers and government bodies viewed their responsibilities, being concerned not just with studying environmental processes *per se*, but with applying this knowledge to the development of policies of hazard reduction. White was inspired and worked within an ethos defined by the interventionist environmental policies initiated by the Roosevelt administration and, as James Wescoat (1992) has shown, there are broad affinities between the *dominant* approach and the pragmatic tradition of the American social thought, especially that proposed by the philosopher John Dewey (e.g. Dewey, 1895-98, 1910, 1916, 1925, 1934), whose ideas were particularly influential in the first half of the twentieth century (Knight, 1921; Rucker, 1969; Lewis and Smith, 1980). Dewey's philosophy may be summarised under four main headings:

1. the precariousness of human life;
2. learning from experience;
3. a pragmatic notion of science and
4. open public discourse within a democratic framework.

There are both philosophical similarities and differences between Dewey and White and the degree to which the former influenced the latter has been debated (see Wescoat, 1992). There seems little doubt that White's pacifist beliefs, which are so prominent in his writings, were inspired by a personal commitment to Quakerism (Hinshaw, 2006). "Each of us should ask what in his teaching and research is helping our fellow man [*sic*] strengthen their capacity to survive in a peaceful world" (White, 1972, pp. 322; see Wescoat, 1992). Following the Second World War, White was joined by like-minded scholars most notably by Robert Kates and Ian Burton and their approach evolved into a set of techniques that were used not only to study flooding in the U.S.A. but also the totality of natural hazards in the world. Because the paths of these pioneer workers crossed at the University of Chicago, an alternative title for the *dominant* approach is the *Chicago School*. These scholars quickly achieved an overwhelming presence in the research literature, which in turn shaped approaches to policies of hazard reduction as framed by national governments, the United Nations Disaster Relief Office and later many academics and policy makers working within the context of the *International Decade for Natural Disaster Reduction* (*IDNDR*) (Lechat, 1990 – see section 2.3), especially up until the middle of the 1990s.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K. 1993. *Volcanoes and Society*. Edward Arnold, London, pp. 351.

Fig. 2.1: The nature of human responses and *adjustments* to volcanic hazards under the *dominant* approach. (From Chester, 1993, pp. 232).

The characteristics of the *dominant* approach are complex in detail (see Burton *et al*., 1978, 1993; Warrick, 1979; Whittow, 1987; Chester, 1993; Hewitt, 1997; and especially Alexander, 2000, pp. 23-53 for further details), but briefly White and his colleagues accepted that factors such as material wealth, systems of belief, experience of previous hazardous events and psychological considerations (e.g. Simon, 1957, 1959 – see Table 2.2) are all important in controlling how individuals, social groups and, indeed, whole societies respond to disasters, but their paradigm is strongly focused around the idea that there exists a range of *adjustments* to natural hazards that are available to individuals and/or societies to deal with extreme events (Objectives 2,3 and 4 – Table 2.1).

Adjustments are immediate, often short-term, responses to specific environmental problems. ‘*Bearing the loss*’ has been the involuntary *adjustment* which societies have adopted through most of their histories. It is still the situation that occurs in many *developing* countries today.

Typically in so-called *pre-industrial* or *folk* societies strategies of harmonising with nature, combined with often complex sociological *adjustments* to hazards, have featured (White, 1974). As Table 2.3 shows, this response is marked by low capital requirements, variability over short distances and flexibility. It is only effective "in the face of low-magnitude hazards; a high magnitude event will probably require massive overseas assistance" (Whittow, 1987, pp. 313). The responses of modern *technological* or *industrial* societies are different and emphasis is placed on shifting the burden from the individual to the society, nation and international community, by loss-sharing, insurance, relief aid and technology. Responses emphasize control over nature, a narrow range of *adjustments*, high costs and, as a result, inflexibility. Finally, there are *post-industrial* responses, which incorporate the best of the *pre-industrial* and *industrial* responses. Their "implementation requires an approach to land planning which, while recognizing the true character of the physical threat, at the same time attempts to harmonize technology to both the natural environment and the perception of the individuals and social groups faced by the danger" (Chester *et al*., 1985, pp. 345). This response represents a future ideal and it is doubtful whether any society has yet reached this stage, although Iceland, Japan and the U.S.A. approach it (Chester, 1993, pp. 237). The transition from *pre-industrial* to *industrial* may be sequential, but this is not normally the case because the characteristics of both types of responses may be seen at the same time within different social groups in disaster-prone regions (White, 1973).

Every natural hazard produces a response and this response may *modify* and *adjust* both the threat from the hazard itself and the human use of a particular area. In short, alternatives to '*loss bearing*' involve measures to: modify the hazardousness of an extreme event; modify its loss potential and adjust to losses; and as Burton *et al*. (1993) pointed out, many societies can cope with extreme natural events by either *adapting* or *adjusting* to them. For volcanic hazards *adjustment* is the response most commonly encountered, but *adaptation* (i.e. biological and cultural) may be important for certain societies (Blong, 1984). *Adjustments* are sub-divided into *purposeful* and *incidental*, with purposeful *adjustments* including most of those listed in Table 2.4 (see Walker, 1974; Burton *et al*., 1978, 1993; Tazieff and Sabroux, 1983; Crandell *et al*., 1984; McGuire *et al*., 1995a, 1995b; and Sigurdsson, 2000 for further details). Incidental *adjustments* are, in contrast, policy measures which are not related directly to hazard reduction, but reflect the normal processes of economic and social development (i.e. better telecommunications to assist in the early warning of extreme events

Table 2.2: Examples of, and remarks on, the factors controlling decision-making and responses to volcanic hazards. (Modified and updated where possible from Chester, 1993, pp. 235-236).

Factors affecting responses to volcanic hazards	Remarks and examples
Experience	Both individual and group responses to hazards depend on experience. Generally the longer the experience and the shorter the recurrence interval between eruptions, the more likely it is that future threats will be assessed accurately, but when volcanoes have long intervals between high-magnitude events, then experience may have the opposite effect. For example in 1975 certain slopes of Mount Baker in the Cascades (U.S.A.) were closed to holiday-makers, because an eruption was possible. Holiday-makers who had visited the volcano many times before and without incident were found to resent the closure far more than those who were first-time visitors and had no previous experience (Hodge *et al*., 1979).
Material Wealth	Material wealth correlates strongly with other socio-economic traits like education, mobility of residence, employment and scientific awareness, and influences the ability of individuals and social groups to recover from the effects of a natural disaster; i.e. though the initial effects of a natural disaster may be broadly egalitarian, wealth is associated with the ability to take locational risks and survive (Hass *et al*., 1977). Considerations of material wealth may be complicated by the adoption of measures which reduce individual losses. Individuals, cultural groups and societies in *more economically developed* countries are more likely to have access to insurance and support from national governments in the event of a disaster, however, the hurricane 'Katrina' disaster (U.S.A., 2005) showed that losses were based on existing divisions within society (Reichhardt *et al*., 2005; Comfort, 2006). In many ways this disaster mirrored differences usually found at the international level, with the poor, Hispanic and people of colour having a '*Third World* type' experience, whereas the rich – who were predominantly 'white' – had outcomes which were more typical of *economically* more advanced countries.
Systems of belief	These can complicate both responses and choices of *adjustment*. An individual's personality traits, such as varying degrees of inner control, perceived and actual leadership aptitudes, the ability to cope, survive and improvise may be crucial in any successful response. Many of these traits correlate with age, intelligence, education and wealth. A further feature is the accuracy with which a person can estimate risk. This depends in part upon the provision of accurate information, but the *gambler's fallacy* has often been observed. This is expressed in a belief that the occurrence of an event at a specific place in a particular year makes it less likely to happen again in the near future.

and improved methods of transport for the distribution of relief aid). Burton *et al*. (1993) created a typology for purposeful and incidental *adjustments* and introduced four characteristic modes of coping with natural hazards (i.e. *absorption*, *acceptance*, *reduction* and *change*), each separated by thresholds (i.e. *awareness* threshold, *action* threshold and *intolerance* threshold). *Loss absorption* is the first mode and it is believed that many societies can absorb the effects of extreme natural events without the need to take any action; for volcanic hazards this is relatively uncommon. *Loss absorption* may involve *adaption* or incidental *adjustment*. It is clear that most volcanic eruptions demand a more positive response and societies affected will cross the threshold of *awareness* and chose to either share or bear losses (Table 2.4). If the magnitude of an eruption and/or its effects are more severe, then the *action* threshold will be crossed and more positive, interventionist measures of loss-reduction will be taken (i.e. the introduction of early warning systems, building codes and regulations of agricultural practices – see Table 2.4). With extremely damaging events, the threshold of *intolerance* will be crossed and *change* as a form of *adjustment* will follow, being exemplified by land-use modifications, relocation of settlements and the introduction of planning measures.

Table 2.3: Responses to natural hazards in societies at differing levels of development. (After White, 1974, with modifications and with additions from: Chester, 1998; Chester *et al*., 2005, 2010).

Pre-Industrial (*Folk*) Responses	**Industrial Response**	**Post-Industrial (*Comprehensive*) Responses**
A wide range of *adjustments*.	A restricted range of *adjustments*.	A *post-industrial response* ideally includes the best elements of the *pre-industrial* and *industrial* and represents a future planning goal. There is innovation, not only of technical responses and planning policies, but are also sensitive to and indigenous methods of coping which are characteristics of a particular society and its history.
Action by individual or small groups.	Action requires co-ordination by the authorities.	
Emphasis on harmonization with, rather than technological control over, nature.	Emphasis is placed on technological control over nature, rather than harmonization with nature.	
Low capital requirements.	High capital requirements.	
Responses vary over short distances.	Responses mostly uniform.	
Responses are flexible and are easily abandoned if unsuccessful.	Responses are inflexible and difficult to change.	Such an approach is in agreement with current international policies, such as those proposed by the United Nations *International Strategy for Disaster Reduction* (*IDNDR*) and which are spelt out in the *Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disaster* (United Nations, 2011).
Losses are perceived as inevitable. The ‘mindset’ of many inhabitants is strongly influenced by notions of supernatural punishment, vengeance and the need to appease divine wrath.	Losses may be reduced by government action, technology, economic development and science.	
Responses continue over time scales ranging from hundreds to thousands of years. There is learning from experience.	*Industrial responses* were not commonly observed until the mid-nineteenth century and not widespread until the mid-twentieth. It is only from the mid-nineteenth century and starting in *economically more developed countries*, that there have been alternatives to bearing losses on an individual, family and local community basis.	*Comprehensive responses* have not been fully innovated anywhere in the world, though Iceland, the U.S.A. and Japan come closest to them (Chester, 1993, pp.237)

Table 2.4: The theoretical range of *adjustments* to hazards from lava flows. (Modified and updated from Chester, 2005, pp. 417-418).

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D. K., 2005. Volcanoes, Society and Culture. In: Marti, J., Ernst, G. J. (Eds.), Volcanoes and the Environment. Cambridge, Cambridge University Press, pp. 404-439.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D. K., 2005. Volcanoes, Society and Culture. In: Marti, J., Ernst, G. J. (Eds.), Volcanoes and the Environment. Cambridge, Cambridge University Press, pp. 404-439.

2.2.2 The critical backlash of the 1980s and 1990s

Until the 1980s, academic writers, national governments and international agencies were strongly committed to policies of loss-reduction, which were heavily grounded in the *dominant* approach, particularly in selecting the most appropriate combination of *adjustments* in order to cope with the threat of a hazard. The *dominant* approach argues that physical processes – in particular their magnitude and frequency – are first-order determinants of a disaster and that differences between societies are at a lower, albeit still significant, level of importance. This emphasis can be seen clearly in the translation of the *dominant* approach into priorities for national and international policy. The aims and objectives of the 1980s United States *Volcano Hazards Program*, which “can be classified under three broad headings: fundamental studies of volcanic processes, volcano hazard assessments, and volcano monitoring" (Filson, 1987, pp. 294; Wright and Pierson, 1996, pp. 6) are, for instance, remarkably similar to those of Argentina (Zupka, 1996) and many other countries of Latin America (Anon, 1994). The policy aims of national governments and international agencies are defined largely in terms of the transfer of technology and administrative experience from areas where responses are observed to have been successful (i.e. *economically more developed* countries) to those where they are either non-existent or perceived to have failed (i.e. *economically less developed* countries) and this thinking is both implicit and explicit in many of the statements which emerged early in the *International Decade for Natural Disaster Reduction* and in the attitudes of both scientists and policy-makers about the *nature* of the *International Decade for Natural Disaster Reduction*. These are summarised by Lechat (1990, pp. 1) as:

> "[a] to improve the capacity of each country to *mitigate* the effects of natural disasters ….. paying special attention to assisting developing countries in the assessment of disaster damage potential and in the establishment of *early warning systems* and *disaster-resistant* structures when and where needed; [b] to devise appropriate guidelines and strategies for applying *existing scientific and technical knowledge*, taking into account the cultural and economic diversity amongst nations; [c] to foster *scientific and engineering endeavours* aimed at closing critical gaps in knowledge in order to reduce loss of life and property; [d] to disseminate existing and new *technical information* related to measurements for the *assessment, prediction* and *mitigation* of natural disasters; [e] to develop measures for the *assessment, prediction, prevention* and *mitigation* of natural disasters through programmes of *technical assistance* and *technology transfer*, demonstration projects and education and training ….."
>
> (United Nations, Resolution 42/169, 1987, quoted by Lechat, 1990, pp. 1, *my emphasis*)

Thirty years ago, Kenneth Hewitt (1983a) edited a volume, '*Interpretations of Calamity*', which ushered in a period during which White's *dominant* approach was severely criticized by a group of scholars who became known as the *radical* critics. The research of *radical* scholars is heavily focused on poor countries and disasters, such as droughts, which have a long-onset time, are of long duration and cause damage to large areas. Although the arguments used by the *radical* critics are complex (see Hewitt, 1983a, 1997), the idea of fundamental importance is that most disasters in poor countries have more to do with political and economic power than with the extreme character of physical processes. Hewitt (1983b, pp. 26) posed a question "what is more characteristic [for the inhabitants of the frequently drought ridden areas of the Sahel] ..... and to be expected by its long time inhabitants: recurrent droughts or the recent history of political, economic and social change". Other authors who contributed to '*Interpretations of Calamity*', developed these ideas more fully.

Susman *et al*. (1983) proposed a new model of disaster occurrence and made use of the Marxist concept of *marginalization* (Fig. 2.2), by arguing that the people who suffer most in natural disasters are those who are either economically marginalized (i.e. they are poor) and/or geographically marginalized (i.e. they live in areas which are prone to disaster losses). They may also be socially marginalized, by not being members of a controlling or advantaged group. Relief aid and technological transfers tend to benefit those people who are already well off and can lead to further marginalization of the poorest sections of a community and greater future *vulnerability* to extreme natural events.

This text box is where the unabridged thesis included the following third party copyrighted material:

Susman, P., O'Keefe, P.,Wisner, B. 1983. Global disasters, a radical interpretation. In: Hewitt, K. (Ed.), Interpretations of Calamity. Boston, Allen and Unwin, pp. 263-283.

Fig. 2.2: The process of *marginalization* and its relationship to natural disasters. (Amended from Susman *et al*., 1983, pp. 279).

The authors of '*Interpretations of Calamity*' (Susman *et al*., 1983) focused on the effects of extreme natural events on countries that are *economically less developed* and in fact most of the published works that are critical of the *dominant* approach are concerned with hazards that occur in *economically less developed* countries. The most extreme *radical* critics (i.e.

Susman *et al*., 1983), proposed an openly Marxist agenda (Table 2.5) and it comes as no surprise to find that this has not proved popular with international agencies such as the United Nations and the World Bank. It may, however, be argued that within the *radical* critique there are themes that are of considerable importance in understanding the reasons why people respond to hazards in the ways they do, particularly the recognition that places are unique, not only in terms of meteorological and geophysical threats, but also because of the particularities of their society and culture. As David Chester (2005, pp. 421) states "Hawaii is not Etna, Iceland is not the Azores and the volcanoes of the Andes and those of the Cascades occur in quite different environments and societies".

Table 2.5: The implications of the *marginalization* theory (From Susman *et al*., 1983, pp. 279-80).

This text box is where the unabridged thesis included the following third party copyrighted material:

Susman, P., O'Keefe, P.,Wisner, B. 1983. Global disasters, a radical interpretation. In: Hewitt, K. (Ed.), Interpretations of Calamity. Boston, Allen and Unwin, pp. 263-283.

2.3 VOLCANOES AND PEOPLE: AN EVOLVING FRAMEWORK OF STUDY

2.3.1 The International Decade for Natural Disaster Reduction (*IDNDR*) and the International Strategy for Disaster Reduction (*ISDR*)

The decade of the 1990s was designated by the United Nations the *International Decade for Natural Disaster Reduction* (*IDNDR*), being superseded from the end of the millennium by the *International Strategy for Disaster Reduction* (*ISDR*) and many countries initiated research programmes to improve understanding of the threat posed to major population centres by natural hazards. In addition the international volcanological community, through its professional body, the *International Association for Volcanology and Chemistry of the Earth's Interior* (*IAVECI*; http://www.iaveci.org) designated 16 'Decade volcanoes' for detailed study (Colima, Mexico; Galeras, Columbia; Mauna Loa, U.S.A.; Merapi, Indonesia; Mount Rainer, Washington, U.S.A.; Nyiragongo, Zaire; Sakurajima, Japan; Santa Maria, Guatemala; Ta'al, Philippines; Ulawun, Papua New Guinea; Unzen, Japan; Mount Vesuvius, Italy), to which the European Union/European Science Foundation added 6 'Laboratory volcanoes' (Mount Etna, Sicily, Italy; Furnas, Azores, Portugal; Krafla, Iceland; Piton de la Fournaise, Réunion Island, Indian Ocean; Mount Teide, Tenerife, Spain; Santorini (i.e. ancient Thera), Greece). Many other countries, most notably the U.S.A., also had major volcano research programmes in the 1990s (e.g. the *Volcanic Hazards Program* of the United States Geological Survey – see Wright and Pierson, 1992 – and section 2.2.2). The 'Decade volcanoes' were selected to represent a wide range of volcanic styles – some explosive others effusive, located in dissimilar countries – some from *developed* others from *developing* countries, and became the focus of "intensive, integrated and multi-disciplinary research involving international co-operation" (McGuire, 1995b, pp. 404 – see Table 2.6).

During the *IDNDR* the critique, as outlined in Section 2.2.2, that hazard research placed too much emphasis on scientific and engineering solutions (Hewitt, 1983b, 1997) was voiced at the United Nations *World Conference on Natural Disaster Reduction* held in Yokohama, Japan, in 1994 (United Nations, 1995) to mark the middle of the Decade. The member states produced the *Yokohama Strategy for a Safer World*, and affirmed that the global society in general had become more vulnerable to natural disasters, and that the poor and socially disadvantaged were invariably the most seriously affected (United Nations, 1995). There was also a slow realisation that, if strategies of disaster reduction were to be successful, they had to be sensitive to place and culture. This is made clear from the sixth affirmation of the *Yokohama* message:

> "Community involvement and their active participation should be encouraged in order to gain greater insight into the individual and collective perception of development and risk, and to have a clear understanding of the cultural and organisational characteristics of each society as well as its behaviour and interactions with the physical environment. This knowledge is of utmost importance to determine those things which favour and hinder prevention and mitigation or encourage or limit the preservation of the environment for the development of future generations, and in order to find effective and efficient means to reduce the impact of disasters"
>
> (United Nations, *Yokohama Strategy for a Safer World*, 1995, pp. 4-5)

Table 2.6: Initiatives proposed at the beginning of the *International Decade for Natural Disaster Reduction* (*IDNDR*) by the *International Association of Volcanology and Chemistry of the Earth's Interior* (*IAVECI*). (From Chester, 2005, pp. 422).

(Footnotes included in the unabridged thesis in Table 2.6 for the definition of *general prediction*[4] and *specific prediction*[5])

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D. K., 2005. Volcanoes, Society and Culture. In: Marti, J., Ernst, G. J. (Eds.), Volcanoes and the Environment. Cambridge, Cambridge University Press, pp. 404-439.

---

[4] *General prediction* (also known as hazard mapping and assessment) is defined as, the study of the past behaviour of a volcano to determine the frequency, magnitude and style of eruptions, and to delineate high risk areas. It uses geological and historical evidence and eruption statistics, to produce a map showing the range of volcanic hazards under differing eruption scenarios. Traditionally the output has been cartographic, but increasingly computer-based *Geographical Information Systems* (GIS) are being employed (Walker, 1974).

[5] *Specific prediction* is based on surveillance of a volcano, and monitoring of changes (e.g. in seismic activity, ground deformation, thermal characteristics and geochemistry of gases), to forecast the time, place and magnitude of an eruption (Walker, 1974).

As the *IDNDR* progressed beyond its mid-point to the end of the Decade, the research agendas of the international and national agencies changed quite noticeably. Traditionally hazard assessment had stressed the physical processes that produce disasters, but this was tempered by a growing acceptance that hazards may act as 'triggers' that bring to the surface more deep-seated economic, political and cultural issues that are already present within a society (Hewitt, 1997; Pelling, 2001); a disaster being viewed as a "highlighter or amplifier of daily hardship and everyday emergencies rather than as an extreme and rare phenomena" (Galliard and Texier, 2008, pp. 347). In order to reduce disaster susceptibility and increase what is termed, *resilience* or *capacity* (see Chapter 3), the more deep-rooted causes of *vulnerability* (see Chapter 3) have to be addressed (Degg and Homan, 2005; Galliard, 2007).

Termed the *International Strategy for Disaster Reduction* (*ISDR*), this was adopted by the United Nations General Assembly in 1999 at the end of the *International Decade for Natural Disaster Reduction* (1990-1999). The United Nations terms its strategy: *A Safer World in the Twenty-First Century: Risk and Disaster Reduction* (United Nations, 1990); and, as well as focusing on the inter-disciplinary studies of hazard mitigation and prediction (i.e. *general* and *specific*), it attaches greater importance to the integration of disaster planning and policies of sustainable development. The aim of the *ISDR* is to continue to work to shift the emphasis away from *natural hazard research* as traditionally undertaken to "incorporating physical and socio-economic dimensions of vulnerability into the wider understanding, assessment and management of disaster risk ..... [and] building disaster resilient communities by promoting increased awareness of the importance of disaster reduction as an integral component of sustainable development, with the goal of reducing human, social, economic and environmental losses due to natural hazards and related technological and environmental disasters" (United Nations, 2011, pp. 11). Key words and phrases in this strategy are: *public awareness*; *moving from cultures of reaction to cultures of prevention*; *vulnerable groups* and *maintain the sustainability of hazard-prone areas* (Hamilton, 1999).

Ten years after the *Yokohama Strategy*, the *World Conference on Natural Disaster Reduction* held in Hyogo, Japan – under the auspices of the United Nations – adopted what is called the *Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disaster* (United Nations, 2011). Beginning with a review of the lessons learned from the *Yokohama Strategy*, the Conference identified five areas for action in order to take forward disaster risk reduction (*DRR*) at both the local and national levels:

1. Governance: organizational, legal and policy frameworks;

2. Risk identification, assessment, monitoring and early warning;
3. Knowledge management and education;
4. Reducing underlying risk factors;
5. Preparedness for effective response and recovery.

These five areas for action are summarised in the three strategic goals of the *Hyogo Strategy*:

> "[a] the more effective integration of disaster risk considerations into sustainable development policies, planning and programming at all levels, with a special emphasis on *disaster prevention*, *mitigation*, *preparedness* and *vulnerability reduction*; [b] the development and strengthening of institutions, mechanisms and capacities at all levels, in particular at the community level, that can systematically contribute to building *resilience* to hazards; [c] the systematic incorporation of risk reduction approaches into the design and implementation of emergency preparedness, response and recovery programmes in the reconstruction of affected communities"
>
> (United Nations, 2011, Hyogo Framework for Action 2005-2015, pp. 3-4, *my emphasis*)

2.3.2 Summary: Contemporary research agendas

The whole tenor of research is now more fully focused on the uniqueness of place, not only in terms of meteorological and geophysical threats, but also in terms of the particular society at risk and those factors that either increase or decrease susceptibility to losses. In short, disaster reduction involves a boosting of *resilience* and a reduction in human *vulnerability* and these concepts are fundamental to the research aims and objectives of this thesis and are examined further in Chapter 3.

Chapter 3

METHODOLOGY

The focus of this Chapter is four-fold: firstly, to identify and summarise the major characteristics of the *direct* and *indirect* volcano and volcano-related hazards posed by many volcanoes; secondly to identify and justify the case studies chosen for investigation; thirdly to outline the methodologies that will be used; and fourthly to discuss the wide variety of data sources that will be employed.

3.1 INTRODUCTION

In order to assess the *vulnerability* and *resilience* of traditional societies and those on the threshold of modernisation it is necessary to first identify those features of *direct* and *indirect* volcanic activity that impact upon societies. From the identification of the *direct* and *indirect* volcano and volcano-related hazards, it is then possible to determine the methodology required to draw out the ways in which people have coped with extreme events in the past.

3.2 DIRECT AND INDIRECT VOLCANO AND VOLCANO-RELATED HAZARDS

In recent years the different types of volcano and volcano-related hazards have been studied in detail (for a summary see: Macdonald, 1972; Whittow, 1980; Walker, 1982; Blong, 1984; Crandell *et al*., 1984; Scott, 1989; Tilling, 1989, 2004; Chester, 1993; Simkin and Siebert, 1994; McGuire, 1998, 2002, 2004; Sigurdsson, 2000; Schmincke, 2004; Bryant, 2005), and it is not the purpose of this chapter to simply repeat these listings, but rather to present the essential features as they apply to the research aims and objectives of this thesis (see Chapter 1). Volcanic hazards may be divided into two broad categories, *direct* and *indirect*, however it should be noted that the distinction between the two can be subjective in some instances, as they are dependent on both the time interval between the eruptive activity and the occurrence of the hazardous event(s) (Tilling, 2005). Table 3.1 summarises the characteristics of the major *direct* and *indirect* hazards posed by volcanoes.

Table 3.1: Major *direct* and *indirect* hazards posed by volcanoes. (Based on information from: McGuire, 1998, with additions from numerous other sources[6]).

Type of hazards	Characteristics	Selected examples
Direct volcano hazards		
Lava flows	Lava flows generally move slowly (ranging from a few metres to several kilometres per hour), along paths determined by topography and do not normally threaten life. They may be sub-divided into: pahoehoe; aa; and block types. Lava flows cause destruction through burial and burning, and this may end all existing land-uses, preventing it being re-established for many centuries.	Nyiragongo (Zaire, 1977) – this represents a rare exception from the norm
Domes	Domes are formed when magma is too viscous and immobile to flow very far.	Mt. St. Helens (U.S.A., 1980)
Pyroclastic falls and lateral (directed) blasts	Pyroclastic material ejected during explosive eruptions ranges from fine ash (less than 2 mm), lapilli (2 mm - < 69 mm) to blocks/bombs (greater than 64 mm). Falls present a number of hazards. Near to the volcano, failure of roofs, power lines and cables and death and injury through the impact of large blocks and bombs, may occur. Ash can destroy vegetation, crops, block roads, clog drains, watercourses and cause damage to equipment. In large eruptions, the dangers to aircraft may be considerable and particles can be spread over the globe and impact on climate and weather. Lateral blasts are highly destructive. Blasts kill by heat, burial and impact. Blasts are caused by the decompression of magmatic gases, or explosion of high pressure hydrothermal systems. Blasts may include pyroclastic flows and surges (see below).	Krakatau (Indonesia, 1883)
Gases	Gases are released from volcanoes both during and after periods of activity (e.g. H_2O, CO, CO_2, H_2S, SO_2, SO_3, SO_4, HF – and other inert gases). They present a number of hazards to both health and vegetation. The effects of gases are at their most severe near to a volcano and wind directions are important in determining the distribution. In the case of large eruptions, gases may have an impact on global climate.	Lake Nyos (Cameroon, 1986)
Pyroclastic flows and	Pyroclastic flows and surges (lower density versions of pyroclastic flows - two sub-types are	Mt. Lamington (Papua, 1951)

---

[6] Further information on the hazards shown in the table may be obtained from the following sources: Crandell *et al*., 1984; Scott, 1989; and Tilling, 1989, 2005.

surges	recognised: hot surges and cold surges) are masses of hot (300°C - > 800°C), dry, pyroclastic material and gases. Flows are mobile and travel at speeds of over 100 km h^{-1}. In addition to the direct effects of pyroclastic flows and surges (i.e. asphyxiation, burial, incineration and physical impact), pyroclastic flows can interact with surface water or water from melted snow and ice to form destructive lahars and floods.	Mt. St. Helen (U.S.A., 1980)
Indirect volcano hazards		
Lahars and floods	Lahars (an Indonesian term for volcanic-mud flow) - which may be classified as either primary, if they occur during an eruption or secondary if they are post-eruption - and floods, are often associated with volcanoes with crater lakes, and in situations where eruptions occur beneath snow and ice (also known as Jökulhlaups). Lahars may be generated by: rapid melting of snow and ice; an avalanche, induced by an eruption, depositing material into a stream or lake; a lava or pyroclastic flow moving into a stream or lake; a volcanic earthquake inducing slope failure and initiating mass movement; heavy rains on a volcano; sub-glacial eruptions; and the breaching of a crater lake.	Katla (Iceland, 1918) Nevado del Ruiz (Columbia, 1985) Mt. Pinatubo (Philippines, 1991/2)
Earthquakes and ground movements	Tectonic earthquakes may be the result of one or more of the following processes: the movement of magma; ground fracturing; caldera/dome collapse; and the explosion of gases. The major hazards are seismic effects on buildings.	Sakurajima (Japan, 1914)
Collapse	Structural collapse to form calderas and major sector collapses are rare. Collapses represent a high potential hazard, but one with a long recurrence interval.	Papandayan (Indonesia, 1772) Unzen (Japan, 1792) Mt. St. Helen (U.S.A., 1980
Tsunami	Tsunamis may be the result of one or more of the following processes: volcanic or volcano-tectonic earthquakes; explosions; caldera collapse; landslides; lahars or pyroclastic flows entering the sea; and atmospheric shock waves. Volcano-related tsunamis have not been a major cause of death in the twentieth century, but in earlier centuries their effects have been catastrophic.	Tambora (Indonesia, 1815) Krakatau (Indonesia, 1883)
Other hazards	These include: starvation; epidemic disease; contamination of water supplies and land; drowning; transport accidents; shock and exposure; cardiac arrests and the breakdown of law and order.	Laki (Iceland, 1783)

3.2.1 Direct volcano hazards

Hazardous events that are produced during or shortly after an eruption (i.e. within minutes to several days) are considered to be *direct* volcano hazards (Tilling, 2005 - Table 3.1). *Direct* hazards include: fall processes, which involve the fall and accumulation of air-borne materials (i.e. pyroclastic falls); flowage processes, which involve eruption-induced movement and deposition of volcanic material (i.e. lava flows, pyroclastic flows and dry surges); and other processes, which involve phreatic explosions (i.e. interaction between lava and water) and the emission of gases. These hazards are summarised in Table 3.1.

3.2.2 Indirect volcano-related hazards

As the term implies, *indirect* volcano-related hazards are destructive processes that are incidental to the eruptive activity themselves (Tilling, 2005), and include: volcano-induced earthquakes and ground movement; lahars and floods; volcano-induced tsunamis; and collapse. These hazards are summarised in Table 3.1. It should be noted that within recent decades the impact of volcanic ash clouds on aircraft has emerged with the development of high-performance jet engines.

3.3 <u>TYPES OF ERUPTION</u>

The detailed behaviour of individual volcanoes is unique. The principal styles of eruptions may be classified into a small number of ‘classic’ categorises: Hawaiian, Strombolian, Vulcanian, Sub-Plinian, Plinian, Ultra-Plinian and Peléean; and their characteristics are listed in Table 3.1. Although most eruption types are named after a volcano that typifies a particular style of behaviour, volcanoes may also show characteristics of more than one style (Blong, 1984; Parfitt and Wilson, 2008). The size of a volcanic eruption may be measured by the *Volcanic Explosivity Index* (VEI), which uses a logarithmic scale from 0 to 8 and is based on the volume of material ejected and the height of the eruptive column (Newhall and Self, 1982). In general, events with a VEI of less than 3 have localised impacts, between VEI 4 and 5 they have the potential to disrupt on the regional scale. Events of VEI 6 or above are capable of affecting the entire planet and its climate. The 1815 eruption of Tambora (Indonesia), had a VEI magnitude of 7 and affected global climate and caused extensive loss of life due to famine, disease and crop failure (Rampino and Self, 1992). The largest event of the twentieth century was the 1991 eruption of Mount Pinatubo (Philippines), which had a VEI of 6 (Wolfe, 1992).

Table 3.2: Types of eruption. (From Blong, 1984, with additions from Cioni *et al*., 2000).

This text box is where the unabridged thesis included the following third party copyrighted material:

Blong, R.J. 1984. *Volcanic Hazards*. Academic Press, Sydney.

Cioni, R., Marianelli, P., Santacroce, R., Sbrana, A. Plinian and subplinian eruptions. In: Sigurdsson, H., Houghton, B., McNutt, S.R., Rymer, H., Stix, J. (Eds.). *Encyclopedia of Volcanoes*. Academic Press, London, pp. 477-494.

3.4 EXPLANATION FOR THE CHOICE OF CASE STUDIES

The *historical* and *contemporary* perspectives used as frameworks for the study of volcanoes and society are outlined in Chapter 2 and in the context of both these together with the research aims defined in Chapter 1, three case studies were developed. The first is focused on Mount Etna (Sicily, Italy); the second, Mount Vesuvius also in Italy; and the third on the islands of São Miguel (i.e. Sete Cidades Volcano, Fogo Volcano and Furnas Volcano) and Faial (i.e. Capelinhos) in the Azores (Portugal). Each of these areas differs in the volcanic and the volcano-related hazards they present to the people who live in these (Table 3.3). Mount Etna is characterised by persistent basaltic summit activity; with frequent flank eruptions every few years (i.e. every 3-7 years over the past few thousand years; see Chester *et al*., 1985) producing a significant threat due to lava flow inundation. In addition the Etna region is exposed to both tectonic and volcano-related earthquakes. Much of the history of Vesuvius has been characterised by strombolian activity, with less frequent sub-plinian and plinian eruptions and punctuated by long periods of quiescence. In contrast, few eruptions have affected the islands of São Miguel and Faial since their first settlement in the mid-fifteenth century. The events that have occurred, however, have been very damaging and frequently occurring, but, have often been caused by other processes (e.g. tectonic earthquakes, floods and landslides). Different types of volcano and volcano-related hazards, and those hazards that are caused by extreme weather, all have differing impacts on the population.

The three case study areas are similar in certain social and economic respects, aspects which were even more marked in the past. All three case study areas have what may be termed a Southern-European economic base (e.g. a focus on agriculture) together with many cultural similarities (e.g. a predominant Catholic faith and a history of out-migration). Until recently each of the case study areas may be termed *pre-industrial* being characterised by: a predominantly rural location; artisan handicrafts rather than industrial production; parochialism, with people rarely travelling outside their local area and being little affected by external events and a feudal or semi-feudal social structure.

The quantity and quality of historical data which are available from the archives and other sources differs across the three case studies. It is because of this, that two different approaches are needed to assess the *vulnerability* and *resilience* of traditional societies to volcano and volcano-related disasters. The first approach, used on Etna and Vesuvius, is based on historical reconstruction from archival data (e.g. newspapers of record; correspondence, letters and telegrams; official reports; maps, paintings; newsreel-films; and still photography). On these two volcanoes historical records stretch as far back as the classical era. The historical-based approach is tested on Vesuvius, to see whether it may be applied on another Italian volcano that has a similar historical record and cultural features, but differs in eruptive styles. The second approach is used on the islands of São Miguel and Faial. It is based on the analysis of *vulnerability* and *resilience* which is tailored to situations where there are fewer eruptions, but many other extreme events. It considers overall disaster, or generic, disaster *vulnerability*.

Table 3.3: The volcano and volcano-related hazards presented within each of the individual case studies.

Type of hazard	**Case study 1** Mount Etna, Sicily, Italy	**Case Study 2** Mount Vesuvius, Italy	**Case Study 3** São Miguel and Faial Islands, the Azores, Portugal
Direct volcano hazards			
Lava flows	✓	✓	✓
Domes			
Pyroclastic falls	✓	✓	✓
Gases			✓
Pyroclastic flows and surges		✓	✓
Indirect volcano hazards			
Lahars and floods		✓	✓
Earthquakes and ground deformation	✓	✓	✓
Collapse	✓	✓	✓
Tsunami			✓

3.5 HISTORICAL RECONSTRUCTION AND VULNERABILITY AND RESILIENCE ANALYSIS

3.5.1 An historical approach to volcanic hazard assessment

"*When we study history, we obtain a more profound insight into human nature, by instituting a comparison between the present and the former states of society. We trace the long series of events which have gradually led to the actual posture of affairs ..... As the present conditions of nations is the result of many antecedent changes, some extremely remote and others recent, some gradual, some others sudden and violent, so the state of the natural world is the result of a long succession of events; and if we would enlarge our experience of the present economy of nature, we must investigate the effects of her operations in former epochs*"

Charles Lyell (1830)

In volcanology in general and particularly in the study of past eruptions, archival and other historical data has been used to reconstruct the characteristic features of past eruptions, nowhere more so than on Etna and Vesuvius (e.g. Romano and Sturiale, 1982; Rosi *et al*., 1993 – see Chapters 4 and 5). In contrast and until recently, historical information has not been widely used in examining human responses, though exceptions do occur. For instance:

Scarth (2002) used sources of historical data to reconstruct the nature and effects of the Mount Pelée eruption in Martinique (1902) and the subsequent destruction of the city of Saint-Pierre. A similar technique was used to examine certain features of the 1943/52 eruption of Parícutin volcano in Mexico (Luhr and Simkin, 1983) and a pioneer study by Stommel and Stommel (1983) successfully unravelled the complexities of the eruption of Tambora, Indonesia, in 1815 and the political and social events that followed it.

3.5.1.1 *Sources of historical and contemporary data*

Even before they were observed by literate observers, eruptions were depicted in art, remembered in legend (i.e. myths and oral traditions) and often became incorporated into religious rituals: volcanoes being perceived as mechanisms of divine retribution on individuals and/or societies (Blong, 1982; 1984). The sources of historical data used within this study includes: newspapers of record, correspondence, letters, telegrams, official reports, major contemporary and near-contemporary publications, paintings and illustrations, woodcuts and engraving, maps, newsreel-films and still photography. These data sources are discussed in section 3.5.1.1.1, and the time period over which they provide information are listed in Figure 3.1.

Documentary records incorporate a broad range of source materials within which descriptive accounts can be found. The specific materials used within the case studies of Etna and Vesuvius are detailed in Chapters 4 and 5.

Newspapers of record – before the arrival of newspapers of record (i.e. newspapers whose editorial standards and news-gathering are considered professional and authoritative) two major forms of periodical news publications are found: first, the hand-written news sheet and the second the single item news publication. The *Daily Acts* (*Actor Diuma*), were, for instance, produced in Rome in 59 B.C. and detailed government announcements. In 1556 the Venetian government published the *Notizie Scritte,* costing one gazetta (a Venetian coin of the time), which led to the name *Gazette*. During the sixteenth and seventeenth centuries the *Gazette* became popular across much of Italy. The first newspapers appeared in the U.K. in 1702. Newspapers did not become widely available until the nineteenth century in many of the major cities, with the distribution area being a reflection on the type of news (i.e. local to international) which was included. Many historical newspapers of record are now available electronically (e.g. *New York Times* and the London *Times*).

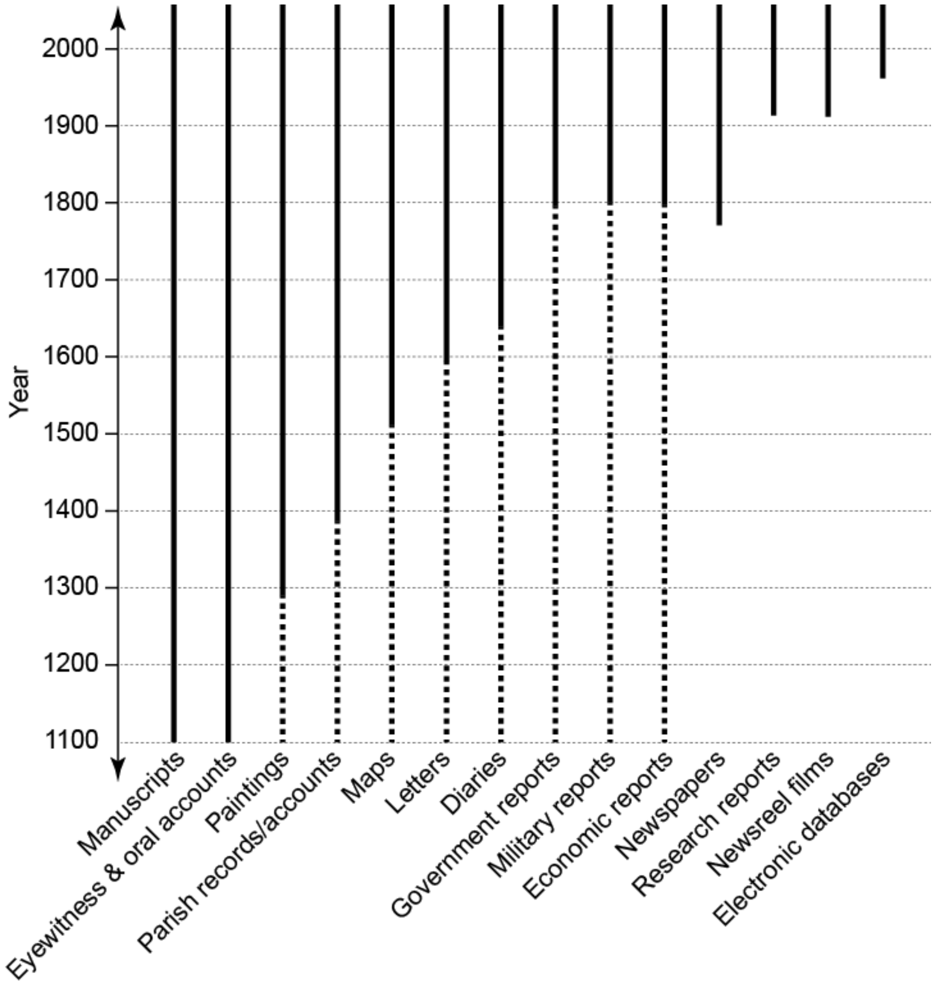

Fig. 3.1: Timeframes over which different historical source materials are available.

Correspondence, letters and telegrams – correspondence often contains information concerning the thoughts and views of an individual. They may include first-hand observations or secondary information detailing an event, responses to it and its aftermath (i.e. minutes to weeks later). Letters and telegrams can be found with differing degrees of formality reflecting the nature and purpose of the sender and recipient. Travel diaries complied by people on the '*Grand Tour*' in the eighteenth and nineteenth centuries comment upon Mount Vesuvius, with many of these narratives being romanticised and embellished descriptions of the volcano, yet providing valuable information when few other accounts are available (Darley, 2011).

Official reports – these cover a broad spectrum and include governmental, military, organisational and economic accounts, which may either directly or indirectly document the impacts and responses of the local societies to extreme events.

Major publications – these are produced directly after, or in subsequent decades following, major eruptions and appear in academic journals, special volumes of the same and reports by national governments and research organisations.

Paintings and illustrations – a wall painting (dated at *ca*. 6200 B.C.) at the town of Çatal Hüyük in Anatolia (Turkey), is the earliest known example of an artistic depiction of a volcano. It shows a volcano located close to a town, which could imply disquiet among the population about future eruptions (Harris, 2000, pp. 1308), or may equally simply "reflect the aesthetic sensibility of the artist" (Chester and Duncan., 2008, pp. 203). Many paintings depict factually incorrect representations of volcanic eruptions, with many including religious connotations associated with 'hell' (Kozák and Čermák, 2010, pp. 13). Although useful in confirming the occurrence of an eruption, the scientific information that can be extracted is relatively limited, though when coupled with documentary accounts this may prove valuable (McGuire *et al*., 2004).

Engravings and woodcuts – a number of eruptions have been captured by woodcuts. For instance Olaus Magnus (1555) depicts an Icelandic eruption and Kircher (1678) the eruption of Etna in 1669.

Maps – Italy has been mapped topographically since the Renaissance and with increasing accuracy over time. As discussed in Chapters 4 and 5, geological maps first appear from the eighteenth century. For the Azores topographic maps date from the time of first settlement, though geological mapping had to wait until the twentieth century. In all three case study areas maps have proved to be valuable source documents.

Still photography – since the development of the camera, photographs have been taken of many natural disasters. Its advantage as a source of information is that when compared to paintings, it captures an image that is unclouded by artistic interpretation.

Newsreel-films – from the early twentieth century news-reel films have been used to capture footage of volcanic eruptions and features of individual and societal responses.

Eyewitness and oral accounts – in recent years oral traditions that preserve the memories of pre-historic disasters have been extensively studied (e.g. Harris, 2000); in some societies these myths have, and continue to, co-exist alongside written records. In the past two decades an increase in detailed studies of oral traditions that are related to volcanic disasters has occurred (e.g. Cronin and Neall, 2000; Kauahikaua and Camara, 2000; Dull *et al*., 2001;

Nunn, 2001; Kauahikaua *et al*., 2002; Barber and Barber, 2004; Cronin and Cashman, 2008; Swanson, 2008). A note of caution needs to be sounded, however, over the use of oral evidence as a source of information. Myths are translated and written down by outsider observers and cultural presuppositions may colour accounts. In addition, fully understanding the explanations of disastrous events reported by indigenous peoples may be difficult.

3.5.1.2 *Reliability of historical records*

The credibility of any source must be carefully considered. A number of variables should be considered in determining the degree of confidence that can be placed within any source. These include: less complete older records; proximity of the observer to the event; duration of time that has elapsed since the event; the perspective of the observer; translation errors; corroborative accounts; syndication of accounts; confidence of the researcher in the account; and how the account relates to current knowledge. These criteria may be used to assess reliability of the data. Historical examples are, nevertheless, of value because they highlight *pre-industrial* responses and may hold important lessons for the future. The potential and possible problems in using particular sources are discussed in the when the three case studies are discussed in detail.

3.5.2 A framework for vulnerability and resilience analysis in volcanic environments

"*Most natural disasters, or most damages in them, are characteristic rather than accidental features of the places and societies where they occur*"

Kenneth Hewitt (1983b)

In 1994, the hazard analyst Piers Blaikie and his colleagues proposed an integrated model for hazard assessment known as *vulnerability analysis*. Whereas hazard assessment focuses on the physical processes that produce extreme and potentially damaging occurrences, *vulnerability analysis* concerns the ways in which these – often in combination with pre-existing social and economic circumstances – produce unsafe conditions for a population (Blaikie *et al*., 1994, pp. 225). In short, *vulnerability analysis* aims 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, pp. 12)

It has been argued that *vulnerability analysis* is somewhat restricted in its application to volcanic hazards. Blaikie *et al.* (1994, pp. 184) argued that "volcanic eruptions endanger any person living within the high risk zone, whether poor or rich, landowner or land-less farm labour, man or women, old or young, member of ethnic minority or majority". This overly deterministic perspective however, does not take into consideration behavioural and psychological features of individuals, communities and societies.

The terms *vulnerability* and *resilience* are often used in: *natural hazard* research, *disaster* research and *risk* analysis literature (Hewitt, 1983b), however there is not a universal definition for either term. Table 3.4 presents a summary of some of these different definitions. In this thesis *vulnerability*, or susceptibility to damage, is defined as "the characteristics of a person or group ..... that influences their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard ..... It involves a combination of factors that determine the degree to which some one's life, livelihood, property and other assets are put at risk" (Wisner *et al*., 2004, pp. 11). In short it is the interaction between an extreme event and a vulnerable human population. In this thesis *resilience*, is defined as the capacity of an individual, community, and society to adapt and recover from a natural event.

In her seminar paper on historical disaster research, Virginia García-Acosta (2002, pp. 65 – see also Sangster *et al*., 2013, Appendix 3) makes the important point that "disasters serve as social laboratories" revealing the ways in which people develop survival mechanisms through boosting *resilience* to extreme natural events, and providing insights into the structure of societies living in vulnerable locations. Developing *vulnerability analysis* for volcanic regions, involves combining conventional hazard analysis with the study of those aspects of the wider physical environment, culture and society, which either increase or decrease its susceptibility to losses and the potential for recovery.

Over the last two decades several scholars have devised typologies, whereby the characteristics that produce human *vulnerability* in societies may be classified (e.g. Cannon, 1994; Alexander, 1997; Zaman, 1999; Degg and Homan, 2005). Zaman identified five types of *vulnerability*, which include:-

1. Physical *vulnerability*.
2. Economic *vulnerability*.
3. Social *vulnerability*.
4. Educational and informational *vulnerability*.
5. Environmental *vulnerability*.

Table 3.4: Examples of past and current definitions used for the concepts of *vulnerability* and *resilience*.

Definition	Reference
The concept of vulnerability	
“the degree to which a system acts adversely to the occurrence of a hazardous event. The degree and quality of the adverse reaction are conditioned by a system’s resilience (a measure of the system’s capacity to absorb and recover from the event)”	Timmerman (1981)
“the potential for loss”	Mitchell (1989)
“the differential capacity of groups and individuals to deal with hazards, based on their positions within physical and social worlds”	Dow (1992)
“a function of the costs and benefits of inhabiting areas at risk from natural disasters”	Alexander (1993)
“the likelihood that an individual group will be exposed to and adversely affected by a hazard. It is the interaction of the hazards of place (risk and mitigation) with the social profile of communities”	Cutter (1993)
“stresses the condition of a society which makes it possible for a hazard to become a disaster”	Cannon (1994)
“the conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards”	United Nations (2005)
The concept of resilience	
“the ‘flip’ – positive – side of vulnerability or the capacity to resist from damage and change in the event of the occurrence of a natural hazard”	Folke *et al.* (2002)
“a component of vulnerability or the ability of an actor to cope with or adapt to hazard. It is a product of the degree of planned preparation undertaken in the light of a potential hazard, and of spontaneous or premeditated adjustments made in response to felt hazard, including relief and rescue”	Pelling (2003)
“the capacity of a system, community or society potentially exposed to hazards to adapt by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organising itself to increase this capacity for learning from past disasters for better future protection and to improve risk reduction measures”	United Nations (2005)
“the rate of recovery from a stressful experience, reflecting the social capacity to absorb and recover from a hazardous event”	Smith (2013)

The five *vulnerability* types identified by Zaman (1999), to study hazards in Bangladesh and also used by Degg and Homan (2005) to study earthquakes responses in Egypt, are inter-connected as more than one of the five types may be present within a single typology. The *vulnerability* and *resilience* method used in this thesis adopts a scheme which develops this approach to study hazard impacts in the Azores, in particularly on São Miguel and Faial Islands (Chapter 6).

Table 3.5: A typology of *vulnerability*. (From Zaman, 1999, pp. 195).

This text box is where the unabridged thesis included the following third party copyrighted material:

Zaman, M.Q. 1999. Vulnerability, disaster and survival in Bangladesh: three case studies. In: Oliver-Smith, A. and Hoffman, S. (Eds). *The Angry Earth: Disaster in anthropological perspective*. Routledge, London, pp. 192-212.

3.5.2.1 *Interviews*

In the case of the Azores and as part of the *vulnerability* and *resilience* methodology discussed in section 3.5.2, the collection of data relevant to present day threats and Civil Defence planning was required. Interviews were carried out on the island of São Miguel. The format of the interviews was semi-structured (Somekh and Lewin, 2005) providing a framework for the discussion and an opportunity for the respondent to talk freely beyond the interview questions about their experiences in general.

3.5.3 Field Observation

In addition to the data discussed in sections 3.5.1 and 3.5.2, field observations were carried out on Etna and on São Miguel Island. The field visit to Etna focused on the identification of historic lava flows (reconstructed from old geological maps) and visits to the local *comuni* affected. These were supplemented by visits to the archives and included liaison with the *Istituto Nazionale di Geofisica e Vulcanologia* (*INGV*) in Catania. The field visit to São Miguel Island focused on interviews with the principal 'actors' in hazard assessment and civil defence planning and contributed to the most recent road survey.

3.6 CRITERIA FOR THE EVALUATION OF THE TWO METHODOLOGICAL APPROACHES

In order to test the strengths and weaknesses of the two methodologies (as outlined in sections 3.5.1 and 3.5.2) that have the potential to reveal how traditional societies and those on the threshold of modernisation have coped in the past with volcanic and volcano-related disasters (i.e. Objective 1 – see Chapter 1), certain aspects need to be explored; such as the frequency and duration of events, and both the quantity and quality of historical (i.e. proxy) data. These aspects are specific to each case study area and are considered in the relevant chapters (Chapters 4, 5 and 6). The use or applicability of either an historical-based approach or one that is based on the analysis of *vulnerability* and *resilience* is dependent on the features mentioned above (i.e. frequency and duration of events, length of historical record and the quantity and quality of historical data). Hence, evaluation of the strengths and weakness of each of these approaches is based on both the usefulness and appropriateness of the data that can be extracted and how these data can then be applied in present-day disaster management.

3.7 SUMMARY

In this chapter clear and concise definitions have been provided so as to define the key terms used within the thesis. Sources of historical information have been identified and consideration has been given to their reliability and suitability. Two methodologies have been identified to assess *vulnerability* and *resilience* of traditional societies: an historical approach (i.e. historical reconstruction) and one that is focused around a set of techniques to analyse *vulnerability* and *resilience* (i.e. *vulnerability* and *resilience* analysis). The historical approach is applied to Etna (Chapter 4) and Vesuvius (Chapter 5), in the latter case in order to test the appropriateness of this methodology. The method based on typologies of *vulnerability* and *resilience* is applied to the Azores (Chapter 6).

Chapter 4

MOUNT ETNA (SICILY, ITALY)

The focus of this Chapter is three-fold: firstly, to summarise the characteristics of the eruptions that occurred between the classical period and 1923; secondly to reconstruct and summarise the particularities of the societal responses and the role of the authorities and how these developed over time; and thirdly to assess the important lessons this history holds for the management of present-day disaster planning within the twin contexts of White's *comprehensive* approach and the Italian policies of civil protection.

4.1 INTRODUCTION

4.1.1 Etna and the Etna region

Mount Etna in northeastern Sicily (Italy) rises to over 3000 m, covers an area of *ca*. 1750 km^2 and is the most active volcano in Europe (Duncan *et al*., 1981). It is located at the intercession of two major fault zones; NNW-SSE (Tindari-Letojanni-Malta), and NNE-SSW (Messina-Giardini) (Frazzetta *et al*., 1981; Cristofolini *et al*., 1985; Bousquet *et al*., 1988; Ferlito *et al*., 2012) and the history of its activity commenced 300-400 ka years ago in a marine gulf (Chester *et al*., 1985; Bonaccorso *et al*., 2004; Ferlito *et al*., 2012). The last major caldera forming eruption occurred *ca*. 15 ka years ago at the close of the *Ancient Mongibello* phase, marked by caldera collapse and an eruption of potentially highly destructive pyroclastic flows, which travelled down the southwestern flank of the volcano (Guest *et al*., 2003). Since then Etna has been characterised by basaltic activity in the *Recent Mongibello* phase. This included persistent activity on the summit, punctuated by infrequent explosive eruptions that deposited a few centimetres of tephra beyond the margin of the volcano. For example in 122 B.C. tephra fall caused extensive damage to Catania (Fig. 4.1) in the Roman period, and more recently, tephra from the 2001 eruption caused disruption to many lines of communications. Further discussions of the history of its activity are summarised in Appendix 1 and in other papers and books (e.g. Rittmann, 1973; Chester *et al*., 1985; Guest *et al*., 2003; Branca and Del Carlo, 2005, 2008; Branca *et al*., 2004, 2008, and 2012).

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

Fig 4.1: Location of Mount Etna and its main settlements. (From Chester *et al*., 2012).

Observations of Etna by literate observers stretch back to the classical era and one of the earliest references to an eruption of Etna was by *Pindar*[7] in his *Pythian Odes*, to the event of

---

[7] *Pindar* (~522-~442 B.C.), an ancient Greek lyric poet, described the events of ~474-~479 B.C. in his *Pythian Odes*, and states "whereout pure springs of unapproachable fire are vomited from the inmost depths: in the daytime the lava streams pour forth a lurid rush of smoke; but in the darkness a red rolling flame sweepeth rocks with uproar to the wide deep sea . . ." (Hyde, 1916; Chester *et al*., 2000; Duncan *et al*., 2005). Hiero, brother of the tyrant Gelon and tyrant of Syracuse, Sicily, from 478 B.C. until *ca*. 467 B.C., and Pindar's patron removed the inhabitants of Naxos and Catania to Leontini in 476 B.C. and repopulated the town with 5000 Syracusans and 5000 Peloponnesians and called it 'Aetna'(Hornblower, 2011).

ca. 474-479 B.C. The history of its activity over the last 2,750 years has been reconstructed by scholars up to the present day in many major research volumes, for instance in Mario Gemmellaro's (1858) *La vulcanologia dell' Etna. La topografia, la geologia, la storia delle sue eruzioni, la descrizione e lo esame de'fenomeni vulcanici* and Francesco Ferrara's (1818) *Descrizione dell'Etna con la storia delle eruzioni e il catalogo dei prodotti*; and in many principal works on Etna from the pre-nineteenth century (e.g. Silvaggio, 1542; Fazzello, 1558; Filoteo, 1590; Carrera, 1636; Earl of Winchilsea, 1669; Hamilton, 1768, 1771 and 1776) and nineteenth and early twentieth century (e.g. Ferrara, 1818; Maravigna, 1811; Recupero, 1815; Alessi, 1829-1835; Rodwell, 1878; Sartorius Vön Waltershausen, 1880; Mercalli, 1883; Hyde, 1916). More recently historical databases have been compiled from archival sources (e.g. Romano and Sturiale, 1982; Chester *et al*., 1985, 2000; Branca and del Carlo, 2004; Branca *et al*., 2012) and archeomagnetic and paleomagnetic dating (e.g. Tanguy, 1981; Behncke *et al*., 2005; Branca and del Carlo, 2005; Tanguy *et al*., 2007, 2012; Siebert and Simkin, 2010; Branca *et al*., 2012; Speranza *et al*., 2012). These record both flank and summit eruptions. Additional references from international newspapers of record and newsreel films are discussed in section 4.1.2. These studies have produced a vast literature that has enabled the impact and recovery from eruptions from the classical times to be identified, and an assessment to be made of the interface and interactions of the environmental, economic and social forces that have shaped Etna into one of the most distinctive, densely settled and productive agricultural regions in Southern Europe (Chester *et al*., 2010).

Etna has always been a region that has attracted human settlement, despite the ever-present threat posed by volcanic and seismic activity (Leighton, 1999; Chester *et al*., 1985, 2010). The southern and eastern flanks of the volcano are more densely populated than the north and west. The south is dominated by Catania, a city whose population has grown from 70,608 in 1861 to over 290,000 in 2011 (Pecora 1968; King 1973; Chester *et al*., 1985; Ligresti 2002; ISTAT, 2011). Catania is an important commercial, industrial and cultural centre and the principal city of the region[8] (Chester *et al*., 2010). On several occasions Catania has been

---

[8] The majority of the land area of Mount Etna is contained administratively within the Province of Catania (*Provincia di Catania*) and accounts for some of the highest population densities found on the island (Ligresti, 2002). In 1806 the population of Sicily was estimated at 1.6 million with 14% residing in Catania Province. This latter figure rose to 17% by 1901, continued to rise until 1923 (1921 census 19%) and reached 20% by 1971 (Pecora, 1968; Chester *et al*., 1985; Ligresti, 2002). The ability of the region historically to support a large population is even more remarkable as today the Plain of Catania to the south of the city is one of the most agriculturally productive sub-regions of

devastated and destroyed at least in part by earthquakes in 1169 and 1693, severely affected on another four instances (i.e. 1542, 1716, 1818 and 1848) and moderately damaged another eight times (Azzaro *et al*., 1999; Chester *et al*., 2012). To this must be added partial destruction by lava flows in 1669; and by tsunamis in 1693, and possibly in 365 A.D. (Tonini *et al*., 2011). This apparent contradiction between the hazardous nature of the environment on the one hand and its attractiveness for human settlement on the other may be explained by a combination of factors, both physical and human, that operate at two different scales. For a more detailed discussion reference should be made to Chester *et al*. (2010).

At a Sicilian scale Italian geographers have termed the distinction between the dry, poverty-stricken interior of the island, and the intensively-cropped, irrigated coastal lands "an ugly picture in a frame of gold" (Milone, 1960; King, 1973, pp.112 - Fig. 4.2). The "ugly picture" is explained in the main from poor land-use decisions made by Roman (264 B.C. - 827 A.D.), Arab (827 - 1091) and later European rulers (i.e. Norman 1091 - 1194, Swabian 1194 - 1268, Angevin 1268 - 1282, Spanish 1282 - 1713, Austrian 1720 - 1734, Bourdon 1734 - 1860 and Italian - from 1860). The Roman, Arab and latter settlers cleared land for settlements, used and exported timber and grazed intensive areas of land, while later rulers added intensive peasant cereal cultivation carried out on large estates (*latifundia*), usually under the ownership and control of absentee aristocrats and agents (*gabelloti*) keen to maximise yields and who controlled the renting of small plots to peasant farmers. Agricultural settlement in Sicily was not diffuse and many farmers and their families lived in *agro-towns*[9] and travelled to their fields on a daily or twice daily basis. The tradition of the *latifundia*, that has become a central feature of Sicilian economic and cultural life, started under Roman rule and became consolidated under subsequent rulers (Chester *et al*., 1985; Benjamin, 2006). In addition *gabelloti* were strongly associated with the mafia, and crime became accepted as part of the culture across much of interior Sicily and the fertile northern coastlands (King, 1973; Chester *et al*., 1985; Dickie, 2011). In contrast eastern Sicily, including most of the Etna region, was relatively free of organised crime (Rochefort, 1961).[10] Irrigation was first introduced by the

---

Etna, yet in the 1940s this area had a low population and little commercial agriculture due to its malaria character (King, 1971).

[9] *Agro-towns* or *peasant cities* had populations of between *ca.* 3,000 - 15,000, and in pre-industrial times had at least 50%, sometimes 90%, of their inhabitants engaged in agriculture (King and Strachan, 1978; Chester *et al*., 1985).

[10] Feudalism was abrogated in 1812 and other feudal institutions were abolished by 1860, but in the interior of Sicily its effects on the rural poor were disastrous leading to a loss of rights to pasture animals, hunt and glean land (King, 1973, pp.124; Finley *et al*., 1986). After Italian unification in 1860 there was further State enforced redistribution of private land and church property (Bandiera,

Romans and became widespread from the time of the Arabs, diffusion being dependant on the availability of easily accessible ground-water resources. The northern coastal region and Etna were particularly favoured and irrigation transformed these coastal lands.

At a more detailed scale, the Etna region contrasts with other parts of the “frame of gold” in a number of important respects. The southern and eastern flanks of the volcano are environmentally different to those of the north and west and it is clear from what has already been discussed that features of climate, vegetation and soils are important, but also particularities produced by economics, history and culture. The region is favoured by: a strong increase in precipitation with height over 1200 mm near to the summit; a steep environmental lapse rate of temperature, with heavy snowfall on western and other sectors of the volcano; and high irrigation potential. Generally there is no settlement above 2000 m on the volcano, although there are a number of scientific and tourist facilities.

This text box is where the unabridged thesis included the following third party copyrighted material:

King, R. 1971. Mediterranean island in torment. *Geographical Magazine* 44, pp. 178-185.

Fig 4.2: The contrast between the intensive and extensive agricultural areas. (From King, 1971, pp.183).

2003, pp. 224). Mafia activity also increased, because there were more individual farmers demanding protection. Some authors argue that the mafia only emerged in the nineteenth century, though other trace it to the seventeenth and eighteenth centuries, but it is without doubt that its malign influence was strengthened after feudalism ended. The Etna region was relatively free of organised crime, and the negative effect of these measures was muted since land was already sub-divided into a large number of small productive plots under various systems of tenure.

Superficially the link between land use and climatically-related factors appears to be deterministic, with more intensive cropping taking place on the irrigated slopes of the east, south-eastern, south and south-western sectors in the *regione piedmontese* (mountain foot region), which stretches from sea-level to 1000 m a.s.l. (Cullotta and Barbera, 2011). Throughout the *pre-industrial* era the relationship was, however, more multifaceted, with the north and north-western sectors being isolated from Catania the principal port for exports, and cropping intensity decreasing in all directions with increasing distance from the city (Fig. 4.1). In the final decade of the *pre-industrial* era, the percentage of land below 2000 m a.s.l. which was utilised intensively for the cultivation of vines, orchard and plantation crops varied from 69% in the southeast to only 3% in the northwest (Chester *et al*., 1985, pp. 54).

4.1.2 Human responses to Etnean eruptions

For societies it is common to classify responses to natural hazards into: *pre-industrial* (folk); *industrial*; and *post-industrial* (comprehensive) (White, 1973). The principal characteristics of these distinctive forms of responses are listed and discussed in Chapter 2. In many of the so-called *pre-industrial* societies strategies of harmonizing with nature, combined with often complex sociological adjustments to hazards, have featured (White, 1973; Burton *et al*., 1993). This may be illustrated by reactions to eruptions of Etna during the *pre-industrial* period (section 4.2 and 4.3).

Earlier detailed research on the responses and adjustments made by the inhabitants of Etna to the threat posed by volcanic activity is limited. Chester *et al*. (1985) summarised the records from Tanguy (1981) and Romano and Sturiale (1982) and extended them to include more historical records, which in many cases documented the threat and destruction to human settlements and livelihoods from the classical era onwards, and created the first comprehensive and detailed publications on the reactions of the inhabitants to eruptions. Fortunately, studies on the responses and adjustments made by the inhabitants of Etna are assisted today by both the quality and quantity of historical records and contemporary and near-contemporary accounts, many of which are now readily available electronically. Examples include: Sicilian scientific journals, in particular the *Atti della Accademia gioenia di scienze naturali* (Catania); major research volumes; and international newspapers of record, especially the *New York Times* and the *Times* (London). In addition English language provincial papers often published accounts of eruptions and these are available electronically from the nineteenth century for both the U.S.A. and U.K.[11] Some nineteenth century reference works are available as reprints, for instance Carlo Gemmellaro's (1858) *La Vulcanologia dell'Etna* (Cucuzza-Silverstri, 1989), whilst others may be obtained from copyright libraries. Particularly useful sources include the *Carta Geolgica d'Italia alla scala 1:100,000* (Gemmellaro, 1885a, 1885b). More recently a major catalogue of earthquakes affecting the Mount Etna region has been published (CMTE Working Group, 2008). It is upon these sources that the present research is based.

Records of eruptions became reasonably complete from the beginning of the sixteenth century and their comprehensiveness increases from the time of the 1669 eruption (Tanguy *et al*., 2007; Branca and del Carlo, 2005). Before the middle of the sixteenth century however, the records are more fragmentary and incomplete, but since the seventeenth century more information is recorded, which no doubt reflects both the development of an educated ecclesiastical community and an increase in flank eruptions, with many causing losses on the southern and south-eastern flanks of the volcano where the largest settlements were located (Duncan *et al*., 1981 - Table 4.1).

From 1792/3 to 1923, a period which the present author and her colleagues (Chester *et al*., 2012 - Appendix 2) have termed the *long nineteenth century*[12], the characteristics of the *pre-industrial* responses may be classified under two headings: responding to emergencies and recovering from losses in the short and longer terms (section 4.2). In both cases people adopted responses that were typically *pre-industrial*. In essence, people responded to eruptions at three levels: as members of families and extended families; as members of communities; and as citizens of a Nation State. The State played only a small part in responses until the early twentieth century.

Chester *et al*. 2012 (Appendix 2) used both recent reviews (e.g. Romano and Sturiale, 1982; Chester *et al*., 1985; Branca and del Carlo, 2004) and those published nearer in time to the events they describe (e.g. Recupero, 1815, Alessi, 1829-1835; Rodwell, 1878; Radice, 1928, 1936), to show how the inhabitants of Etna coped with eruptions during the *long-nineteenth century*. This research, supplemented where possible with new information, is summarised in

---

[11] These are available from Gale Databases (Gale CENGAGE Learning) - (http://find.galegroup.com.exproxy.liv.ac.uk/menu/commonmenu.do?userGroupName=livuni).

[12] The British historian, Eric Hobsbawm (*b*. 1917), defined the period between the start of the French Revolution (1789) and the beginning of World War I (1914) as the *Long Nineteenth Century*. The present author and her colleagues have extended this to include the 1923 eruption of Etna within this timeframe, as the response were more common in character to earlier eruptions.

Table 4.1: The effects of the major eruptions on the settlements of Etna from 1400 – 1923. Locations are shown in Fig. 4.1. Ticks indicate that loss of land occurred to the *coronas* of those settlements mentioned.

Eruption	Settlements affected	*Coronas*[13] affected
1408	Trecastagni and Pedara were destroyed	
1536	Lava threatened Randazzo	✓
1537	Nicolosi was destroyed	
1566	Lava threatened Linguaglossa	✓
1595	Lava threatened Adrano	✓
1610	Lava threatened Adrano	✓
1646	Several small settlements on the northern flank	
1651/3	Lava threatened Bronte	✓
1669	Belpasso[14], Camporotondo, Mascalucia, Misterbianco, Nicolosi, S. Giovanni de. Gelermo, S. Pietro Clarenza and fourteen other small settlements on the southern and south-eastern flanks were destroyed	
1689	Several small settlements in the vicinity of Macchia	✓
1792/3	Zafferana partially destroyed	✓
1811	Lava threatened Milo	
1832	Lava threatened Bronte	✓
1843	Lava threatened Bronte	✓
1852/3	Lava threatened Zafferana, Ballo, Caselle and Milo	Zafferana
1879	Lava threatened Passopisciaro	✓
1886	Lava threatened Nicolosi	✓
1892	Lava threatened Nicolosi	✓
1910	Lava threatened Nicolosi and Borello (a suburb of Belpasso)	Nicolosi
1923	Lava threatened Linguaglossa, Rovittello and destroyed Cerro and Catena (a suburb of Linguaglossa)	Rovittello and Linguaglossa

section 4.2. It is clear from this research that the *long-nineteenth century* responses were already deeply engrained within the *milieu* of the region, and that extending the historical record may yield further fruit showing how people coped with Etna's eruptions and related phenomena from the classical period onwards (section 4.3). In addition the 1928 eruption is transitional between a *pre-industrial* and a more state-initiated and focused (i.e. *industrial* - White, 1973) way of coping. Much that is characteristically *pre-industrial*, nonetheless, remained in place in 1928. Although this eruption has been the subject of detailed historical study (Duncan *et al.*, 1996; Chester *et al.*, 1999b), over the past decade more archival

---

[13] Fringes of settlements included a *corona*, a roughly circular rim of particularly intensive agriculture that could easily be worked a short distance from the agro-towns.

[14] Before 1695 the village of Belpasso was known as Malpasso. After the 1537 and 1669 eruptions it was re-named Phoenicia Moncada, was again devastated by an earthquake in 1693 and only after 1695 has been officially known as Belpasso. In this Chapter and in most accounts of this eruption the village is called Belpasso, even though at the time it was known as Malpasso (Anon, 2012c).

materials have become available, allowing a more detailed evaluation of its *pre-industrial* elements to be undertaken (section 4.3.2).

4.2 RESPONDING TO EMERGENCIES DURING THE LONG NINETEENTH CENTURY (see Chester *et al*., 2012 - reproduced as Appendix 2)

In the period from 1792/3 to 1923 there were: 13 major eruptions (i.e. 1792/3, 1809, 1832, 1843, 1852/3, 1865, 1879, 1883, 1886, 1892, 1910, 1911 and 1923); two minor events (i.e. 1802 and 1918) and two larger events (i.e. 1811/12 and 1819), whose affects were largely confined to the Valle del Bove. It should be noted that no major settlement was destroyed during the *long-nineteenth century*. Table 4.2 summarises the characteristics of eruptions that occurred between 1792/3 and 1923.

Throughout the course of the *long-nineteenth century* it is clear that there was already a well-established history of people coping with volcano-related emergencies. The distinctive Sicilian lifestyle practiced in *pre-industrial* times (King, 1973, pp.51-65; Chester *et al*., 2010) influenced how people coped during the *long nineteenth century*, and in the Etna region included: tight bonds within families and extended families; a mistrust of outsiders; and an adherence to a particular form of popular Catholicism (King, 1973). The subsequent sections (4.2.1 to 4.2.3) discuss and summarise these characteristics.

4.2.1 Family coping strategies

One feature of behaviour that is commonly blamed for deaths in disasters is panic. Panic is defined as “irrational, groundless, or hysterical flight that is carried out with complete disregard for others” (der Heide 2004, pp. 234). Experience from many disasters around the world shows that panic is largely a myth and rarely features in responses to disasters (Blong, 1984; Quarantelli, 1999), whereas rational behaviour even though people are frightened is commonly encountered, this being a recurring theme in responses to eruptions during the *long nineteenth century*. Fear and even apprehension are mentioned many times in first-hand accounts, for instance, in: 1792 (Recupero, 1815), 1865 (Reclus, 1865, pp.111; Rodwell, 1878, pp.108); 1883 (Anon, 1883d); 1886 (Anon, 1886b); 1910 (Hyde, 1916); 1911 (Vinassa de Regny, 1911) and 1923 (Anon, 1923a), but panic rarely features – some reactions in 1911 (Anon, 1911a) being possible exceptions – and fear never prevented families from coping in a positive manner (Chester *et al*., 2010, 2012). Normal day-to-day activities continued

Table 4.2: Mount Etna, summary of the major eruptions during the *long-nineteenth century*. (Based on information from: Romano and Sturiale, 1982 and Branca and del Carlo, 2004, together with the contemporary materials that are cited in Chester *et al*., 2012 pp.68-71 in Appendix 2).

Eruption	Dates and (duration) (days)	Nature of activity and location
1792/3	23 May - (*ca*. 380)	Precursory earthquakes. Eruptive fissure opened on the west wall of the Valle del Bove (1900 m a.s.l.). Lava flow field extended beyond Monte Calanna and threatened Zafferana.
1809	27 Mar - 9 Apr (14)	Precursory earthquakes. Eruptive fissure opened on the north – northeastern part of the summit cone above 2000 m. One small lava flow was erupted which flowed to the north – northwest, with another flowing to the east threatening Rovittello. Between March 28 and March 29 successively lower boccas opened down the northeastern rift from *ca*. 1500 m to *ca*. 1400 m in altitude.
1832	30 Oct - 22 Nov (22)	Eruption from a vent *ca*. 3000 m on the southeastern flank; lava threatened the Casa Inglesi[15] and reached the Valle del Bove. Another fissure opened on the western flank between 2650 to 1700 m a.s.l. and formed the Monte Nunziata cone. Lava threatened Bronte.
1843	17 Nov - 28 Nov (11)	Eruptive fissure opened on the western flank between 2375 and 1830 m a.s.l. From 15 boccas, a simple flow field extended for 13.5 km cutting the Consolare Palermo – Messina road. On November 25 a phreatic burst occurred at the flow front near Bronte and killed 59 people.
1852/3	20 Aug - 27 May (280)	Eruptive fissure opened in the Valle del Bove (between 1950 and 1700 m a.s.l.). Strombolian activity formed the Mts. Centenari scoria cones and two streams of lava – one approaching Milo, the other Zafferana – threatened Zafferana, Ballo (a northern suburb of Zafferana), Caselle and Milo. Intermittent ash fall to the southeast of Catania and Syracuse and northeast towards Taormina and Messina.
1865	30 Jan - 28 Jun (150)	Precursory earthquakes. Eruptive fissure opened on the northeastern flank between 1825 and 1625 m a.s.l. Strombolian activity formed the Sartorius cinder cones. Lava travelled more than 6 km in 2 – 3 days and advanced towards the towns of Linguaglossa, Mascali and Piedimonte. Earthquake in Fondo di Macchia on July 19 after the eruption.
1879	26 May - 7 Jun (12)	Precursory earthquakes. Strombolian activity formed the Mts. Umberto and Margerita at 2250 to 2100 m a.s.l.

---

[15] The Casa Inglesi (English house), was built (1811) by British soldiers occupying Sicily during the Napoleonic Wars. It was subsequently incorporated into the astronomical observatory (1879) and in the early twentieth century became part of a volcanological observatory.

		Eruptive fissure opened on the northeastern flank and another on the south – southwestern flank (2680 m a.s.l.). Lava almost reached the Alcantara River, cut the Randazzo to Linguaglossa road and threatened Passopisciaro and Moio Alcantara. Ashes were distributed as far away as Messina, 67 km distant.
1883	22 Mar - 24 Mar (3)	Eruptive fissure opened from the summit cone on the southern flank between 1200 – 950 m a.s.l. and formed Mt. Leone. Seismic activity before, during and after the eruption and were felt in towns across Etna: from Linguaglossa in the north; Aci Reale in the east; and Bronte in the west. Damage was reported in Nicolosi, Belpasso and Zafferana.
1886	18 May - 7 Jun (20)	Eruptive fissure opened on the southern flank between 1500 and 1300 m a.s.l. and formed Mt. Gemmellarro. Explosive activity from the central crater formed an ash column leading to ash and lapilli fall on the lower flanks. Seismic activity before, during and after the eruption.
1892	9 Jul - 29 Dec (193)	Eruptive fissure system opened on the southern flank at a height of *ca*. 2000 to 1800 m, accompanied by earthquakes. Intense strombolian activity formed the Silvestri Cones. Lavas travelled 7 km and threatened Belpasso and Nicolosi.
1910	23 Mar - 18 Apr (26)	Precursory earthquake. Eruptive fissure opened on the southern flank from 2850 m down to 1950 m a.s.l. Eruptive boccas opened below 2750 m a.s.l. Lavas erupted from the fissure travelled 5 km in the first 10 hours, thereafter the rate of advance reduced. Lava crossed the Nicolosi to Ragalna road and threatened the Nicolosi to Borello road. Ash fall on Mangano, Giarre, Mascali and Fiumefreddo.
1911	10 Sep - 23 Sep (12)	Seismic activity before and during the eruption. Eruptive column 2 km high generated. Fissures opened progressively down the North-East Rift forming eruptive vents between heights of 2550 m and 1650 m. Lavas cut the *Circumetnea* railway and the Linguaglossa – Randazzo road. Large earthquake after the eruption near Fonda Macchia destroyed the same settlement as the event of 1865.
1923	17 Jun - 18 Jul (31)	Eruptive fissures opened between 2500 and 1800 m a.s.l. on the northeastern flank. Eruptive boccas opened successively downslope at 2400 m, 2200 m and 1900 – 1800 m a.s.l. Lava from the latter bocca travelled 7 km in 10 hours. Lavas cut the Randazzo-to-Linguaglossa road and overwhelmed the railway station at Castiglione. Major damage occurred in the towns of Cerro and Catena – a suburb of Linguaglossa. Earthquakes were felt before, during and after the eruption.

unabated and people still farmed their land. Thus a strong sense of solidarity is evident as families and extended families coped with and recovered from lava incursions.

On Etna, lava incursions have affected agricultural land and villages on many occasions. Between 1500 and 1900, 8% of area of the volcano below 2000 m was effectively sterilised by lava, a figure which falls to *ca*. 3.5% for flows erupted between 1792/3 and 1923 (Chester *et al*., 2012, pp.71-2). By the nineteenth century families were well aware of the risks they faced and the action they should take in order to deal with them. Following many eruptions people often made use of family and extended families by leaving threatened villages in order to live with relatives until it was safe to return. Examples included: Nicolosi in 1886, when many people went to live in Catania, Pedara and Belpasso (Silvestri, 1886); and in 1923 when refugees fled to Catania and Messina (Anon, 1923c).

Other people were not prepared to leave their home village or farm and many accounts are suggestive of considerable suffering amongst the rural population. Examples included: in 1809 a correspondent from a group of British army officers observing the eruption noted that he was greatly affected by the "scene of public distress" (Anon, 1809a); in 1843 and again in 1886 (Anon, 1843c, 1886a) there was spontaneous and unplanned evacuation of several settlements; in 1879 people are described as wandering aimlessly in the streets (Anon, 1879d); in 1883 the inhabitants who moved out of Nicolosi, Belpasso and Borello (Fig. 4.1) are depicted as sleeping in the fields (Anon, 1883e) and in 1892 widespread suffering is noted in Nicolosi, Borello and Belpasso (Anon, 1879d). The tent and field dwellers were not necessarily the marginalized poor, as many nineteenth century contemporary accounts imply, because many farmers had permanent shelters located on their family plots that were usually used for a daily siesta in the hot summer months and/or for storage of tools and fodder, but they could easily be converted into temporary family accommodation (Chester *et al.*, 2005). Many families could effectively spread their losses because they held land in fragmented holdings in diverse areas of a single municipality (i.e. *comune*), in several adjacent municipalities (i.e. *comuni*) or even on different sectors of the volcano so that a single eruption is unlikely to wipe out all a farmer's property. This land use pattern was long established on Etna and has been an important coping mechanism in many twentieth century eruptions (Clapperton, 1972). Contemporary accounts do not record whether this was a deliberate adjustment to risk, or just good fortune and merely a consequence of inheritance laws. Pastoralism also provided a means of increasing security and, in *pre-industrial* times provided a valuable additional source of income for farmers especially in times of distress (Chester *et al*., 2005).

4.2.2 Mutual support

Sicilian society was in the past and is today focused on the extended family, and in coping with disasters these networks were essential. Some responses involved the mobilization of larger numbers of people including neighbours and those who resided in either rural areas where losses occurred, or in the agro-towns that were threatened. Responses often involved people learning from the experience of earlier eruptions and then using similar techniques (e.g. preventing deaths from phreatic activity by avoiding flow fronts where interaction between lava and water was possible). For example, in 1865 and clearly learning from the disastrous phreatic explosion which occurred in 1843, local leaders ordered water to be pumped out of wells and cisterns (Anon, 1865a). As mentioned in Section 4.1.2, in *pre-industrial* societies people harmonized with nature by accepting that, although losses might be inevitable, these might be minimised. For example, often much could be salvaged (e.g. household furniture, personal effects and even crops) in advance of an area being covered by lava. The ways in which this occurred are listed in Table 4.3, but mutual support also included trying to account for losses and propitiating the deity (or deities) supposedly responsible through the practice of *popular Catholicism* (section 4.3.1).

The perception that natural disasters are actions of divine punishment sent to punish sinful people transcends religious tradition, time and culture (Chester *et al*., 2008; Sangster *et al*., 2013 - Appendix 4). Religion and, more specifically, the spiritual beliefs found in Southern Italy and Sicily, have shaped the ways in which people have reacted to disasters caused by earthquakes and volcanic eruptions (Chester *et al*., 2008). Three elements of Italian Catholicism have a long pre-Christian antecedence: supernatural control of eruptions; divine appeasement and the role of heroic figures (Chester *et al*., 2012). These three features have been modified in the Italian South.

Eruptions during the *long-nineteenth century* became associated with liturgies of divine appeasement[16]. Intercession through the agency of the Madonna and the saints was an

---

[16] As argued by the present author in Chester *et al*. (2012) “theodicy represents attempts to reconcile notions of a loving God with the existence of suffering in the world, and in the popular Catholicism of the Italian south the three pre-Christian elements were modified. Losses have to be accepted as justified expressions of God’s anger with a sinful people, who could nevertheless propitiate divine wrath by liturgical actions many of which involved the use of relicts, statues and other images of

established part of mainstream Catholic teaching, in the form of *popular Catholicism* practised on Etna this took an extreme and distinctive form with saintly relics, statues and votive objects believed to have the power to prevent disasters (Chester *et al*., 2008). The principal religious responses to eruptions during the *long-nineteenth century* are summarised in Table 4.4., but it should be emphasized, that in *pre-industrial* times and more specifically during the *long-nineteenth century* there was a marked inconsistency between beliefs and actions. Sometimes called *cognitive dissonance* or *parallel practice* (Dibben, 1999)[17] the people of Etna, while accepting that disasters were manifestations of divine wrath that had to be accepted, had no difficulty in accepting measures to reduce their risk exposure, for example, help from extended family networks and accepting help from outsiders, the government and their agencies (section 4.2.3).

4.2.3 The role of the State in responding to emergencies

Records show that, whereas the volcanological characteristics of 1792/3, 1809, 1811/12 and 1819 eruptions were recorded by both Sicilian-based scientists (e.g. Recupero, 1815; Gemmellaro, 1819) and foreigners (e.g. Dolomieu, 1792; Scrope, 1825), local communities responded to these emergencies with little outside help. Beginning modestly with the 1832 eruption, when Prince Manganelli, the *intendente* (i.e. prefect) visited Bronte (Radice, 1928, 1936 - Fig. 4.1), outside assistance became progressively more significant during each subsequent eruption but local leadership remained dominant and State influence inchoate.

---

saintly figures who could be appealed to by means of intercessory prayer. At the heart of popular religion was a belief in heroic supernatural individuals, who had the power to change God's mind through intercession. Catholic orthodoxy asserts that Christ is co-equal to God the Father, Mary and the saints are mortal, having no power on their own and only intercede through the agency of Christ. In southern Italy this ranking is changed: 'Christ is more powerful than God the Father, Mary is more powerful than Christ; and Saint Joseph, the universal father, is more powerful than God the father, Christ and the Madonna together. But more powerful than God and all the saints is the one saint that - from as far back as .... the Middle Ages - the inhabitants of a given place have selected as their patron' (Carroll, 1992, pp.15-16). Despite this theology being heterodox, on Etna it was legitimised by the participation of local clergy and even Sicilian-born bishops. Intercession through the saints is an established part of mainstream Catholic teaching, but in the popular Catholicism of the Etna region this took on an extreme and distinctive form, with saintly relics, votive objects and statues being widely believed to have the power to present disasters. In the eighteenth century and under the influence of European Enlightenment alternative models of theodicy were given prominence, especially the view that the earth is the 'best of all possible worlds' that could have been created, notwithstanding extreme events that cause death and injury. In Sicily rural Catholicism remained committed to notions of divine punishment with the 'greater good' being found in virtues of social and family cohesion, public service and self sacrifice" (Chester *et al*., 2012, pp.74 - Appendix 2).

[17] In hazard studies believing in two mutually incompatible explanations is known as *cognitive dissonance*, however in religious and psychology studies *cognitive dissonance* has a more restrictive definition (Carroll, 1990, pp.123-4) and for this reason the term *parallel practice* is used in this chapter.

Table 4.3: Examples of coping mechanisms involving neighbours, rural communities, and the inhabitants of agro-towns. (From Chester *et al*., 2012).

Means of Loss Reduction	Examples
Mutual Assistance	**1892** Committees were established to help those in need (Anon, 1892e). **1910** Neighbours expressed solidarity by receiving refugees (Anon, 2010b).
Protection of property and agricultural land from lava flows and ashes	**1832** People in Bronte tried to protect fields and vineyards by building stone walls and trying to reduce the forward motion of the flow by breaking its levees (Gemmellaro 1858; Giocomelli and Pesaresi undated). **1879** Farmers protected trees from tephra by shaking them, because ash was known to be injurious to vegetation (Anon, 1879e), and erected stone barriers to try and halt the advance of lava (Anon, 1879i). **1923** Trenches were dug to halt the advance of lava. Largely a local initiative, but the Carabinieri and Fascist National Militia were also involved (Anon, 1923a, 1923d).
Salvage	**1843** Salvage of timber and people removed tiles, doors and household effects from rural dwellings (Anon, 1843d). **1852/3** People from Milo cut down trees for timber and recovered all they could from their homes (Anon, 1852b). **1865** Farmers removed all they could as lava advanced (Reclus 1865). **1886** Systematic recovery of farm property (Anon, 1886d). Wine was removed and stored in Riposto and Catania (Anon, 1886b, 1886f). The roads were choked with people transporting household goods and other effects to places of safety (Anon, 1886e). **1910** People assisted their neighbours in removing materials and personal items from threatened homes (Hood 1915). **1911** Removal of household goods, farm animals and portable property from Castiglione, Francavilla and the rural areas in the vicinities of these settlements (Anon, 1911b). **1923** A film clip shows the careful removal of household goods, fixtures and fittings. The military and the Carabinieri were also involved (British Pathé, 1923).
Learning from previous experience	**1843** 59 people were killed by a phreatic blast near to Bronte (Anon, 1843b). This lesson were quickly learnt:- a. **1865** Wells were pumped dry to reduce the danger of explosions (Anon, 1865a) and farmers emptied cisterns (Reclus, 1865,). b. **1883** Water tanks were drained to prevent explosions (Silvestri, 1886). In an agricultural region which depends on irrigation, water supply can easily be disrupted during eruptions and concerns were expressed in 1865 and 1886. Worries about explosive activity were balanced against the needs of agriculture.

The most important ways in which the State viewed its role during the *long-nineteenth century* was in the maintenance of law and order by supplying police officers and/or soldiers (i.e. in 1874, 1879, 1883 and 1892). In fact as in many other well documented volcanic eruptions, including the eruption of Vesuvius in 1944 (Chester *et al.*, 2007), or studies of disasters more generally (der Heide, 2004, pp.362-3), on Etna there were virtually no examples of civil unrest and/or looting, the only exceptions being the 'religious riots' of 1923 (see Table 4.4), and an isolated instance of looting in 1911 when so-called "marauders" from Catania were allegedly involved (Anon, 1911c). More commonly police officers and soldiers assisted local people in locally-based methods of coping through helping with evacuation, removing materials from homes and salvaging agricultural products. In 1886 124 carts were sent from Catania to Nicolosi in order to remove agricultural goods and personal property from danger, wine was removed and stored in Riposto (Fig. 4.1) and Catania (Anon, 1886b, 1886e, 1886f) and in 1923 troops assisted with the digging of lava diversion channels (Anon, 1923a).

The State also attempted to make sure that lessons from previous eruptions were learnt. In 1865 soldiers and firefighters were sent from Catania and Giarre to Fondo di Macchia (Fig. 4.1) and other villages to clear rubble and rescue people from buildings destroyed by volcano-induced earthquakes (Anon, 1865b; Reclus, 1865). When the *Prefect* of Catania arrived he applauded the relief work carried out by the *comune* and he received a telegram from the Ministry of the Interior making funds available for rescue work (Anon, 1865b). The authorities both civil and religious subsequently closed churches in 1883 (Anon, 1883d) and 1892 (Anon, 1892c) and prevented people returning to their homes in 1886 until the dangers of seismic activity had abated (Anon, 1886g). The fifty-nine deaths in 1843 not only brought forth a visit to Bronte from the *Intendente* of Catania, but also led to a government enquiry into the cause of the fatalities (Anon, 1843b, 1844), with the authorities subsequently being aware of the dangers of water/lava interactions (e.g. in 1865 - Anon, 1865a and 1886 - Silvestri, 1886). From the last two decades of the nineteenth century the authorities were regularly consulting scientists – especially the Directors of the Etna Volcano Observatory[18] - on the course eruptions may take, Professor Orazio Silvestri being involved in 1883 and 1886

---

[18] In 1879 an astronomical observatory was established and central government called on the observatory to establish a volcanological section. At the beginning of 1881 a Royal Degree nominated Professor Orazio Silvestri as first Director of the *Royal Volcanological Observatory.* After Silvestri's death in 1890, the observatory went into decline and the professorship in volcanology was discontinued. After 1911 and following lobbying in the press by interested academics, the chair was

Table 4.4: Summary of religious responses to eruptions during the *long-nineteenth century*. (From Chester *et al*., 2012).

Eruption	Religious Reactions
1792/3	A statue of the *Madonna della Provvidenza* (our lady of Providence) was carried in procession and was claimed to have successfully 'halted' the lava before it reached Zafferana. A memorial was built and every year a pilgrimage commemorates this event, as does a memorial bronze plaque in the parish church.
1809	Several rural estates were threatened and images of saints were brought from Castiglione, a service was held on the balcony of an aristocratic seat. It was widely accepted that the house was saved through saintly intercession on behalf of its owner (Anon, 1809a, 1809b).
1843	Following the deaths of 59 people from the phreatic explosion at the lava front, many inhabitants in Bronte felt that their patron saint had abandoned them, however the discovery near to the lava of a marble statue of the Madonna with tears convinced many that their suffering was necessary, S. Mary acting in solidarity with those who were bereaved (Anon, 1843b)).
1865	Priests and monks used saintly images and crucifixes to try and halt one arm of a flow. People were alarmed and felt that the villages of Linguaglossa, Piedimonte, Mascali and S. Alfio were threatened, even though in the event the lava never anywhere near to these settlements. Sobbing people prayed to the virgin, the bells of convents and churches were rung, statues and images of S. Agatha and other patron saints were processed (Reclus, 1865, pp. 111).
1879	Pictures of saints and apostles were placed on trees and vines in the path of the advancing lava. In Randazzo much of the population visited the flow front, carrying an image of the Madonna (Anon, 1892f).
1883	Processions from Nicolosi paraded statues of the Madonna del Grazie (Lady of Graces), Antonio da Padova and S. Antonio Abate, after 36 hours the lava stopped (Anon, 2010c). It was widely believed by others that one of the St. Anthonys had been responsible.
1886	The Archbishop took a leading role and travelled to Nicolosi with S. Agatha's veil. One friar called on the people to be penitent for God was tired of their sinfulness and blasphemy (Anon, 1886d, 1886e, 1886f; Silvestri, 1886). Images of the saints were paraded to an outdoor altar, the *altarelli*, but the lava continued to advance until the Archbishop of Catania brought up the veil of S. Agatha and three days later the lava stopped (Hyde, 1916). The Archbishop was Giuseppe Benedetto *Cardinal* Dusmet (1818-1894) who was born Palermo in Sicily and was Archbishop between 1867 and 1894.
1910	The parish priest at Belpasso, Giuseppe Grassi, wrote to the Cardinal Archbishop who latter visited the village imploring people to seek divine aid and to organise pilgrimages. Religious processions were also held in Catania (Anon, 2010b). The Archbishop was Giuseppe *Cardinal* Francica-Nava de Bontifè (1846-1928) who was born in Catania and was Archbishop between 1895-1928.
1911	The Bishop of Arcireale visited the lava flow to encourage the faithful, conduct services, lead processions and impart benediction (Anon, 1911b).

---

re-established and entrusted to Gaetano Ponte. The observatory was re-opened in 1926 and in 1933 the *Volcanological Institute* in Catania was established with Ponte as its director (Anon, 2011d).

	The Bishop was Giovanni Battista Arista (1863-1920) who was born in Palermo and was bishop from 1907-1920.
1923	People from Piedimonte brought the statue of S. Antonia, their patron saint, and placed it the town square where people prayed day and night accompanied by the tolling of a church bell. People in Linguaglossa took the staff of S. Eglidius from the parish church and carried it in supplicatory procession, the population believing that his intercession had saved the town on previous occasions. When they heard about this, the people of Castiglione became agitated because they felt that the salvation of Linguaglossa could spell doom for their village, and a riot broke out between rival groups of saintly supporters and in the *melee* some members of the Fascist militia were injured. Shots were exchanged and eventually the Carabiniere had to restore order (Anon, 1923e, 1923f).

eruptions and Professor Gaetano Ponte in 1923 (Anon, 1883f, 1883g; Silvestri, 1886; Anon, 1923a). Towards the end of the *long-nineteenth century* there are examples of: soldiers breaking down earthquake-weakened walls and providing tents (Anon, 1883b); and forcing the evacuation of dwellings in 1911 and 1923 (Anon, 1911b). The 1923 eruption marked the first example of the authorities deliberately using the favourable publicity generated by its response to an emergency to boosts its popularity. In 1923 the *Duce* and King Vittorio Emanuele visited Etna, an aircraft was used for the first time to monitor the progress of the eruption (Chester *et al*., 1999b). Mindful of the powerful roles of *popular Catholicism* and heroic figures alike, one pro-fascist newspaper claimed that the arrival of the *Duce* was of Messianic import being the reason why the eruption suddenly ended and caused so little damage (Anon, 1923g, h; Mack-Smith, 1968, pp. 118).

Throughout the *long-nineteenth century* the level of official aid in most eruptions was modest: 2000 lire from the *prefect* in 1865 (Anon, 1865b); 500,000 lire from central government in 1879 to cover both the eruption and the flooding in northern Italy (Anon, 1879g); 100,000 lire from the State budget, plus a gift from the King in 1886 (Anon, 1886c; Gentile-Cusa, 1886); 10,000 lire from the Ministry of the Interior in 1892 (Anon, 1892f); and 75,000 lire from the monarch and the Pope in 1923 (Anon, 1923c, 1923i).[19] During the *long-nineteenth century*, no comprehensive state-based system of financial relief was in place, although in 1886 claims against the 100,000 lire voted by the State were co-ordinated by local *Sindaci* i.e. mayors (Gentile-Cusa, 1886, pp.196-206). In the absence of State aid initial recovery was assisted by: public collections, significant efforts being made in 1865 (Anon,

---

[19] A full discussion on converting figures into present day values using the consumer price index measure as an inflation measure can be found in Chester *et al*., (2012) and in Appendix 2.

1865b); 1886 (Gentile-Cusa, 1886) and 1892, when committees were formed in Catania and many villages on the southern flanks (Anon, 1892e, 1892f); in 1923 by the Red Cross (e.g. Anon, 1923j, k, l); by the Catholic Church on numerous occasions (e.g. Anon, 2010b) and, after the advent of the telegraph in the 1850s, by collections both in mainland Italy (Anon, 1879h) and even abroad (Anon, 1886h).

4.3 EXTENDING THE HISTORICAL RECORD (see Sangster *et al.*, 2013 – reproduced as Appendix 3)

It is clear that the three-levels of responses that have been identified during the *long-nineteenth century* (i.e. family coping strategies, mutual support within village communities and State intervention) are deep-seated. Sources from classical literature and from contemporary and near-contemporary accounts, will be used better to understand responses to the activity of Etna from the classical period to 1792/3.

4.3.1 Eruptions from the classical period to 1792/3

Despite poorer and more incomplete records from the classical period to 1792/3 this research is based on new and more accessible information from historical records, contemporary and near-contemporary accounts and from recent reviews (e.g. Romano and Sturiale, 1982; Stothers and Rampino, 1983; Chester *et al.*, 1985, 2000; Uchrin, 1990; Tanguy *et al.*, 2012). For some eruptions information comes only from radiometric dating of volcanic products, other accounts are too brief to allow anything to be written about how people coped, but for some high magnitude events which occurred on the heavily populated southern and eastern flanks – the record is much richer (section 4.3.1.2). Table 4.5 summarises the characteristics of the major eruptions that occurred from the classical period to 1792/3.

4.3.1.1 *Pre-Industrial responses to Etnean eruptions from the classical period to 1792/3*

From the classical period until *ca*. eighteenth century there are few historical examples of State involvement during and following eruptions of Etna (Chester *et al.*, 2005), the best recorded examples include: the Roman authorities granting a 10-year tax moratorium for the city of Catania following the eruption of 122 B.C. (Rodwell, 1878, pp.82); and in 1669 A.D. the Spanish Viceroy sent soldiers to restore order and provided monetary aid to the region (Mack-Smith, 1968). Arguments from silence are never strong and all that may be concluded is that in the *pre-industrial era* before 1792/3 State intervention was minimal.

Table 4.5: Mount Etna, summary of the major eruptions from the classical period to 1792/3. (Based on information from: Romano and Sturiale, 1982; Chester *et al.*, 1985, 2000; and Branca and del Carlo, 2004, together with the contemporary materials that are cited in the text).

Eruption (year)	Eruption months and (duration)	Nature of activity and location
122 B.C.	Unknown	Eruptive fissure opened on the southern flank at 425 m a.s.l. near Trecastagni (Mt. Trigona). Explosive activity at the summit craters and ash deposited to the south-east of the volcano (Rodwell, 1878).
252 A.D.	Unknown (9)	Flank eruption. Possibly formed Mt. Peloso 2 km north north-east of Nicolosi. Lava threatened Catania.
1408	9 Nov – 20 Nov (12)	Eruptive fissure opened at a height of 950 m a.s.l. on the southern flank (Mt. Arso) (Alessi, 1829-1835; Vön Waltershausen, 1880). Lava travelled 12 km and damaged Pedara and Trecastagni.
1444	Unknown (20)	Eruptive fissure opened on the south-eastern flank at a height of 1200 m a.s.l. and formed the Montarello cone (950 m a.s.l.). Lava travelled 9 km to the south-east.
1536	22 Mar -	Unlocated flank eruption from either a vent north-west of Mt. Pomiciaro (lava threatened Randazzo), or from Mt. Nero degli Zuppini on the southern flank, or from both. Earthquakes felt before, during and after the eruption.
1537	11 May - 29 May (18)	Eruptive fissure opened between 1900-1700 m a.s.l. on the southern flank. Mt. Nero and Mt. Palomaros formed (Rodwell, 1878). Lava travelled 10 km and threatened Nicolosi.
1610	6 Feb - 3 May (88) (Eruption also dated 28 Jun 1607 - 3 May 1610 (1041)) [20]	Eruptive fissure opened at a height of 2550 m a.s.l. on the southern flank. Lava travelled 10 km; reached Piano del Lago and threatened Adrano (Carrera, 1636; Recupero, 1815).
1614/24	Unknown	Eruption started at Mt. Deserti (about 2500 m a.s.l.) a small chain of cones on the NE rift. It lasted 10 years. Due Pizzi hornitos were formed downslope from the vent area.
1634/6	18 Dec -	Precursory earthquake. Eruptive fissure opened at a height of *ca*. 2000 m a.s.l. on the south side of the Valle del Bove. Lava threatened Fleri.
1651/3	17 Feb -	Precursory earthquake. Eruptive fissures opened between 2500-2100 m a.s.l. on the western flank. Lava flow field travelled at a rate of 0.5 km h^{-1}. Lava threatened Bronte.
1669	11 Mar - 11 Jul (122)	Precursory earthquake. Eruptive fissures opened between 200-2800 m a.s.l. from Piano di S. Leo to Mt.

---

[20] The dates of certain historic flows erupted between the classical period and 1792/3 are disputed (see Tanguy *et al*., 2007) and are corrected to take into account of the recent publication of Tanguy *et al*., (2012).

		Frumento Supino. Mt. Rossi formed. Lava overwhelmed Monpilieri and threatened Belpasso and Mascalucia. March 13/14 Belpasso overwhelmed and lava threatened Mascalucia, S. Pietro, Camporotondo and S. Giovanni Gelermo. Lava reached Catania.
1689	14 Mar -	Eruptive fissure opened in the Valle del Bove at a height of 1300 m a.s.l. Lava flowed until it reached Macchia. Another fissure may have opened at 1400 m a.s.l. on March 19.

The system of beliefs held by those suffering losses is fundamental to any understanding of *pre-industrial* responses. The tradition that Etna has a divine status is deep-seated and can be seen even before the Hellenic era with the Sikel god, Hybla, being associated with a mud volcano at Paterno on the south-western flank of the volcano (Maniscalco, 2005 - Fig. 4.1). Later in the classical period the idea that appeasement of the volcano was required to reduce losses became well established, with Lucilius Junior (first century A.D.) recording how the inhabitants would offer incense to the gods who controlled the volcano (Hyde, 1916; Chester *et al*., 2000). This idea of propitiation was taken over and developed in Christian times and became an integral part of Catholic observance (see section 4.2.2 – footnote 10). In the Christian tradition, *theodicy* refers to arguments advanced to resolve the dilemma between a loving God and the occurrence of human suffering, with Sicilian *popular Catholicism* maintaining that disasters were instruments by which a vengeful God could punish human sinfulness. As argued elsewhere (Chester *et al*., 2012 - Appendix 2), a limited understanding of the 'greater good' was also recognised, involving qualities of public service, communal solidarity and not least self-sacrifice, with the latter being seen in some of the earliest records. For example the Roman Stoic philosopher, Seneca (4 B.C. - 65 A.D.), recounts the narrative or legend of Anapias and Amphinomus – the so-called '*Fratelli pii*' or pious brothers – who rescued their parents from Catania, with the lava opening up in front of them like the Biblical Red Sea to allow them to escape (Chester *et al*., 2010), while more than 1,500 years later in 1669 A.D. the actions of Diego Pappalardo and his band of helpers quickly became an inspirational story (see section 4.3.1.2).

Under the prevailing theodicy of divine punishment, the inhabitants of Etna: appealed to God's mercy through prayer; attempted appeasement by liturgical action and, after the eruption ended, resolved to live better lives. Conventional Catholic teaching embraces intercession through the intervention of the saints and the Madonna, but on Etna this was not just distinctive, but also extreme (see section 4.2.2 and footnote 16). Saintly relics, votive objects and, indeed, temporary altars were displayed at flow fronts on many occasions in order to arrest the advance of lava. As early as 252 A.D. when lava approached Catania, the inhabitants processed the veil of the recently martyred St. Agatha[21] at the flow front which it was claimed was immediately halted. Later the veil was used many times with its efficacy being tested, for instance, in: 1408 (Alessi, 1829-1835), 1444 (Fazello, 1558), 1446 (Recupero, 1815), 1537 (Carrera, 1636), 1634/6 (Recupero 1815), 1651/3 (Vön Waltershausen, 1880) and 1669 (Winchilsea, 1669). One feature of the Etnean landscape is the abundance of shrines dedicated to local saints and martyrs, many of whom are commemorated by elaborate memorials drawing attention to their roles in preventing the destruction during particular eruptions and an important aspect of traditional village life is the festival (*festa*) which is held in the name of a local patron saint.

Throughout the recorded history of Etna towns and villages of various sizes have suffered the direct effects of lava flows and volcano-related activity despite the apparent successes of local coping mechanisms already discussed. Table 4.6 summarises the details of urban losses from the classical period to 1792/3, however, it must be emphasized that for the earlier part of the *pre-industrial* period the losses may be far greater than is recorded due to an absence of literate observers. There is also good evidence to suggest that certain early flank eruptions were ignored by historians (Wadge, 1977) but, despite this it is clear that urban losses have not been equally spread across the settlements of the region. On the one hand Catania has been threatened, partially or wholly destroyed by volcanic activity on eight occasions (i.e. 693 B.C., 425 (or 424) B.C., 122 B.C., 40 A.D., 252, 1371 (or 1381), 1444 and 1669), whereas Acireale - the second largest city of Etna - has throughout its long history never been invaded by lava flows and only been seriously damaged by earthquakes (i.e. in 1693). The five largest towns in the nineteenth century - Paterno, Giarre, Adrano, Bronte and Biancavilla - have also never been invaded by lava flows, though some have been threatened from time to time (see Table 4.6). The main effect has been the destruction of small towns and villages on the southern and south-eastern flanks and one remarkable feature of loss-bearing on Etna was that, although cities, towns and villages could be badly affected even destroyed, they normally recovered rapidly. For example, Nicolosi was destroyed by lava in 1537, but was a prosperous settlement when an earthquake again badly affected the settlement in 1633 and was probably fully re-built by the time of the 1669 eruption (Chester *et al*., 1985). This is not

---

[21] Information on the martyrdom is unreliable, but further information may be found in: Kirsch (1907-14).

Table 4.6: The effects of eruptions on the settlements of the region during *pre-industrial* times from the classical period until 1792/3. (Based on information from: Rodwell, 1878; Vön Waltershausen, 1880; Hyde, 1916; Baedeker, 1930; King, 1973; Stothers and Rampino, 1983; Chester *et al*., 2005, 2010).

Location of settlements	Year	Effect on settlement	Land affected	Subsequent expansion of the settlement over the lava flow
Northern Sector				
Passopisciaro	1646	Threatened	*Corona* and upslope pasture	The village was built on the flow and later expanded
Randazzo	1536	Threatened	*Corona*	A small settlement was built on the flow
North-eastern Sector				
Linguaglossa	1566 *or* 1180	Threatened	*Corona*	Village expanded
Eastern Sector				
Macchia	1689	Several small villages were destroyed and lava threatened the outskirts of the town	*Corona*	Village expanded and the lava flow is densely settled
South-eastern Sector				
Acireale	396 *or* 394 B.C.	Threatened		Several small villages are now located on this flow
Pedara	1408	Destroyed		Relocated a short distance from the flow
Trecastagni	1408	Destroyed		Relocated a short distance from the flow
Southern Sector				
Belpasso	1669	Destroyed		The town was later relocated a short distance from the flow
Camporotondo	1669	Destroyed		The town was later relocated a short distance from the flow
Catania	693 B.C.	Destroyed		Despite being devastated so many times the city of Catania was never fully destroyed.
	425 *or* 424 B.C.	Partially destroyed		
	122 B.C.	Threatened		Catania expanded over sterilized land
	40 A.D.	Threatened		
	252	Threatened		
	1371 *or* 1381	Threatened	*Corona*	

	1444	Threatened	*Corona*	
	1669	Partially destroyed		
Mascalucia	1669	Destroyed		The town was later relocated a short distance from the flow
Misterbianco	1669	Destroyed		The town was later relocated a short distance away from the flow
Nicolosi	1537	Destroyed	*Corona*	The town was later relocated a short distance away from the 1669 flow and named 'Phoenicia Moncada', but the air was reported to be unhealthy and the town was relocated on its present site in 1695, about 1 km from the flow
	1669	Destroyed		
S. Giovanni di Gelermo	1669	Destroyed		The town was later relocated a short distance from the flow
S. Pietro Clarenza	1669	Destroyed		The town was later relocated a short distance from the flow
South-western Sector				
Adrano	1595	Threatened	*Corona* and pasture land	Little urban expansion on either flow
	1610	Threatened		
Western Sector				
Bronte	1651/3	Threatened	*Corona*	Village expanded

an isolated example, and a productive area was never abandoned even though some of it was covered by lava, with villages either being rebuilt in the same location or close to it (Chester *et al.*, 2005, pp. 103; 2010, pp. 247, table 15.4 – see Table 4.6). This response, however, was not without its practical difficulties. When an earthquake destroyed a settlement no sterilization of land occurred, rubble was quickly cleared, and rebuilding could commence. In the case of land inundated by lava, rebuilding was extremely difficult because only basic earth moving techniques were available. The substrate, which is composed of solid – sometimes – hot rock, would also not be suitable building land for some time. It was reported that following the 1669 eruption, lava took eight months to cool and peasant farmers were able to boil water on it for a considerable period of time (Rodwell, 1878; King, 1973). With the exception of low intensity rough grazing, lava flows had little agricultural value for centuries until weathering converted them into agriculturally useful soils, but could be built over without reducing the productive agricultural land area of a community. Even when settlements were not destroyed, land sterilized by lava was often used to accommodate urban expansion (i.e. Catania has spread over the 1371 flow and Macchia over the 1689 flow); a policy of hazard adjustment that held two advantages: cheap building plots; and no loss of agriculturally productive land (Chester *et al.*, 2010).

4.3.1.2 *The 1669 eruption*

No account of the *pre-industrial era* is complete without reference being made to the largest and most widely reported historical eruption of Etna. On March 11, 1669, Mount Etna erupted. Early in the morning on March 11, (at about 5 a.m.) preceded by seismic activity, a 2 m wide fracture opened, extending for 9 km from the base of Mt. Frumento (2800 m a.s.l.) to Piano S. Leo (1200 m a.s.l.). Later that day a new fracture opened from Mt. Nocilla to Mt. Fusara, vents erupted juvenile tephra until the evening when a lava flow was erupted from the site where, in this eruption, the main cinder cone (Mt. Rossi) formed (Corsaro *et al.*, 1996). Lava flowed around the undated cone of Monpilieri and headed towards Belpasso to the west and Mascalucia to the east (Fig. 4.1). Both were reached and destroyed, respectively, on March 12 and March 13. From March 14 effusive activity produced a fan-like field, lava streams travelled downslope in three main branches and headed towards the Camporotondo countryside, St. Pietro Clareza and St. Giovanni Galermo (Fig. 4.3), respectively. On the morning of March 25 (at about 10 a.m.) a violent explosive event occurred, followed by the partial collapse of the summit cone. On March 20 a lava stream travelled rapidly southwards and then towards the western side of the city of Catania. The branch reached the city walls on April 1, later surrounded the Ursino Castle and flowed towards the sea on April 23 with a 2 km wide front (Corsaro *et al.*, 1996). In the next two months the branch directed to Catania was continually fed and kept slowly flowing to the sea. The eruption ended July 11 and in total some 937.5 x 10 m^3 of magma had been erupted (Romano and Sturiale, 1982).

Contrary to what might be assumed from the literature there are in fact relatively few primary sources on the impact of the 1669 eruption on the people of Etna (e.g. Anon, 1669; Winchilsea, 1669; Borelli, 1670), and information from these sources has often been re-cycled over the centuries. It is clear, however, from a critical re-examination of the contemporary and near-contemporary accounts that not only did the people of Etna respond in ways which were typically *pre-industrial*, but some of these characteristics also influenced future policy.

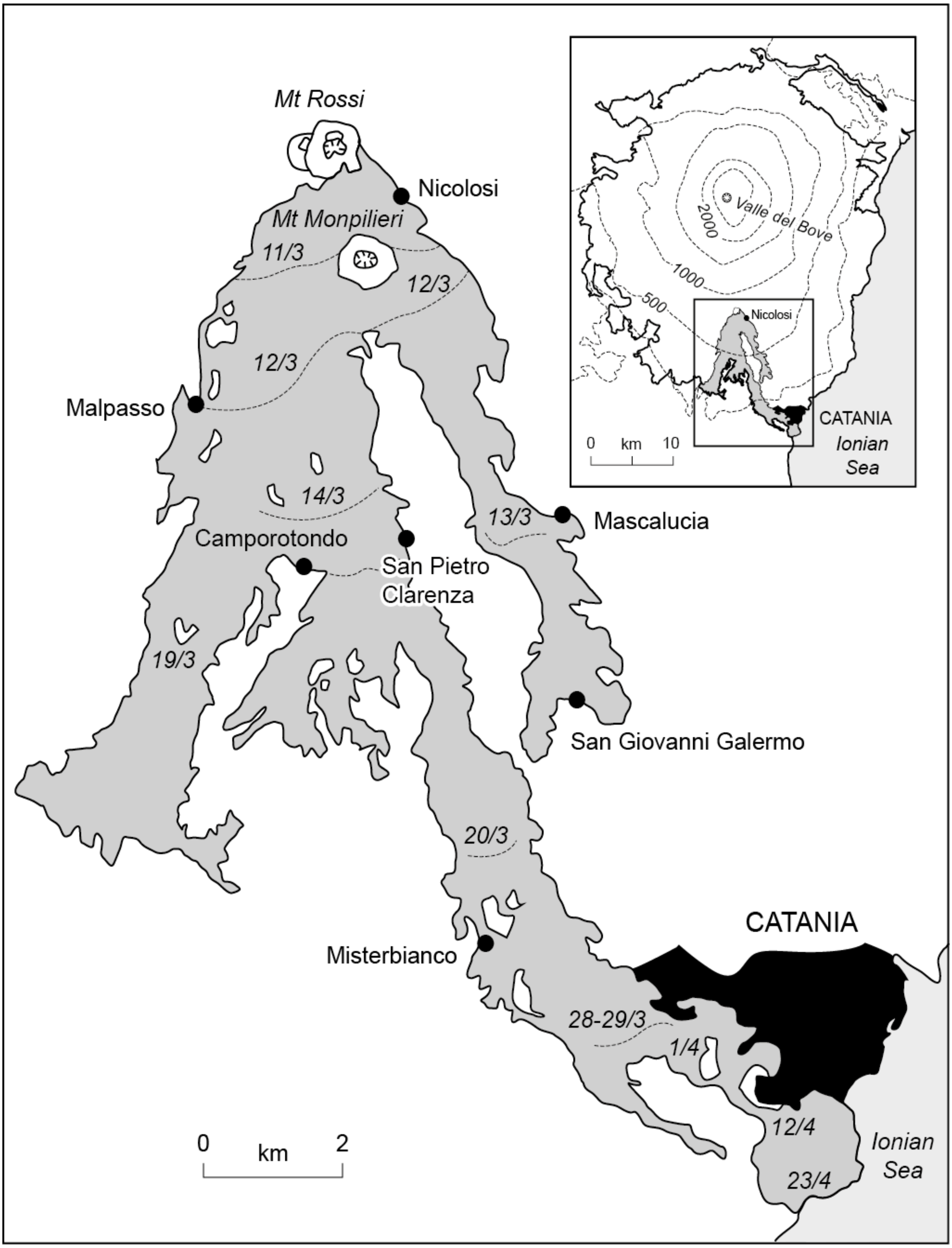

Fig. 4.3: Evolution of the 1669 lava field at March 12, 14, 17, 25 and 29; April 4, 16 and 23 and at the end of the eruption, with the location of the main settlements and localities at the time of the eruption. (Based on information from: Corsaro *et al*., 1996 and Branca *et al*., 2013).

The State hardly impinges on people living in *pre-industrial* societies and, even during times of eruption, the people of Etna were no exception. Following the 1669 eruption the Spanish Viceroy sent money and troops to the region. The troops promptly restored order, but rumours spread that the authorities only provided aid because they wished to steal the sacred veil of St. Agatha, which was thought to have the power to 'halt' lava flows (Mack-Smith, 1968). It is also reported that Diego Pappalardo and some fellow citizens of Catania attempted to divert a lava flow that threatened their city. This caused civil unrest because the diverted lava placed the city of Paterno at risk (Fig. 4.1). Futile attempts were also made to arrest the forward movement of lava threatening Catania by the rapid construction of walls (Rodwell, 1878), while the ancient city walls caused the flows to be diverted into the Ionian Sea for several days. Eventually the walls were breached and lava invaded the city (Vön Waltershausen, 1880). Due to the social unrest such diversions were declared illegal and were not attempted again until 1983.

A theodicy based on a vengeful God meant that virtually all eruptions from the classical period became associated with a well-developed liturgy of propitiation, most notably in the eruption of 1669 A.D. There are accounts of people praying and crying out to God and to the saints; it was believed that St. Agatha's veil prevented all of Catania being destroyed. People mortified themselves with whips and made other corporal signs of penance (Winchilsea, 1669, pp.17). During the 1669 A.D. eruption, a church near Nicolosi was destroyed by lava. The church contained the statue of the Madonna (Lyell, 1835, pp.172-3). There is an apocryphal story that, following the eruption, someone dreamt that they knew where the church was and that the statue of the Madonna was still intact. People dug through the lava, found the statue and placed it on an ox cart. The ox moved 25 m but refused to move any further, so a new church was built on this site (Pinkerton, 2006 quoted in Chester *et al*., 2008).

Settlements of various sizes were destroyed and much agricultural land was sterilised during the eruption of 1669 (Table 4.6 and 4.7). In those settlements that were destroyed, devastation was invariably either total or nearly so, and the usual decision was to rebuild the town or village as close as possible to the original site, maximizing any locational advantages, particularly communication. In Camporotondo Etneo re-building was delayed until 1681; Misterbianco's population of 3,656 in 1652 did not recover until the early eighteenth century and was only *ca*. 2,500 in 1798; Pedara lost over 25% of its population

Table 4.7: Summary of the effects of the 1669 eruption on the settlements of the region. (Based on information from: Rodwell, 1878; Vön Waltershausen, 1880, Hyde, 1916; King, 1973; Stothers and Rampino, 1983; Chester *et al.*, 1985, 2010; Branca and del Carlo, 2004; Anon, 2012b).

Settlements affected	Nature of actual and potential loss	Responses and adjustments
Nicolosi (11 March)	Town destroyed by an earthquake before the eruption	The town was later relocated a short distance away from the flow and named 'Phoenicia Moncada', but the air was reported to be unhealthy and the town was relocated on its present site in 1695, about 1 km from the flow
Belpasso (12 March)	Town destroyed	The town was later relocated a short distance away from the flow. The town's population relocated SW of the flow to the newly named settlement 'Phoenicia Moncada', however, some families decided to resettle to the E of the flow in 'Stella Aragon'. Belpasso's post-eruption population had recovered by the middle of the nineteenth century when it had reached 7,438
S. Pietro Clarenza (13 March)	Town destroyed	The town was later relocated a short distance away from the flow. S. Pietro Clarenza's pre-eruption population of 1,021 in 1652 fell to 603 in 1737
Mascalucia (13 March)	Town destroyed	The town was later relocated a short distance away from the flow. Mascalucia's pre-eruption population of 1,150 in 1602 had recovered by 1713 and had reached 1,570
Camporotondo Etneo (13 March)	Town destroyed	The town was later relocated a short distance away from the flow. Camporotondo Etneo's pre-eruption population of 1,600 in 1655 continued to fall after the disastrous earthquake (in 1693) to 181 in 1714. Many people fled to Catania and decided to settle there on a permanent basis
S. Giovanni di Gelermo (15 March)	Town destroyed	The town was later relocated a short distance away from the flow
Misterbianco (25 March)	Town destroyed	The town was later relocated a short distance away from the flow on land belonging to the Monastery of S. Chiara Catania. Misterbianco's pre-eruption population of 3,656 in 1652 did not recover until the early eighteenth century and was only *ca*. 2,500 in 1798
Catania (12 - 23 April)	City partially destroyed	The city was subsequently rebuilt on the same site. Catania's pre-eruption population of 14,241 had risen to 24,000 at the time of the 1693 earthquake, which then fell by over 60%
Fourteen small villages on the southern flank	Villages destroyed	Some of the villages were later relocated near to the flow; the fate of others is uncertain

following the 1693 earthquake and after 1669 Nicolosi was reconstructed on a new site which also housed refugees from Belpasso and Mompilieri. This village was named Phoneicia Moncada[22], but was quickly abandoned – possibly because it was an unhealthy site – and after 1671 the original location was redeveloped under priestly patronage. Nicolosi's pre-eruption population of *ca*. 2,400 was not surpassed until the end of the eighteenth century, standing at 2,520 in 1798 (Anon, 2012a; Anon 2012b). Less than 25 years after the eruption Catania was destroyed by a major earthquake (i.e. 1693), which caused the deaths of 18,000 people and almost overwhelmed the region's resilience (see section 4.4).

4.3.2 Post-1669: Changing styles of activity

From 1600 to 1669 the activity of Etna was characterised by a high volumetric output of lava with a mean eruption rate of 1.19 m^3s^{-1} (Hughes *et al*., 1990). This was then followed by a pause in flank eruptions and significant activity was only re-established from the middle of the eighteenth century. After 1750 the output of lava in flank eruptions was lower than in the previous century, with the mean eruption rate falling to 0.18 m^3s^{-1}. Branco and Del Carlo (2004, 2005) in their analysis of the eruptive behaviour of Etna from 1670 to the end of the twentieth century, show that the activity of the volcano was complex with variations in both the frequency of events and rates of magma movement.[23]

4.3.2.1 *Pre-Industrial responses in the 1928 eruption*

The 1928 flank eruption is the only eruption of Etna since the seventeenth century which has destroyed a town in Sicily (Imbò, 1928; Chester *et al*., 1985). It is also transitional between a characteristic *pre-industrial* and a more typically *industrial* response. On November 2, 1928, Mount Etna erupted (Imbò, 1928). A flank fissure opened on the eastern flank, at a height of 2,600 m (Imbò, 1928), and a small lava flow was erupted. Early the next morning a new vent opened between about 2,200 and 1,550 m on the Serra delle Concazze in the second phase of the eruption. On the night of November 4 further vents opened up along the Ripa della Naca fault at 1,200 m (Anon, 1928a; Chester *et al*., 1985). At 12 points along this rift, vents developed and voluminous lava streams from the lowermost regions of the fissure travelled rapidly downslope and threatened the towns of S.Alfio, Puntalazzo, Giarre and Riposto (Fig.

---

[22] In some accounts this new town was named Mezzocampo (e.g. Chester *et al*., 2010), but may refer to the post-eruption site of Misterbianco.

[23] Branco and Del Carlo (2004, 2005) classify flank eruptions into two classes: *Class A*, the most common type between 1670 and 2000, is manifest by lava effusions with weak strombolian activity at the vent(s), this typically being restricted to the early phase of an eruption; and *Class B*, where vigorous explosive activity persists throughout most of an eruption.

4.1). On the night of November 4/5, the third and final phase of the eruption started. Fissures opened at *ca*. 1,000 m and by November 6 lava had travelled some 6.5 km and cut the *Circumetnea railway* and entered the town of Mascali (Anon, 1928b, 1928c, 1928d; Duncan *et al*., 1996). Parts of the villages of Nunziata and Portosalvo (near to Nunziata – Fig. 4.1) had already been destroyed and much highly fertile land rendered sterile for many decades (Jaggar, 1928a, b, 1929). By November 7 much of Mascali had been overwhelmed, however, the rate of advance of lava slowed and the east coast railway line was not cut until November 11 (Anon, 1928e, 1928f). The flow front finally stopped on November 16. The eruption ended on November 20 1928.

Mascali was a typical Sicilian *agro-town* (section 4.1.1) with narrow streets and a high population density and at the time of the eruption, with an estimated population of *ca*. 2,000, was the largest settlement in the Mascali *commune*. In just two weeks Mascali *commune* was transformed: *ca*. 700 houses had been destroyed and a further 50 damaged; *ca*. 4,300 - 5,000 people made homeless; communication lines disrupted and some 1.6 km^2 of land was effectively sterilised by lava. Since the lower slopes on Etna were, and remain, one of the most productive regions in the whole of the Italian south, the loss of productive capacity was considerable (Anon, 1928f).

This text box is where the unabridged thesis included the following third party copyrighted material:

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

Figure 4.4: (From Duncan *et al*., 1996) Maps showing the destruction and reconstruction of Mascali: *(a) Mascali before 1928 eruption; (b) lava engulfing Mascali, 6-7 November 1928; (c) the final stages of the eruption, 7-11 November; and (d) 'New' Mascali (note the 'grid iron' street plan and the prominence given to public buildings).*

According to newspapers and contemporary and near-contemporary accounts, in keeping with responses from the *pre-industrial* period, religious processions were held and people prayed for a miracle (Anon, 1928d, 1928g, 1928h). The patron Saint of Mascali is S. Leonardo and in 1928 votive objects supposedly associated with this saint were used to try and bring a 'halt' to the lava (Anon, 1928d - Fig. 4.5). In Giarre (Fig. 4.1) images of the patron saints of the villages of Piedimonte and Linguaglossa were carried in procession, the latter being held responsible for preventing the destruction of the town, and in S. Alfio the parish priest, Monsignor Nicotra (Archbishop)[24], announced that he would offer his life to save the village. "His request was granted, S. Alfio was saved, and four months later he died" (King, 1973, pp.163).

As mentioned in section 4.1 in *pre-industrial* societies people often harmonized their livelihoods with nature. The stages from *pre-industrial* to *industrial* should not be viewed as sequential because elements of more than one response may be seen at the same time. For example firefighters, the municipal guard, both soldiers and military transport were used extensively to assist local people in removing personal possessions, household furniture and even parts of the fabric of their homes (Fig. 4.6). Contemporary newsreel films even show the removal of roof tiles. The State also deployed police officers and soldiers to maintain law and order. General Scipioni, the local military commander, liaised with the Director of the Etna Volcano Observatory, Professor Gaetano Ponte, and made plans to construct barriers and channels to protect the towns of Riposto and Giarre. In the event these measure were never required.

Since 1928 there have been eight significant flank eruptions on Etna, in 1950/1, 1971, 1979, 1981, 1991/3, 2001, and 2002/3. All the main flank eruptions that have occurred in the twentieth century are summarised in Table 4.8. None have caused the same level of destruction as the 1928 eruption and inhabitants are therefore, less aware than they should be of the potential risks faced. 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 Etna Sud tourist complex. The damage to these facilities was estimated to be *ca*. $30 million ($US 1983) (Chester *et al*., 1985). The 1985

---

[24] Sebastiano Nicotra (*b*.1855) - former Archbishop and Papal nuncio to Portugal – retired due to ill health and made his home in S. Alfio, his place of birth, early in 1928. Though elderly and infirm he went in procession with the sacred relics of the three saints, together with three priests (Pelluzza, 1928).

This text box is where the unabridged thesis included the following third party copyrighted material:

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

Fig. 4.5: A procession with the statue of S. Leonardo (copyright Finocchiaro Forografi).

This text box is where the unabridged thesis included the following third party copyrighted material:

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

Fig. 4.6: (From Duncan *et al*., 1996) An inhabitant of Mascali who temporarily stored his possessions on the street, before the destruction of his home. Local inhabitants were greatly assisted in the removal of possessions from their homes by soldiers using military transport.

Table 4.8: The effects of flank eruptions of the twentieth century since the eruption of 1928. (Modified from Chester *at al*., 1985, pp. 358-359).

Eruption (year)	Location of eruption	Effect on the inhabitants
1942	High level eruption (3000-2240m)	Little effect on populated area
1947	Eruption associated with NE rift (3050-2200m)	Little effect on populated area. Some woodland and agricultural land destroyed
1949	Fractures near summit	Little effect on populated area
1950/1	Fractures in Valle del Bove	Threatened Fornazzo.
1971 (April)	Fissures near summit	Etna observatory and upper part of the cable-car route destroyed
1971 (May)	Fissures (1800m) E sector	Threatened Fornazzo and S. Alfio
1974	Fissures (1675m) W sector	Little effect on populated area.
1978	Fissures (2800-2500m) E sector	Grazing land destroyed.
1979	Fissures (1800-1700m) E sector	Cut communication to Fornazzo.
1981	Fissure (2500-1800m) NW sector	Threatened Randazzo and Montelaguardia. Cut communications to the east sector. Woodland and agricultural land destroyed.
1983	Fissure (*ca.* 2400m) S sector	Destroyed the Etna Sud tourist complex. Threatened Ragalna and Nicolosi
1989	Fissure (2670-2550m) NE sector	Threatened Fornazzo
1991/3	Fissure (3100m) E sector	Threatened Zafferana
2001	Fissure (3020-2980m) S sector	Closure of Catania airport for several days. Destroyed the cable-car route and ski lift.
2002/3	Fissure (2850-2600m) NE and S sector	Pro-longed closure of Catania and Reggio Calabria airports. Damaged Etna Nord tourist complex

and 2001 eruptions damaged the cable-car system (Branca and del Carlo, 2004). The State played an increasingly important role after each of these eruptions. Although the effectiveness of some of these State sponsored initiatives, particularly those before the 1983 eruption, have been questioned in terms of their effectiveness (Duncan *et al*., 1996 and references; Chester *et al*., 1999b).

4.4 CONCLUSIONS: THE IMPORTANCE OF PRE-INDUSTRIAL LOSS BEARING

Close study of the major eruptions of Etna during the *pre-industrial* period shows a resilient society and one that is not just able to survive but to prosper. As discussed in Chapter 2, v*ulnerability* is defined as the propensity of a society to suffer damage in this context from volcanic activity, whereas *resilience* is its capacity to resist and recover (Galliard, 2007, pp. 522-3; Manyena *et al*., 2011). In all cultures disasters expose the balance between the two.

Hence in *pre-industrial* societies such as Etna Region during the *long-nineteenth century*, when much land was sterilised but only two small settlements were destroyed, resilience was exemplified by rapid recovery. The only time the region's resilience was almost overwhelmed by its vulnerability was the second half of the seventeenth century when in less than 25 years, the combined impacts of the largest historic eruption in 1669 and the 1693 earthquake affected the densely populated eastern, south-eastern and southern sectors of the volcano, and inhibited production and population growth in the highly productive south-eastern sector until well into the eighteenth century. Today and in common with other *economically more developed* countries, when disasters strike the State through the government and its agencies is responsible for disaster relief. Overall, vulnerability (e.g. measured by mortality, morbidity and personal economic distress) falls, but economic losses rise because there is more of value to be destroyed. Methods of coping become 'top down' and uniform across societies (e.g. engineering approaches to lava diversions and land-use planning based on hazard mapping), rather than being tailored to the particular needs of a given community. On Etna, although State-based policies have boosted overall resilience, the traditional deep-seated resilience of *pre-industrial* times has been reduced. Much of the traditional Sicilian way of life and the distinctive character of the agro-town have disappeared, though some features are still present in the isolated communities located on the northern and north-western and western sectors of the volcano (Dibben, 2008; Chester *et al*., 2010).

Since 1923 major flank eruptions affecting housing and/or agricultural activity have occurred in 1928, 1971, 1974, 1981, 1983, 1991-3, 2001 and 2002-3 (Guest *et al*., 2003). State involvement increased in each successive eruption. Today volcanic and volcano-related emergencies are closely managed by the Ministry of Civil Protection (*Dipartimento della Protezione Civile* - founded in 1992), who can use the expertise of local authorities (*comuni*) and scientific bodies, especially the National Institute of Geophysics and Volcanology in Catania (*Istituto Nazionale di Geofisica e Vulcanologica INGV - sezione Catania*). Not only is the volcano monitored by an array of geophysical procedures including seismology and geochemistry, but forward planning also makes use of hazard mapping and land-use zoning. In this respect Etna is typical of the manner in which active volcanoes are managed in economically more developed parts of the world (Chester *et al*., 2005, 2010).

Elements of *pre-industrial* loss bearing on Etna have nonetheless survived and still feature in contemporary hazard responses. The most prominent surviving feature of *pre-industrial* times are the liturgies of divine appeasement which are still carried out every time a major eruption occurs. These liturgical actions are still supported and in July 2001, the Sicilian-born Archbishop Luigi Bommasrito of Catania, celebrated mass in the village of Belpasso (Fig. 4.1), in order to ask God to ‘halt’ the progress of the lava flow that was thought to have been threatening the village. At the time it was estimated that between 7,000 and 10,000 people attended this open-air mass, representing a wide cross-section of the village’s population, including many professionals and well-educated people (Kennedy, 2001). In fact a teacher is quoted as saying that local people still believe in miracles, “if human technology cannot keep the lava back, the eternal father is our only salvation” (Kennedy, 2001, pp. 10). The ‘parallel practice’ noted in section 4.2.2, in which people not only believed that disasters express God’s wrath and can only be prevented liturgical actions to propitiate them but also and at the same time fully accepted State support to reduce risk and aid recovery, is still part of the psychological makeup of the population of the Etna region.

Salvaging all that may be easily removed from a building and/or agricultural holding remains an important coping mechanism on Etna and may reflect a continuation of nineteenth century and even earlier precedents for such actions. This traditional action may, alternatively, be related to the low take-up of domestic property insurance which is both costly and of limited availability (Chester *et al*., 1985). In the near future this situation may change because in 2008 the *Dipartmento della Protezione Civile* (Department of Civil Protection) was in discussion with the *Association Nazionale fra le Impresse Assicuratrici* (Italian National Insurance Association) to develop a national system of disaster insurance and in 2010 a new scheme was proposed. The most likely future option is that compulsory insurance will be underwritten by the State (Garonna, 2011).

The nature of the society living on the flanks of the volcano has changed over the past nine decades, especially since the late 1960s. Poverty has been reduced through aid from the Italian State and the European Union and agriculture is more mechanized, although on Etna some of the traditional character of the *regione piedmontese* has been maintained (Dazzi, 2007), especially on the more remote western, north-western and northern flanks. Over the past forty years investment has been concentrated in more environmentally favoured and larger more easily worked and accessible holdings both within the *regione piedmontese* and the Plain of Catania. Some abandonment from cultivation of more marginal land often at higher altitude and/or more inaccessible locations has taken place. The numbers employed in agriculture have fallen, those in service occupations have increased and many *comuni* particularly those within easy driving distance from Catania, are now principally commuter settlements, providing homes for inhabitants who are less conscious of the vulnerabilities of location than their historic forebears (Dibben, 2008).

Educating local people about how to react when a disaster strikes is viewed as an increasingly important element in Civil Defence, with examples of how people coped successfully in the past being used to inform and inspire people today. For example, in November 2008 and to commemorate the eightieth anniversary of the 1928 eruption the *commune* of Mascali held a number of events including an exhibition and interviews with local people and academics. In an exhibition emphasis was placed on the action of local people, both their sacrifices during the eruption and their recovery from its effects. Disaster education is taken very seriously by the *Istituto Nazionale di Geofisica e Vulcanologica (INGV)* and one recent initiative is *Edurisk* (*Itinerari per la riduzione del rischio* - programmes for Risk Reduction - translation from Chester *et al*., 2012) aimed at school children.

As mentioned in section 4.2 volcano-related earthquakes caused minor damage in many nineteenth century eruptions, but in 1883 and especially in 1865 and 1911 produced major losses. The Etna region has been fortunate that since 1911 volcano-related earthquakes have not caused major damage, though buildings were severly damaged in Milo and Fornazzo by shallow earthquakes in the 2002 eruption, the threat clearly remains and is largely un-ameliorated. Although modern buildings are more resistant to earthquakes, the city of Catania and most towns and villages on Etna are still dominated by traditional buildings constructed of lava blocks and rubble stone, which remain highly susceptible to earthquake-induced failure. Buildings are, moreover, often constructed on debris from previous eruptions and loose soil, standards for earthquake design having only been enforced at *comune* level since 1981 (Faccioli *et al*., 1999; Barbano *et al*., 2001).

From 1669 until 1983 it is often stated that diversion of lava flows was illegal. Legislation was passed after the 1669 eruption (section 4.3.1.2) when civil unrest broke out when men from Catania tried to divert a lava flow. This action would have caused Paterno to be threatened and was strongly resisted by the inhabitants (Chester *et al*., 1985, pp. 323; Behncke, 2011). The civil unrest aroused by this episode led to the declaration that those interfering with a lava flow could be held liable for any damage that may subsequently occur. Despite this legislation attempts to control lava are recorded in 1832, 1879 and 1923, in the latter case with some official sanction. For example in 1983 action was taken to divert the lava from its original channel using explosives and earthen barriers to prevent lateral spread. Barriers and other initiatives were again used in 1992 (Barberi and Villari, 1984; Barberi *et al*., 1993), but these attempts - in common with those tried in the nineteenth century - require time to organise so that equipment and materials may be brought to locations where they are required. Boris Behncke (2011) has pointed out, in order to have time to intervene, eruptions have to have high altitude eruption vents and/or low effusion rates and these conditions did not obtain in eruptions of 1809, 1843, 1879, 1910, 1911, 1923, 1928 and 1981 where lava flows quickly approached populated areas. In order to overcome time constraints it has recently been proposed that wire baskets (i.e. *gabions*) filled with earth, scoria and lava blocks should be pre-prepared and transported to the areas affected once eruptions begin (Scifoni *et al*., 2010), but even this action might not be quick enough to deal with some highly effusive events occurring at low altitudes. Due to its frequent eruptions and the presence of settlements, roads and scientific and tourist facilities at relatively high elevations, Etna is both a high economic risk volcano and also an ideal site to test such techniques (Barberi *et al*., 2004).

Chapter 5

MOUNT VESUVIUS (ITALY)

The focus of this chapter is four-fold: firstly, briefly to review the characteristics of the major eruptions between the classical period and 1944; secondly to examine the impact on society of the well documented 1944 eruption; thirdly to examine the impacts on society of the poorly documented 1906 eruption on the basis of, not only the limited contemporary material that is avalaible, but also of the importance of responses to the 1944 eruption in relation to those identified in 1906; and finally to assess the suitability of the historically-based methodology that worked so successfully on Etna, on another Italian volcano which is culturally very similar, but volcanologically different.

5.1 INTRODUCTION

In this Chapter on Vesuvius the focus is not on the detailed historical reconstruction of responses of society to past eruptions from the classical period, but instead seeks to test whether the use of a similar historically-based methodology to that applied in Chapter 4 is suitable for another Italian volcano. At first sight this volcano is very similar, having a comparable record of eruptions that stretches back to the classical era, but differs in its style of activity and frequency of eruptions. Consequently, sections 5.1.1 and 5.1.2 are merely brief summaries of the historical activity from the classical period to the most recent events of 1906 and 1944. It is the impacts of these particular eruptions that are examined in detail. The 1906 eruption is an under-researched eruption. Although its volcanological characteristics are well known (e.g. de Lorenzo, 1906; Johnston-Lavis, 1909; Bertagnini *et al*., 1987, 1991; Mastrolorenzo *et al*., 1993; Santacroce *et al*., 1993; Lirer *et al*., 2005; Ricciardi, 2009), with the exception of the report by Lieutenant-Colonel Sir Charles Delmé-Radcliffe who was a British military attaché to the Italian government and produced an account of responses of society and State to this event[25] (Delmé-Radcliffe, 1906), relatively

---

[25] A single copy of the detailed eye-witness account of the effects of the 1906 eruption by Lt. Col. Delmé-Radcliffe is archived within the British Library and is only available for on-site consultation or

little would be known in the published literature. In fact even this report was not widely disseminated until 2007 (Chester *et al*., 2007a). As a consequence, the eruption of 1906, is examined using this report, together with newspapers of record (especially the *New York Times* and the London *Times*), many of which are now available electronically. These are supplemented where possible by contemporary and other publications. Obtaining additional information on the impacts of the 1906 eruption would require the examination of local archives in Naples and within the *comuni* affected. The 1944 eruption is transitional between a *pre-industrial* and more state-initiated (i.e. *industrial*) means of responding. Previous studies (e.g. Pesce and Rolandi, 1994; Chester *et al.*, 2007b) have undertaken detailed analyses of the eruption and its associated responses using archival sources and additional materials which are cited in this Chapter. In addition the present author's research considers the degree to which *pre-industrial* elements identified in 1944 were present in 1906, and whether the historically-based methodology allows a detailed analysis of the individual, community and State responses to be carried out.

5.1.1 The geology of Mount Vesuvius

Mount Vesuvius in southern Italy is one of the world's most dangerous volcanoes, with around 600,000 people living on its flanks and an estimated 3 million within range of a future eruption (Santacroce *et al*., 2005; Scarth, 2009). It is located at the intercession of two major fault zones; NW-SE to NNW-SSE and NNE-SSW to NE-SW (Finette and Morelli, 1974; Scandone and Cortini, 1982; Luongo *et al*., 1991) and the history of its activity commenced 300-500 ka years ago (Kilburn and McGuire, 2001; Guest *et al*., 2003). It is a relatively small volcano, with a height of 1281 m a.s.l. and a diameter of only *ca*. 12 km. The summit cone sits in a 4 km diameter caldera, known as Somma Caldera, which is open to the sea (Fig. 5.1). This structure truncates an older cone known as the Somma Volcano, forming the main crater. The trough formed between the Somma caldera and the Vesuvius summit cone is known as *Atrio del Cavallo* to the west and the *Valle dell'Inferno* to the north. Much of the activity of Vesuvius has been associated with the summit, with explosive activity from the summit crater and lava effusion from the base of the summit cone. Nevertheless, flank eruptions have also occurred, either forming lavas from fissures, or building cinder cones over effusive vents.

---

reproduction by means of expensive photocopying by library staff. It cannot be borrowed and has effectively been made unavailable to researchers outside the United Kingdom.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M. 2007. Lieutenant-Colonel Delmé-Radcliffe's report on the 1906 eruption of Vesuvius, Italy. *Journal of Volcanology and Geothermal Research* 166, 204-216.

Fig. 5.1: Location of Mount Vesuvius and its main settlements. (After Chester *et al*., 2007).

5.1.2 A summary of the volcanic history of Vesuvius

Observations of Vesuvius by literate observers stretch back to the classical era and one of the earliest references to an eruption of Vesuvius was by *Pliny the Younger*[26] in his two letters to Tacitus to the event of 79 A.D. The history of its activity over the last 2,000 years has been reconstructed by scholars over several centuries and in major research volumes; Giovanni Battista Alfano (1924) *Le eruzioni del Vesuvio fra il 79 e il 1631* and Giovanni Maria Della Torre (1755) *Storia e fenomeni del Vesuvio*, being particularly noteworthy. In addition many less comprehensive – though still useful – works date from both the pre-nineteenth century (e.g. Carafa, 1632; Mascolo, 1634; Varone, 1633; Paragello, 1705; Sorrentino, 1734; Serao, 1738; Mecatti, 1754, 1759; Della Torre, 1755, 1761; De Bottis, 1768; Hamilton, 1772, 1776, 1779 and 1795) and nineteenth and early twentieth centuries (e.g. Monticelli and Covelli,

---

[26] *Pliny the Younger* (62-115 A.D.), nephew of *Pliny the Elder* the admiral of the Roman Imperial Fleet, described the events of 79 A.D. in his letters to Tacitus, and states “On 24 August, in the early afternoon, my mother drew his [*Pliny the Elder's*] attention to a cloud of unusual size and appearance ..... It was not clear at that distance from which mountain the cloud was rising; its general appearance can best be expressed as being like an umbrella pine, for it rose to a great height on a sort of trunk and split into branches ..... Sometimes it looked white, sometimes blotched and dirty, according to the amount of soil and ashes it carried with it” (quoted in Smolenaars, 2005).

1823; Monticelli, 1841; Scacchi, 1850; Palmieri, 1859, 1862, 1865, 1870, 1874 and 1895; Johnston-Lavis, 1891; Matteucci, 1891; Baratta, 1897; Furchheim, 1897; Delmé-Radcliffe, 1906; Lacroix, 1906, 1908; Perret, 1924; Alfano and Friedlander, 1929; Imbò, 1951). More recently historical databases have been compiled from archival sources (e.g. Carta *et al*., 1981; Stothers and Rampino, 1983; Scandone *et al*., 1993; Lirer *et al*., 2005; Ricciardi, 2009) and archeomagnetic and paleomagnetic dating (e.g. Santacroce, 1987; Rolandi *et al*., 1998; Principe *et al*., 2004; Cioni *et al*., 2008; Siebert and Simkin, 2010). These studies have produced a vast literature on the physical characteristics of the eruptions from the classical era, but many have an absence of detailed information on the societal responses to them.

Historic activity of Vesuvius began with the plinian eruption of 79 A.D. Before this eruption Vesuvius was not generally recognised as an active volcano, though scholars including Strabo[27] had recognised a volcanic origin on the basis of the mountain's morphology (Scandone *et al*., 1993). The 79 A.D. eruption was the most explosive eruption of Vesuvius to have occurred in historical times (Guest *et al*., 2003). After 79 A.D. there are few records of activity until 472 A.D., the date of the next plinian eruption (Rolandi, *et al*., 2004), but – by using documents and archeomagnetic dating – Principe *et al*. (2004) have produced a chronology of eruptions from 79 A.D. to 1631. In the period up to the so-called *Pollena* eruption in 472 A.D., there was a major eruption in 203 A.D. and a number of minor events. From 787 A.D. a new style of activity began with mixed explosive and effusive eruptions, and a number of lava flows were produced which flowed to the coast (Fig. 5.2). This phase of activity ended with the 1139 eruption, after which there was a period of quiescence until the large sub-plinian eruption in 1631 (Rolandi *et al*., 1993).

The 1631 eruption was followed by a well documented phase of almost continuous activity that ended in 1944 (Scandone *et al*., 2008). This persistent activity took place at the summit crater and mostly involved strombolian activity. Eruptions that did occur involved lava either flowing over the crater or being erupted from fractures on the upper flanks of the volcano;

---

[27] Strabo (64 B.C. – 25 A.D.), an ancient Greek geographer, geophysicist and historian, provides the most accurate description of Vesuvius of his time, and states "above these places lies Mt. Vesuvius, which, save for its summit, has dwellings all round, on farm-lands that are absolutely beautiful. As for the summit, a considerable part of its flat, but all of it is unfruitful, and looks ash-coloured, and it shows pore-like cavities in masses of rocks that are soot-coloured on the surface, these masses of rock looking as though they had been eaten out by fire; and hence one might infer that in earlier times this district was on fire and had craters of fire, and then, because the fuel gave out, was quenched" (quoted in Scandone *et al*., 1993).

This text box is where the unabridged thesis included the following third party copyrighted material:

Guest, J.E., Cole, P., Duncan, A.M., Chester, D.K. 2003. Volcanoes of Southern Italy. Geological Society, London.

Fig. 5.2: Location and distribution of the historical lava flows on Mount Vesuvius. (From Guest *et al*., 2003).

most of these events were small, but some lavas reached the sea (i.e. 1805). Sometimes these eruptions were accompanied by explosions and fire fountains of lava (Carta *et al*., 1981; Arnò *et al*., 1987). In other cases effusion near the foot of the summit cone produced dome-like accumulations of lava (i.e. 1881/3, 1891/4 and 1895/9). Brief repose periods (i.e. 2-6 years) interrupted the persistent activity and 18 cycles of activity may be recognised (i.e. 1631-82, 1685-94, 1696-8, 1700-1707, 1712-37, 1742-61, 1764-7, 1770-79, 1783-94, 1799-1822, 1825-34, 1835-9, 1841-50, 1854-61, 1864-8, 1870-72, 1874-1906 and 1907-1944 (Alfano and Friedlander, 1929; Arnò *et al*., 1987; Kilburn and McGuire, 2001); ranging from 2 to 32 years. Cycles tended to terminate with what are somewhat confusingly termed *final eruptions*. Typically these *final eruptions* displayed a pattern, beginning with effusive activity and the outpouring of lava over the course of a few days. As the effusive activity waned, explosions at the summit increased and generated high eruption columns – typically 5-15 km height – together with fire fountains. Towards the end of this phase there was often evidence of phreatomagmatic activity, producing wet ash and pisolites[28]. The explosive

---

[28] *Pisolites* (accretionary lapilli) “are spherical or nearly spherical masses of indurated ash, ranging from a few millimetres to several centimetres in diameter. These form as moist aggregates of ash in eruption clouds and can result from rain falling through an eruption cloud” (quoted in Guest *et al*., 2003, pp. 247).

phase often led to collapse of part of the summit cone. *Final eruptions* of this type occurred in 1737, 1794, 1822, 1872, 1906, 1929 and 1944.

5.2 HUMAN RESPONSES TO THE ERUPTIONS OF VESUVIUS

Detailed studies on the responses and adjustments made by the inhabitants of Vesuvius to the threats posed by volcanic activity are limited; the effects of earlier events are poorly known compared to later ones (as found for Etna, see Chapter 4). Records became more complete from the beginning of the eighteenth century as a result of the establishment of the Volcano Observatory in 1841[29], which not only spurred observational science, but also stimulated preservation of relevant books and archives (e.g. *Annals Osservatorio Vesuviana*). These sources provide the majority of contemporary understanding of the early responses, but these often fail to detail the specific information on the individual, community and State-based responses. These are discussed in sections 5.2.1 and 5.2.2 in respect to the 1906 and 1944 eruptions.

5.2.1 The 1906 Eruption

From 1872 Vesuvius had been in a period of relatively continuous activity involving periodic effusion of lavas. The 1906 eruption lasted 18 days and was very destructive. It is probably the best documented volcanologically of any of the *final eruptions* that occurred in the period 1631-1944 (Johnston-Lavis, 1891; Delmé-Radcliffe, 1906; Lacroix, 1906, 1908; Mercalli, 1907; Perret, 1924). On April 4, 5 and 6, lava flows were erupted from several vents which opened at progressively lower altitudes on the south-eastern flank of the volcano (Fig. 5.1), with the first vent opening at 1200 m a.s.l. Lava effusion was associated with moderately explosive activity at the summit and this waxed-and-waned every few hours. The longest lava flowed *ca*. 5 km from the cone. On April 7 fire fountains reached a height of 3 km and lava devastated part of Boscotrecase (Fig. 5.1), with around 100 homes being destroyed in the suburb of Oratorio (Anon, 1906j – Fig. 5.1). Lava also entered the church of Santa Anna and eventually came to a halt on April 8 *ca*. 10 km from the cemetery at Torre Annunziata (Albatino, undated; Anon, 1906d – Fig. 5.1). The central crater was the site of explosive activity which increased early on April 8. At 12.30 a.m. there were strong explosions and an earthquake, and at 2.30 a.m. a violent earthquake and emission of ash covered the north-

---

[29] Founded in 1841 the *Osservatorio Vesuviana* is the oldest scientific institution in the world devoted to the study of volcanoes. Sited on a small hill about 300 m below the summit, it was protected from lavas and to some extent pyroclastic flows, but not from heavy ash falls. King Ferdinand II appointed Macedonni Melloni (1798-1854) as the first director.

eastern sector of the volcano with a considerable quantity of tephra (both ash and lapilli). The villages of Ottajano and San Giuseppe (Fig. 5.1) were both badly affected and tephra reached a thickness of 1.25 m, causing several buildings to collapse including a church roof at Ottajano (Anon, 1906e; Delmé-Radcliffe, 1906, pp. 3). After approximately 3.30 – 4.00 a.m. a sub-plinian ash column was generated and during the following afternoon reached a height of 13 km. This sub-plinian phase lasted 18 hours and eroded the walls of the crater, eventually leading to the collapse of the summit cone. Large volumes of ash were erupted which fell on many settlements in the region including the city of Naples, whilst heavy rainfall generated lahars causing extensive damage particularly in and around Ottajano. When the eruption ended, 216 people had been killed and 122 injured in San Giuseppe and Ottajano and 11 killed and 30 injured in Naples. An estimated 20 x 106 m^3 of lava had been produced. Vesuvius was reduced in height by 115 m and the new crater was 700 m across and 600 m deep.

5.2.1.1 *Traditional responses*

The *traditional* responses identified in the 1906 eruption are two-fold: those based on individual coping strategies and those based on complex religious rituals. Table 5.1 summarises the characteristics of these responses and though self-explanatory there are two points that need to be emphasized. First, the *folk* memory of previous eruptions in 1855, 1861 and 1872 was still alive in 1906, and this meant that older people had both the experience of hazardous events and the knowledge about how to deal with them. From the examination of newspapers of record and contemporary accounts it is clear that people knew the importance of not venturing outside their homes without protecting their heads, for example, people used umbrellas to protect themselves from ash fall (Anon, 1906c) and there is also a report that people tried to protect themselves in the streets with mattresses and blankets and even pots and pans (Avvisati *et al.*, 2006). In areas of tephra fall, many inhabitants cleared their roofs to prevent collapse (Anon, 1906f). It should be noted that the social memory mentioned here is not fully captured within the many of documentary records despite it being a principal component of the individual coping strategies, which have been shaped by previous knowledge, with those living on the flanks of the volcano in 1906 having retained greater behavioural knowledge from both individual and societal experience of events in 1855, 1862 and 1872. In the contemporary accounts unless responses were particularly noteworthy it is likely that these have not been captured in official records. These types of responses may have been recorded in more personal documents, such as diaries, but these are unlikely to have been held within centralised depositories. The collation of individual ‘*diffuse literature*’ would require specialised investigation to capture the full array of *traditional* responses noted briefly in this eruption.

In the 1906 eruption religious responses, which used the full expression of *popular Catholicism* as previously noted with respect to Etna (Chapter 4), were also evident. This included: intercessory prayer to the Madonna and local saints; processions of relics and sacred images and a predominant theology of divine wrath. Table 5.1 summarises the characteristics of these religious responses. Two additional quotations provide a ‘flavour’ of these responses, although it should be noted that both observers – particularly the first – are ‘outsiders’ and unsympathetic to a Southern-European popular Catholic culture.

“Beyond running away the utmost the people did to help themselves, was to carry about images of their saints in front of the lava in processions which largely consisted of women and girls, with their hair loosened, wailing and singing. This strikes the feminine spectator as very ‘touching’ and picturesque, but is really a pitiful exhibition of superstition, a mixture of vanity, and hysteria on the part of the women and indulgence and ignorance in the men. It is also deplorably unpractical.”

(Delmé-Radcliffe, 1906, pp. 5-6)

“The behaviour (*sic*) of these stricken folk was admirable, and a greater patience, resignation and ‘savoir faire’ could hardly been expected of any race.”

(Perret, 1924, pp. 48)

5.2.1.2 *State-sponsored responses*

The State hardly impinges on people living in *pre-industrial* societies and, even during times of eruption, the people of Vesuvius were no exception. There are relatively few accounts of the eruption of 1906, which reflect State involvement, but archival sources allow a few additional points to be made, particularly Delmé-Radcliffe’s report (1906) and these have been summarised in Table 5.1. First, there was the widespread use of troops and police to aid evacuation. There seems to have been no law and order issues, although there is one isolated instance of looting recorded when so-called ‘thieves’ were encountered in Bosco Trecase (Anon, 1906g), a point made more fully with respect to the 1944 eruption (see section 5.2.2). Secondly, Delmé-Radcliffe indicates that at the time a zone-based evacuation plan was drawn

Table 5.1: Examples of *traditional* coping mechanisms and State-based responses to the 1906 eruption.

Responses	Comments and Implications	Examples of actions
Individual, family and village		
Religion	Complex responses grounded within the beliefs and practices of Southern Italian *popular Catholicism* (see Chapter 4), which included: intercessory prayer to the Madonna and local saints (particularly San Gennaro[30]); processions of relics and sacred images and a predominant theology of divine wrath.	"*Inhabitants of small villages near crater are escaping and processions of villages carrying the Madonna and praying for a cessation of activity are passing through the neighbouring towns*" (Anon, 1906a) "*The entire population rushed to the streets in terror, many persons crying: 'The Madonna has forsaken us! The end of the world has come*" (Anon, 1906b) "*….. procession of San Gennaro ….. carried by a few chanting priests followed by some thousands of weeping women bearing candles*" (Anon, 1906j)
Coping strategies involving: families; support within villages	Despite sparse records the individual and community actions are suggestive of a long-standing tradition of behavioural response to eruptions.	"*Peasants at Portici cleared land of vineyards and trees 'in the effort to lessen the danger from fire and resisted the progress of the lava to their upmost*" (Anon, 1906d) "*Much spontaneous evacuation in: San Giorgio; Cremona, Portici, Resina and Torre dell'Greco. Inhabitants of Torre dell'Annunziata were prepares to leave at a moment's notice*" (Anon, 1906e)
State		
Solidarity with victims	Visits from the monarch and government officials reflect a greater awareness of the need for solidarity with victims of the event and for the State to be seen to be responding to the situation.	"*A visit of the royal family and Prime Minister have done much to quiet fear*" (Anon, 1906g)
Relief aid	Provision of monetary aid is	"*Camp kitchens established at a*

---

[30] The skull and two vials of the blood of San Januarius (San Gennaro), who was martyred in 305 A.D., were often appealed to by the inhabitants of Naples during eruptions of Vesuvius. For a more detailed discussion on the martyrdom of San Gennaro reference should be made to Chester *et al.* (2008).

including monetary support	limited, but provision of shelter and cooking facilities is generous.	*number of places and free meals provided*" (Anon, 1906g) "*A committee formed to collect funds and organize assistance for the relief of sufferers ….. government heads subscription list with donation of $100,000. Total amount to date $300,000*" (Anon, 1906g)
Logistics	The State provided the co-ordination of relief efforts through the supply of troops and police officers to maintain law and order and to help evacuation.	"*Transportation facilities sent to Torre del Greco and police and carabiniri are guarding abandoned buildings*" (Anon, 1906b) "*At Bosco Trecase soldiers dug wide ditches and embankments to divert the flow*" (Crawford, 1906) "*The Duke had engineers and soldiers erect parapets and dig ditches to try and change the course of the lava*" (Anon, 1906d)

up, but no detailed copy of this has been located by the present author and it is not mentioned subsequently. Finally, although monetary aid was limited (see Table 5.1), there was an acceptance of responsibility by the Italian State and this was seen not just in terms of the monetary aid given and careful collaboration with the Director of the *Reale Osservatorio Vesuvianna* – Professor Matteucci – but also in the expression of solidarity from central governments and the monarch who visited the areas (i.e. *comuni*) affected (Anon, 1906d; Anon 1906i; Avvisati *et al*., 2006).

5.2.2 The 1944 Eruption[31]

A period of repose followed the *final* eruption of 1906 which lasted until 1913. Persistent activity then followed (1913-1944), during which the crater of 1906 filled with lava, with occasional eruptions of moderate explosive activity occurring on the upper flanks (e.g. June 1929). By the start of 1944 a small cone had formed and the crater had filled, the cone collapsed

---

[31] March 1944 marked an active phase in the campaign by the Allies to capture southern Italy from the Axis forces in the Second World War (1939-1945), as such the lens through which the responses and activities of the State and individual are considered, are not necessarily those that would be common during other periods of activity. Individuals, communities and the State were already under considerable strain, with a lack of food, only recently re-established civil structures, disease, wartime destruction and lawlessness all serious issues. For a more detailed discussion on the socio-economic, political and military contexts of the region reference should be made to Chester *et al*., (2007b).

and filled the crater (March 13). The March 1944 eruption was the latest, but probably not the last, eruption of Vesuvius. It is transitional between a characteristic *pre-industrial* and a more typically *industrial* response. On March 18, 1944, Mount Vesuvius erupted (Santacroce, 1987; Abatino, 1989; Kilburn and McGuire, 2001; Guest *et al*., 2003). Late in the afternoon on March 18, (at about 4.30 p.m.) lava spilled over the crater rim forming two streams of lava, one headed towards San Sebastiano and Cappella Nuova, near to Torre del Greco, however the flow front ceased 3 km from the town (Anon, 1944a; Pesce and Rolandi, 1994 – Fig. 5.1), and the second entered the *Atrio del Cavallo* valley. Lava flowed through a notch in the caldera wall and entered a second valley, upon which it travelled towards the towns of San Sebastiano, Massa di Somma and Cercola (Chester *et al*., 2007b). These towns had already been destroyed by lava three times previously. By the early morning of March 21 (about 3.00 a.m.) the lavas reached San Sebastiano and Massa, destroying the bridge at 3.30 a.m.; travelling between 50 and 100 m h^{-1} (Chester *et al*., 2007b). A fire fountain was identified in the main crater by the late afternoon (about 5.00 p.m.), with a convective column reached a height of around 7,000 m at 5.30 p.m. (Anon, 1944a); in total eight episodes of between 18 to 40 minutes in duration of fire fountaining are recorded (Scandone *et al*., 1993), with the resulting tephras deposited to the south and east. On the afternoon of March 22 the first stream of lava threatened Camaldoli near Torre del Greco (Fig. 5.1) and the second approaching Cerola slowed and came to a stop. The final fire fountain at 7.30 a.m. on March 22 reached a height of 1,000 m (Marianelli *et al*., 1999). Violent explosive activity, a large eruptive column, electrical storm and seismic activity are recorded during the evening of March 22. The series of seismic events triggered a number of landslides on the flanks of the cone of Vesuvius and pre-1944 materials failed and generated avalanches (Hazlett *et al*., 1999). During this phase of the volcanic activity tephra became more of a hazard than the lava, with the worst affected towns being to the south-east; Terzigno, San Giuseppe and Poggiomarino (Fig. 5.1), with light tephra fall also recorded in Portici. The eruption ended on March 30 and in total some 35-40 x $10^6 m^3$ of magma had been erupted, in less than 12 days (Kilburn and McGuire 2001).

5.2.2.1 *Traditional responses*

The responses to the eruption in 1944 clearly evidence a high degree of *folk* memory within the population, with older members of the community able to re-call eruptions in 1872, 1906 and 1929. Elements of *traditional* responses could still be seen, as people recognized the importance of protecting their heads when leaving their homes and the need to clear tephra from roofs to prevent collapse (Chester *et al*., 2007b). This degree of *folk* memory may also explain why residents did not appear to panic, particularly when confronted with lava flows and their associated hazards. The use of structures capable of withstanding the greater strains presented by tephra accumulation within the communities of Terzigno and Poggiomarino (Fig. 5.1) are reflective of an Arab-influence, in contrast, the traditional building structures employed in the settlements of Pagani and Nocera (Fig. 5.1) were unable to withstand the extra burden of the tephra, resulting in roof collapse and 20 fatalities (Chester *et al.*, 2007b).

Religious responses practiced in 1944 featured elements of *popular Catholicism* which included well attended processions in San Giorgio, Ercolano, and Angri – near to Pompeii and San Sebastiano (Anon, 1944c; Bracker, 1944; Simonetti, 1983 – Fig. 5.1). Statues and other images of saintly figures were carried in procession in front of the flow, along with prayers asking for God's intercession, with a number of towns also holding services and communal prayers, including those led by Cardinal Ascalesi of Naples (Anon, 1944d).

5.2.2.2 *State-sponsored responses*

The volcanic ash emitted from Vesuvius during the eruption of 1944 resulted in the heavier loss of allied military aircraft than the Japanese had inflicted on the attack of Pearl Harbour (Chester and Duncan, 2009), with parts of several of the towns destroyed. The death toll however, was kept to a minimum as a result of the efforts of Allied personnel, and particularly of one individual, U.S. army officer, Lieutenant-Colonel (James) Leslie Kincaid, who co-ordinated the evacuation, organised relief efforts and assisted in rehousing and rebuilding affected communities. The response can be characterised as having four key features: clear scientific advice and field reconnaissance; the capacity to rapidly deploy large number of troops with clear command structures; early development of contingency plans permitting rapid responses to changing conditions; and aid provision.

Temporary headquarters were located near the metal bridge that connected the settlements of San Sebastiano and Massa di Somma, following the loss of the bridge on March 21 to the lava flow, Colonel Kincaid subsequently requisitioned the town hall (i.e. *Municipio*) in Cercola. The entire staff of the Allied Control Commission (*A.C.C.*) Provincial Headquarters were joined by a further 89 British and American officers (Bentley and Gregory, 1944) once it became clear that insufficient staff were available for an effective emergency operation to be undertaken. Scientific advice on the eruption was provided by the eminent Italian volcanologist Professor Giuseppe Imbò, Director of the then *Reale Osservatorio Vesuvianna.* Small detachments of soldiers and officials were distributed throughout affected regions, to provide regular updates back to the headquarters and to react to local needs. This organisational structure permitted the concentration of troops and resources on two occasions; on March 20 Kincaid guaranteed to provide transport to the inhabitants of San Sebastiano, Massa di Somma and Cercola should evacuation be required and provide food distribution centres for evacuees, with several operated by the American Red Cross. A number of telegrams in the British archives from the Chief Commissioner of the *A.C.C.* Lt. Gen. Sir (Frank) Noel Mason-Macfarlane to his superiors on the progress of the eruption and the civil defence measures being put in place, but also the development of a contingency plan to evacuate refugees to Sicily by rail and sea should the eruption become more serious (see Chester *et al.*, 2007). Should an evacuation operation have been required it would have placed a severe strain on Allied capabilities and on Colonel Kincaid's command. Despite the destruction of two-thirds of San Sebastiano, between 1,500 and 1,800 people were safely removed, with slightly fewer than 2,000 evacuated from Massa di Somma and around 7,000 from Cercola (Chester *et al*., 2007), with the majority of evacuees accommodated with families and friends in nearby villages.

The greatest damage from the eruption occurred in the settlements of Poggiomarino, San Giuseppe and Terzigno, with tephra drifts, some of which were more than a metre deep, covering most fields. This resulted in acute food shortages with the *A.C.C.* importing food into the area for some 20,000 people, with green vegetables and animal fodder locally unavailable (Bentley and Gregory, 1944, pp. 23). Food was imported through the recently restored port at Naples and along the *autostrada*, with distribution undertaken by relief organisations distributed throughout the *communes*. Poggiomarino airfield was abandoned and restored to agricultural practice. A number of financial and medical support schemes were provided to settlements, particularly on the north-western flank of the volcano. Building surveys were undertaken by the Italian civilian authorities, who classified buildings in terms of whether they should be demolished, repaired or re-occupied, with tents provided for the homeless (Pesce *et al*., 1994). The funicular (i.e. cable car) which had previously carried tourists to the summit of Vesuvius was sold by the Thomas Cook Company to *Circumvesuvian Railway* who subsequently re-opened it.[32]

---

[32] In 1953 the funicular was replaced by a chair-lift, which now no longer operates. The rack railway proved to be unprofitable and closed in 1955 (Abatino, 1989).

5.3 CONCLUSIONS

The main conclusion of this Chapter is methodological: the historically-based approach which was successful on Etna (see Chapter 4), did not work as well for Vesuvius, in spite of the strong cultural affinities between the two regions. This point is addressed in more detail in Chapter 7, which concludes the thesis. Research on the 1906 eruption was hampered by a lack of materials available internationally to the present author, and whilst *pre-industrial* responses were evident in 1944 and were clearly well established, little documentary evidence was identified for 1906. It should be noted that the lack of material available to the present author for the pre-1906 materials may be in part due to some source materials being located in locations undetermined yet within the local region. It is clear, however, from the available contemporary and near-contemporary accounts that responses to the 1906 eruption featured predominately *pre-industrial* ways of coping, however the absence of detailed individual and societal responses to the event, present a challenge within the framework of the methodologies used in this Chapter. In contrast, the 1944 eruption is well documented and shows a successful more *industrial* response under difficult circumstances, though elements of the *pre-industrial* remained in evidence.

In considering Vesuvius within the framework of this thesis, there are clear challenges to applying an historically-based methodology (see Chapter 3), where there is limited information on individual, family and extended family responses and, indeed, when accounts of State aid are also spares. This case study highlights the need for greater knowledge of the responses of society and individuals to eruptions and requires an interrogation of the more '*diffuse literature'*. In particular further research requires interrogation of: local sources held within the *comuni* affected; provincial government archives in Naples and at the *Osservatorio Vesuvianna*.

Chapter 6

THE ISLANDS OF SÃO MIGUEL AND FAIAL (THE AZORES, PORTUGAL)

The focus of this chapter is three-fold: firstly, to identify and summarise the volcano and volcano-related hazards that have occurred in the Azores, in particular on the islands of São Miguel and Faial; secondly to define and summarise the particularities of *vulnerability* and *resilience* in the context of the physical threats faced by the inhabitants of São Miguel and Faial and relate this to the cultural and economic characteristics of the islands; and thirdly to identify areas of *vulnerability* which require further research so that emergency planning may be improved.

6.1 INTRODUCTION: THE HAZARDOUS AZORES

The Azores archipelago is located astride the triple junction between the Eurasian, Nubian and North American tectonic plates (Guest *et al.*, 1999; Fernandes *et al.*, 2006 - Fig 6.1). The islands stretch across 1,450 km of ocean in the North Atlantic, the area of the Azores is characterised by three main tectonic features (Guest *et al.*, 1999; Martins *et al.*, 2012):-

1. The Mid-Atlantic Ridge (MAR) crosses the archipelago between the islands of Faial and Flores (Kurase and Watkins, 1970; Steinmetz *et al.*, 1976; Madeira and Ribeiro, 1990; Guest *et al.*, 1999; Fernandes *et al.*, 2006). The ridge trends 10^{o} to the north of latitude 35^{o}50’ N and between 10^{o} and 20^{o} to the south (Searle, 1980).
2. The East Azores Fracture Zone constitutes the Eurasian-Nubian plate boundary and extends broadly east-west from the MAR to Gibraltar (Kurase and Watkins, 1970).
3. The Terceira Rift extends from the island of Santa Maria northwest to the MAR (Machado, 1959; Vogt and Jung, 2004).

For the Azores Platform (Needham and Francheteau, 1974; Lourençeau *et al.*, 1998), the boundary between the American and Eurasian plates is well-established. However, the location and nature of the eastern branch of the Azores triple junction is still controversial (Madeira and Ribeiro, 1990; Lourcenço *et al.*, 1998; Madeira, 1998).

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Dibben, C., Coutinho, R., 1995. Report on the Evacuation of the Furnas District, São Miguel, Azores. Image Centre University College, University of London, Open File Report, CEC Environment/ESP Laboratory Volcano Furnas Azores.

Fig. 6.1: General location of the Azores. The islands of São Miguel and Faial are shown in bold. (Modified from Chester *et al*., 1995).

There is a degree of uncertainty about when humans first became established in the Azores. It is argued in some sources that maps such as the Angelino Dulcert of 1339 A.D. and the Mediceu atlas of 1351 A.D. showed the Azores before the official discovery by the Portuguese in 1427 (Chapin, 1898). The initial settlement of the islands, led by Gonçalo Velho Cabral, occurred on Santa Maria Island (Chapin, 1989). The rapid settlement of the islands resulted in an estimated population of *ca*. 100,000 by 1640 (Chapin 1989). After the settlement of Santa Maria, São Miguel and Terceira were settled in *ca*. 1439. Reports suggest that population numbers on São Miguel doubled between 1592 and 1640 (Chapin, 1989). Faial, also known as the ‘garden of Portugal’ was first settled in 1466, attracting immigrants from both mainland Portugal and Flanders in the period up to the nineteenth century (Callender and Henshall, 1968; Costa, 2008). Emigration to Brazil from the Azores may be traced back to the seventeenth century, however, mass migration dates from the middle of the nineteenth century and acted as a ‘safety-valve’ whereby population pressure was relieved by emigration first to Brazil and later to the U.S.A. (Ávila and Mendoça, 2008).

The climate and geology of the Azores generates a number of hazards, either operating on their own or in combination (Table 6.1). The warm marine current arriving from the Gulf of Mexico, produces mild, wet, conditions with little variability in temperature throughout the year, which coupled with the presence of the *Azores Anticyclone* (Azevedo, 2002), produces a warm temperate climate across the Azores. The variability in the weather over daily to weekly time scales, reflecting changes in both the intensity and position of the anticyclone and frontal systems. Ponta Delgada, the capital and principal settlement of São Miguel, houses the only meteorological station on the island (World Meteorological number 08513 – Fig. 6.2) with a comprehensive record from 1865 to present. A meteorological station can also be found at Horta on Faial (World Meteorological number 08506: height 62 m – Fig. 6.3). The station at Horta can be considered as representative of conditions over the whole island, with the exception of areas near the island's summit caldera (height 917 m). In contrast the climate of São Miguel varies spatially, dependent on height and location. A full discussion of climate and hydrology on São Miguel and Faial is beyond the scope of this chapter, but the essential features are:

a. There is no single prevailing wind direction, with winds possible from all directions throughout the year;

b. Winds from the east, southeast and south are less common than from other directions;

c. During winter winds from the northwest, west and south are less common than in other seasons;

d. During summer (i.e. May to September), winds are light and calm conditions, are common especially in July and August;

e. Gales are common in winter; and,

f. Due to light pressure gradients and the considerable relief amplitude between the interior and coast of São Miguel, *katabatic* (i.e. “drainage”) winds are common on winter nights.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Dibben, C., Coutinho, R., Duncan, A.M., Cole, P.D., Guest, J.E., Baxter, P.J., 1999a. Human adjustments and social vulnerability to volcanic hazards: The case of Furnas Volcano, São Miguel, Açores. In: Firth, C.R., McGuire, W.J. (Eds.), Volcanoes in the Quaternary. London, Geological Society of London Special Publication 161, pp. 189-207.

Fig 6.2: Location of São Miguel and the main settlements. (Modified from: Chester *et al*., 1999a).

Table 6.1: Geological hazards of the Azores region: major hazardous events from 1400 to present. Locations are shown in Fig 6.1. (Based on information from: Weston, 1964; Forjaz and Machado, 1968; Silveira *et al*., 2003; Marques *et al*., 2005, 2006, 2008; Andrade *et al*., 2006; Gaspar *et al*., 2007; Coutinho *et al*., 2008; Calado *et al*., 2011).

Geological Hazards	Examples	
Volcanoes	a. **São Miguel**	*ca*. 1439 (Furnas), 1563 (Fogo) - 2 killed, 1630 (Furnas) - up to 259 killed and 1652. Offshore eruptions occurred in 1638, 1682, 1713, 1720, 1811, 1907, 1911 and 1981;
	b. **Terceira**	1761 (Santa Bárbara). Offshore eruptions occurred in 1800, 1867, 1902, 1998;
	c. **São Jorge**	1580 (Pico Queimados) - caused some deaths, 1808 (Urzelina) - more than 30 killed. Offshore eruption occurred in 1718;
	d. **Pico**	1562 (Pico), 1718 (Pico) and 1720 (Pico). Offshore eruption occurred in 1718;
	e. **Faial**	1672/3 (Cabeço do Fogo and Picarito) - 3 killed and 1957/8 (Capelinhos). Offshore eruption occurred in 1963.
Tectonic-earthquakes	a. **São Miguel**	1522 - 3-5,000 killed,1591 - many killed, 1638, 1656, 1713, 1810, 1811, 1848, 1852 - 9 killed, 1932, 1935 - 1 person killed, 1952;
	b. **Terceira**	1547, 1571, 1591, 1614 - more than 200 killed, 1698, 1800, 1801, 1808, 1841, 1980 - 54 killed;
	c. **São Jorge**	1641, 1757 - more than 1,200 killed, 1797, 1964, 1980;
	d. **Pico**	1964, 1973;
	e. **Faial**	1647, 1672, 1690, 1759/60, 1808, 1862/3, 1871, 1872, 1890, 1892/4, 1896, 1898, 1915, 1917, 1920, 1924, 1926 - 20 killed, 1946, 1958, 1973, 1998 - 8 killed;
	f. **Graciosa**	1730, 1787, 1817, 1837 and 1980.
Landslides	a. **São Miguel**	1522, 1630, 1918, 1919, 1920, 1924, 1925, 1926, 1928, 1932, 1933, 1934, 1938, 1939, 1942, 1946, 1948, 1949, 1952, 1968, 1969, 1980, 1981, 1982, 1983, 1985, 1986, 1996, 1997 - more than 30 killed, 1998, 2001, 2002 and 2005.
Tsunamis	a. **São Miguel**	1571, 1591, 1969, 1975;
	b. **Terceira**	1614, 1676, 1691, 1755 - 6 killed, 1757, 1761, 1855, 1939, 1941, 1980;
	c. **São Jorge**	1641, 1668, 1792, 1856, 1899;
	d. **Pico**	1757, 1926, 1931, 1969;
	e. **Faial**	1757;
	f. **Graciosa**	1847 - more than 10 killed.
Floods	a. **São Miguel**	1744 - more than 65 killed, 1896 - caused some deaths, 1901, 1986 and 1996;
	b. **Terceira**	1588, 1608;
	c. **São Jorge**	1588, 1606 and 1713.

The average temperature at Ponta Delgada (1894-1970) ranges from 17°C in January to 25°C in August (British Admiralty, 1992), similarly the average temperature at Horta (1901-1970) ranges from 17°C in February to 26°C in August (British Admiralty, 1992). Precipitation rates on the islands are high and precipitation can occur in any seasons; with no dry months. Figures for Ponta Delgada show an annual average of *ca*. 911 mm, with some 68% falling between October and March inclusive. In contrast, precipitation figures for Horta show an annual average of *ca*. 1,213 mm. Heavy precipitation events are predominately rainfall, but some hail and even snow can occur at high altitudes in winter (Stieglitz, 1990).

This text box is where the unabridged thesis included the following third party copyrighted material:

Coutinho, R., Chester, D.K., Wallenstein, N., Duncan, A.M. 2010. Responses to, and the short and long-term impacts of the 1957/1958 Capelinhos volcanic eruption and associated earthquake activity on Faial, Azores. *Journal of Volcanology and Geothermal Research* 196, 265-280.

Fig 6.3: Location of Faial and the main settlements. (Modified from: Coutinho *et al*., 2010).

Geologically, São Miguel is located in a tectonically active region, with the Terceira Rift, which runs from the MAR through Terceira to the Gloria Fault, crossing the western part of the island (Fig 6.1). It comprises three quiescent central trachytic volcanoes with summit calderas (Sete Cidades Volcano, Fogo Volcano and Furnas Volcano – Fig 6.2), linked by zones of fissure-based volcanism (Picos Fissure-Based Volcanic System and Congro Fissure-Based Volcanic System). The eastern part of the island is older and considered inactive, and includes the Povoação Volcanic Complex and the Nordeste Volcanic Complex. Five eruptions have occurred on land since the settlement of the island in the mid-fifteenth century: two at Fogo in 1563 (Wallenstein *et al.*, 1998); one in the so-called ‘waist’ region between Sete Cidades and Fogo in 1652 – when a cinder cone to the west of Fogo was produced – (Booth *et al.*, 1978) and two at Furnas in 1439/43 (Queiroz *et al.*, 1995) and 1630 A.D. (Da Purificação, 1880; Corrêa, 1924; Dias, 1936; Cole *et al.*, 1995).

Furnas is the most easterly of the three active central volcanoes on São Miguel (Zbyszewski, 1961; Booth *et al.*, 1978, 1983; Moore, 1991a, 1991b). It is truncated by a caldera complex with steep walls, and the formation of these calderas is probably associated with major explosive ignimbrite eruptions. Outside the caldera complex, on the volcano’s flanks, 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, on the southern flank a N-S trending fracture, a possible NW-SE fracture system and E-W fracture system. Of the two historic eruptions at Furnas (Table 6.1), the first is recorded to have taken place at the time of the original settlement of the island and the most recent eruption (i.e. 1630) has been well documented in contemporary and near-contemporary accounts (see Cole et al., 1999; Corrêa, 1924; Dias, 1936; Cole *et al.*, 1995). For a more detailed discussion on the history of its activity reference should be made to Guest *et al.* (1999).

Fogo (also known as Água de Pau in some of the older literature) is the largest of the three active central volcanoes on São Miguel and dominates the centre of the island (Fig 6.2). With a complex morphology the volcano rises to almost 1,000 m and a summit caldera has formed as a result of numerous collapses and explosions, the most recent occurring during the sub-plinian eruption of 1563 A.D. and the phreatomagmatic 1564 A.D. event (Table 6.1). Higher levels on the volcano have been heavily dissected by fluvial systems and on the southern flank deep valleys reach the coast. The northern flank has been down-faulted by the Ribeira Grande graben system, which trends in a north north-west/south south-east direction (Moore, 1990; Wallenstein *et al.*, 2005, 2007). Fogo began to form more than 200 ka years ago, but older products are poorly exposed. A more complete stratigraphy, based on exposures on the southern flank, has been established for the last 40,000 years and three trachytic plinian eruptions have been recognised: Roída da Praia (*ca.* 15,000); Ribeira Chã (*ca.* 8-12,000) and Fogo A (*ca.* 4,600) (Wallenstein, 1999).

Sete Cidades has been the most active of the three central volcanoes on São Miguel, although it has not erupted historically (Table 6.1). There have been at least three major caldera forming events in the last *ca.* 36,000 years (i.e. *ca.* 36,000 – Risco; *ca.* 29,000 – Bretanha;

and *ca*. 16,000 – Santa Barbara), with the caldera currently containing two lakes. Queiroz (2008) identified 17 intra-caldera eruptions and in addition there have been five offshore eruptions (Table 6.1). For a more detailed discussion on the history of its activity over the last 5,000 years reference should be made to Queiroz (1998) and (2008).

In contrast, the volcanic history of Faial is not so complex, and comprises activity at the principal edifice (now represented by the caldera), some peripheral activity and the Capelinhos eruption of 1957/8. Capelinhos lies on the most westerly tip of the island, at the end of a rift zone. The Capelinhos eruption is the second of the two historic basaltic eruptions to have affected Faial, and was characterised by surtseyan and strombolian activity (Machado *et al*., 1959; Zbyszewski and Ferreira, 1959; Machado *et al*., 1962). The first was the 1672/3 Cabeço do Fogo eruption that occurred on the fissure system which extends west northwest from the central caldera (Coutinho *et al*., 2008 - Table 6.1). In addition to volcanism, Faial is seismically active and significant earthquakes have frequently occurred (Table 6.1).

6.2 HAZARD VULNERABILITY AND RESILIENCE IN THE AZORES

The method used for the analysis of *vulnerability* and *resilience* is detailed in Chapter 3. In this chapter, the five *vulnerability* typologies are tailored to the specific vulnerabilities of the Azores in general, and São Miguel and Faial in particular. These are presented in Table 6.2. It should be noted that within this study *resilience* is considered as an embedded aspect of the specific features of *vulnerability* that are identified within the typologies of human *vulnerability* identified on São Miguel and Faial.

6.3 CATEGORIES OF HAZARD VULNERABILITY ON SÃO MIGUEL AND FAIAL

6.3.1 Locational vulnerability

On São Miguel and Faial *locational vulnerability* are features of: their size and position; the distribution of their populations and settlements and the characteristics of their evacuation plans.

6.3.1.1 *Size and Position*

In common with other island communities, one feature of pre-existing *vulnerability* on São Miguel and Faial is their position, with the islands stretching across 1,450 km of ocean (Fig

Table 6.2: Typology of human vulnerability to volcano and volcano-related hazards on São Miguel and Faial.

Type of vulnerability	Characteristics on São Miguel and Faial
Locational (section 6.3.1)	Size, position, population distribution/settlement and the characteristics of evacuation plans
Building (section 6.3.2)	Housing quality
Demographic and economic (section 6.3.3)	Detailed demographic characteristics of the population at risk: their economic status; demographic structure and dependent cohorts within the population. Implication for emergency planning and leadership
Social and cultural (section 6.3.4)	The social structure and cultural *milieu* of the people at risk
Behavioural (section 6.3.5)	Accurate and inaccurate perceptions of risk
Educational and informational (section 6.3.6)	The lack of accurate information and ineffective information diffusion.

6.1)[33] and being located c. 900 km from metropolitan Portugal. Faial is also vulnerable because of its small size (173 km^2), with there being limited scope for intra-island evacuation in the event of a major emergency (see section 6.3.1.3). In fact, the effects of the relatively small 1957/8 hydromagmatic Capelinhos eruption presented the limit of what could be handled within Faial. The eruption of Capelinhos was located on the far western coast of Faial (Fig. 6.3), almost as far distant as possible from Horta, the island's capital, yet the Civil Governor (Dr António de Freitas Pimentel) was making contingency plans for seaborne evacuation should the eruption have taken a more severe course. He had identified possible ships and destinations (Coutinho *et al.*, 2010). At the time of the crisis the island did not have an airport and only seaborne links to metropolitan Portugal and other islands in the archipelago would have been possible. Today, seaborne evacuation may still be required depending upon whether or not ash causes the closure of the airport, a factor which would depend to a degree on eruption magnitude and prevailing winds. Similar considerations might apply to the airport at Ponta Delgada on São Miguel, if an external evacuation was required.

In comparison with Faial, Chester *et al.* (1995) have predicted that on São Miguel, in the event of an eruption with a similar magnitude to that of 1630, it is highly probable that the

---

[33] The Azores were important in the early stages of transatlantic aviation. In the late 1930s, Pan-American Clippers (using Boeing 314 seaplanes) called at Horta (Faial), a service rendered obsolete after the Second World War by the availability of long-distance piston-engined aircraft (Coutinho *et al.*, 2010).

inhabitants of the *Furnas area* could be accommodated within the island, though a survey of accommodation – both temporary and semi-permanent – would have to be undertaken (Guest *et al*., 1994; Chester *et al*., 1995). It should be noted that in this study *areas* comprise those *concelhos* (i.e. county or municipality) and *freguesias* (i.e. parishes) that are likely to be affected by the most probable future volcanic eruptions/volcano-related events. There is a more remote possibility, however, that a higher magnitude eruption could occur. Guest *et al*., (1994) have argued that the so-called Furnas '*C*' eruption, which occurred *ca*. 1,900 years ago, was probably the highest magnitude event to have arisen at the Furnas centre during the past 5,000 years. It represents, for that reason, a possible worst case scenario and would require a much more extensive evacuation, probably involving the removal of inhabitants to other islands or to the Portuguese mainland, at least on a temporary basis.

6.3.1.2 Distribution of population and settlement

The most recent fully published census (2001), identified that the resident population of São Miguel was 131,530 (INEP, 2002) and by early 2011 had risen to 137,830 (SREA, 2011b)[34]. About 9% of the population lives in the *Sete Cidades area*, 43% in the *Fogo area* and 19% in the *Furnas area*, some 71% of the total (Fig. 6.4). Throughout the twentieth century São Miguel has maintained its position as home for some *ca*. 50% of Azoreans, but has nonetheless lost over a quarter of its inhabitants since 1960 (see section 6.3.3.1). In contrast at the time of the 2001 census the resident population of Faial was recorded as 15,063 (INEP, 2002) and by early 2011 had fallen to 14,994 (SREA, 2011b). Faial is a single *concelho* administrated from Horta, which is sub-divided into 13 *freguesias*: Capelo; Castelo; Branco; Cedros; Feteira; Flamengos; Angústias; Conceição; Matriz; Pedro Miguel; Praia do Almoxarife; Praia do Notre; Ribeirinha and Salão (Fig. 6.5). The overall population distribution on São Miguel and Faial shows two general characteristics:-

1. The interior of the islands are mountainous and populations are concentrated near to the coast, with Sete Cidades, Covoada, Arrifes, Fajã de Cima, Fajã de Baixo[35], Pico da Pedra (Ribeira Grande *concelho*), Cabouco, Santa Bárbara (Ribeira Grande *concelho*), Furnas and Nossa Senhora dos Remédios, being the only inland settlements of importance (Fig. 6.4).

---

[34] The most recent census was held in March 2011. In between censuses the *Serviço Regional de Estatística dos Açores*, provide estimates of the population resident in each *concelho*, for various years since 2001, the latest data being for December 2008 (SREA, 2011b). At the time of writing provisional data from the 2011 census is available, however, some socio-economic statistics and housing numbers have not yet been published.

[35] Covoada, Arrifes, Fajã de Cima and Fajã de Baixo are suburbs of Ponta Delgada.

2. Populations are focused around the islands principal settlements, Ponta Delgada and Horta. Ponta Delgada contains 15% of the island's inhabitants in the four *freguesias*, which represent the capital in official statistics. This figure is doubled if adjacent commuter settlements are included and rise to 48% if the whole *concelho* is taken into account (INEP, 2002; SREA, 2007). The three *freguesias* which constitute Horta contain 41% of the population of Faial in official statistics.

The overall distribution of settlement is highly fortuitous, as much of the land in the three volcanic *areas* is rural with many *freguesias* having low population densities; with many *freguesias* in the north-east and east of the Furnas and Fogo *areas* containing less than 100 people per km^2. In the Sete Cidades *area* figures are only slightly higher and range from *ca.* 72 to *ca.* 171 people per km^2. The low population densities represent a major impediment to successful evacuation in many volcanic regions, as it may be difficult to locate people in a disaster. On São Miguel the high proportion of the population located within the principal settlements (*povoação sede de freguesia*) of each parish means that this is less of a problem. Detailed maps (1: 25,000 scale), aerial photographs, and field data identify how isolated some farms and houses are. In the event of a planned evacuation these would require special attention.

Despite infrequent eruptions on São Miguel (Table 6.1) settlements continue to remain at considerable risk from volcano-related hazards. Intense rainfall, high drainage densities, steep relief and a generally warm temperate climate together with its volcanic character contribute to a number of natural hazards. A number of landslides and slope failures have occurred over the past few decades that have resulted in damage and loss of life. For example, on October 31 1997 after a long period of heavy rainfall, around 1,000 small landslides occurred in Povoação *concelho* (São Miguel), two of these were responsible for 29 fatalities, 114 residents being left homeless predominately in the village of Ribeira Quente (Fig 6.4 - Gaspar *et al*., 1997; Cole *et al*., 1999; Wallenstein *et al*., 2005; Malheiro, 2006; Marques *et al*., 2008). For over 12 hours Ribeira Quente was cut off from the rest of the island with total economic losses estimated at over €20 million (Cunha, 2003). Following these losses Marques *et al*., (2008) studied the historical records for Povoação *concelho* and examined rainfall intensity (mm/day) against rainfall duration (D days), showing that intensity increases exponentially as duration decreases. Historical data indicate that landslides are related to both: short duration (1-3 days) precipitation events, with high mean intensities of between 9 and 22 mm/day(s), rainfall regimes with these characteristics are

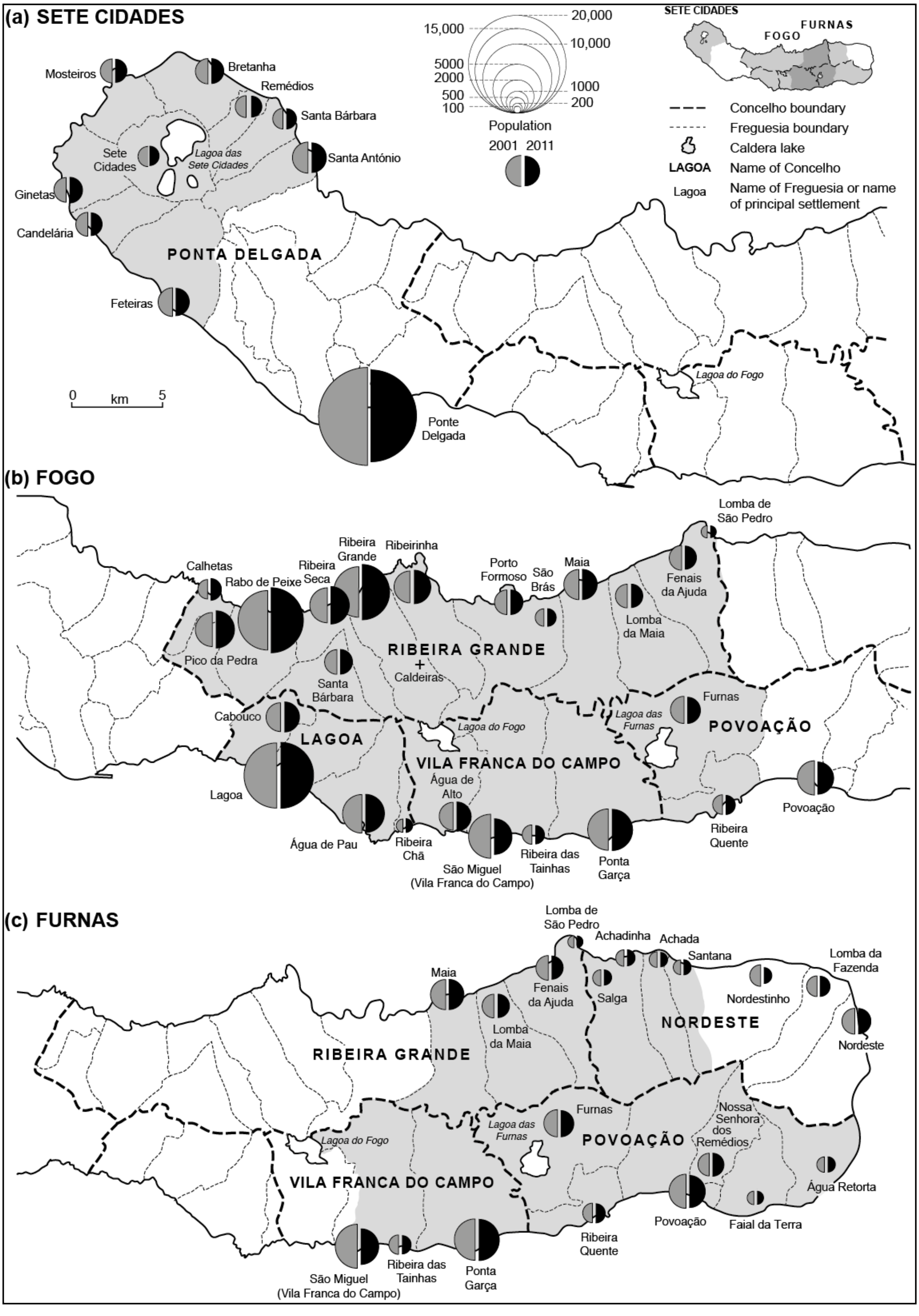

Fig 6.4: The limits of the Sete Cidades, Fogo and Furnas *Areas*. The figures also show population for each *freguesia* based on the 2001 and provisional 2011 census data. The three maps are based on: Gomes *et al*., 2006 - Sete Cidades; Wallenstein *et al*., 2005 - Fogo and Chester *et al*., 1999 - Furnas. It should be noted that in July 2002 Bretanha *freguesia* was sub-divided into two new parishes: Ajuda da Bretanha and Pilar da Bretanha. Because most statistical data relate to the pre-2002 boundaries, the sub-division is not recognised in this figure. The population total for Ponta Delgada includes the four *freguesias* (i.e. Matriz, São José, São Pedro and Santa Clara) which are recognised in official statistics (INEP, 2002), together with adjacent commuter settlements.

common between October and March. Some 85% of historic landslides occurred between October and March between 1918 and 2002 in Povoação *concelho*, with 40 instances being classified as ‘minor’ (Marques *et al.*, 2008, pp. 484). Seismic activity may also trigger landslides; for example over 46,000 earthquakes occurred in the Fogo *area* between May and December, around 180 were felt by residents near to the epicentre. The strongest shocks occurred on September 20 and 21 with a magnitude (M_L) of 4.1 and 4.3 respectively, causing extensive slope failure in central São Miguel triggering more than 250 landslides (Marques *et al.*, 2007).

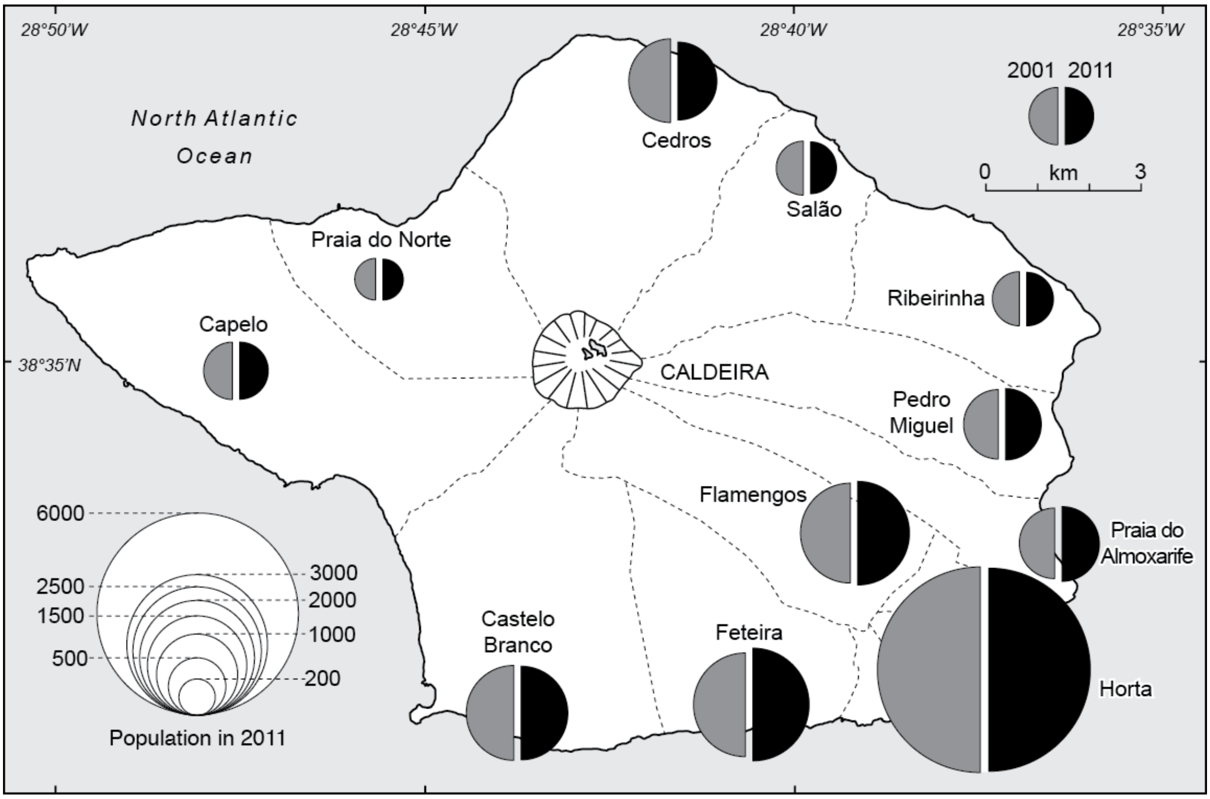

Fig 6.5: *Freguesias* of Faial. The figure also shows population numbers for each *freguesia* based on the 2001 and provisional 2011 census data. The population total for Horta includes the three *freguesias* (i.e. Angústias, Conceição and Matriz) which are often combined for statistical purposes.

6.3.1.3 *Evacuation plans*

Coastal settlements on São Miguel are connected by the main roads, which are often located close to the coast (Fig. 6.4), the subsidiary roads connecting to some inland settlements are highly vulnerable. Examples can be seen at Furnas and Sete Cidades villages, which are located within active calderas. These would require early evacuation if an eruption threatened. Isolated coastal settlements, such as Ribeira Quente (Fig. 6.4 and Table 6.3) are also particularly at risk as the road network utilizes the steep-sided and narrow valleys which are at risk from flooding and/or temporary damming, which would destroy the road, making early evacuation essential if major loss of life were to be avoided (Chester *et al*., 1995). Similar comments apply to the small village of Praia, located 1 km to the west of Água de Alto (Fig. 6.4), where the draining of the Lagoa do Fogo through the south flowing Ribeira da Praia would produce similar widespread destruction.

Research undertaken on Furnas (Chester *et al*., 1995, 1999; Duncan *et al*., 1999) and Fogo (Wallenstein, 1999; Wallenstein *et al*., 2005, 2007; Table 6.6 and Fig. 6.4) volcanoes detailed the roads that could be used should an evacuation of the *areas* be required. These studies highlighted two further areas of human *vulnerability* (many of which also apply to Sete Cidades):-

1. The risk of landslides and debris flows leaves many evacuation roads highly vulnerable. Landslides have the potential to seriously restrict capacity and/or destroy large stretches of road. On Fogo there are particular problems on the northern and southern coast roads (En 1-1[a]) and at certain points on En 2-1[a], which links Furnas village to the north coast (Fig. 6.6). Fogo is located in the centre of São Miguel (Fig. 6.2) and both the northern and southern coastal routes would be cut by even a small eruption, a landslide, an episode of heavy rainfall or an earthquake, so isolating the population living in the *freguesias* of the *Fogo Area* (i.e. in excess of 45,000 people), together with those living to the east in the *concelhos* of Nordeste and Povoação (*ca*. 10,000 people). To avoid this eventuality, evacuation would have to begin before the main phase of the eruption.
2. Masonry bridges present a particular *vulnerability*, together with a relatively high proportion of *rubble-stone* buildings in many towns. These structural features are highly susceptible to earthquake damage and may block access routes severely hampering evacuation (see section 6.3.2). Disruption to the northern and southern coastal roads in the *Furnas* and *Sete Cidades Areas*, could isolate many communities. On Sete Cidades, the *freguesias* of Bretanha, Mosteiros and Ginetes are particularly vulnerable and involve a possible *ca*. 4,000 people, whereas in the *Furnas area* and to its east affected *freguesias* could include Salga, Achadinha, Achada, Santana, Nordestinho, Lomba da Fazenda, Nordeste, Água Retorta, Faial da Terra, Nossa Senhora dos Remédios and Povoação and *ca*. 9,600 people would be affected (Fig. 6.2 and 6.4).

In 2007 work began on a new programme of high speed roads on São Miguel (Fig. 6.6). Known by the acronym SCUTS (*Estradas sem custos para utilzador*, or roads without charge to the user), this programme involves private finance of 325 million Euros and is funded from general taxation over a 30-year period (Anon, 2010d). The new roads were all fully open by the end of 2011, during the final months of construction the present author contributed to the most recent road survey assessing their *vulnerability* to hazards. The *vulnerability* of the *Fogo* and *Furnas areas* has been reduced by SCUTS as several towns (e.g. Água de Pau, Água de Alto and Vila Franca do Campo), are now bypassed. At Ribeira Grande a major 'bottle neck' which could have impacted on evacuation was removed, whilst the stream flowing through the town has effectively been bridged. The Ribeira Grande to São Brãs and the São Brás to Lomba da Fazenda roads on the north of the island, and the Lagoa to Vila Franca do Campo road in the south opened towards the close of the construction period. It is only with time that an assessment will be able to be made on whether these new roads increase or decrease the *vulnerability* and *resilience* of communities in the event of an eruption. The new roads provide a higher standard and faster travel times (e.g. from Ribeira Grande to Nordeste being cut by some 45 minutes - Anon, 2010d) and have been built further inland, at greater heights, using modern engineering practices. These new structures provide greater capacity for accommodating floods, landslides and laharic activity. Several of the new roads however, supplement existing routes and therefore may still contain vulnerable sites (e.g. São Bras to Nordeste – Table 6.6). This may produce new features of *vulnerability* that may include:-

1. Poor weather, particularly fog, higher rainfall and strong winds at high altitudes particularly in winter.
2. The new routes are closer to the Furnas and Fogo calderas and during an eruption could carry a higher ash loading than may be the case with existing roads.
3. The vulnerability of access points from the existing road system to the new roads is not clear.

In time a new road survey will be required and revised evacuation plans will have to be published.

Faial is a small island (see section 6.3.1.1) and there is not the same pressing need for a road survey because evacuation on foot would be possible in many emergencies, nonetheless following the destructive earthquake in 1998 a full hazard assessment of roads was undertaken by Professor Rui Coutinho (1999) of *Universidade dos Açores* (University of the Azores) and with his permission this detailed survey, together with some additions by the present author is included in Appendix 5. The principal points of the survey are:-

1. Major roads are usually located at lower altitudes and there is not the same potential for landslides as is the case on São Miguel.
2. Many valleys are bridged with masonry bridges, which pre-date seismic coding and could be 'weak' under conditions of ground shaking. A more detailed investigation is required.
3. Traditional *rubble-stone* walls adjacent to some roads could be weak and fail under earthquake/landslide conditions. Again a more detailed survey is required. These roads could be blocked with rubble following an earthquake or landslide, not only impeding escape by the residents in the immediate vicinity, but also blocking evacuation routes that serve more distant settlements.
4. Minor streams are unlikely to be a problem unless they are blocked by sediment, when under conditions of high rainfall temporary dams being formed so inducing flooding.
5. 'Gathering' points and airborne evacuation sites have been made identified.

This text box is where the unabridged thesis included the following third party copyrighted material:

Wallenstein, N., Chester, D.K., Duncan, A.M. 2005. Methodological implications of volcanic hazard evaluation and risk assessment: Fogo Volcano, São Miguel, Azores. *Zeitschrift für Geomorphologie Suppl.* 140, 129-149.

Fig 6.6: The principal roads on São Miguel: A. Before the improvements carried out under the SCUTS Programme 2007-12; and B. Roads constructed under the SCUTS Programme. (Modified from Wallenstein *et al.* 2005).

Table 6.3: Site characteristics of the principal settlements of the *Fogo Area*, and issues raised by the survey of roads (after Wallenstein *et al*., 2005 and updated by data collected in the field). Areas are defined by *freguesias* (Fig 6.4) and population data are taken from the 2001 census (INEP, 2002), updates where possible by the estimates provided by *Serviço Regional de Estistí dos Açores* (SREA, 2011a). This table should be read in conjunction with Fig 6.6.

This text box is where the unabridged thesis included the following third party copyrighted material:

Wallenstein, N., Chester, D.K., Duncan, A.M. 2005. Methodological implications of volcanic hazard evaluation and risk assessment: Fogo Volcano, São Miguel, Azores. *Zeitschrift für Geomorphologie Suppl.* 140, 129-149.

This text box is where the unabridged thesis included the following third party copyrighted material:

Wallenstein, N., Chester, D.K., Duncan, A.M. 2005. Methodological implications of volcanic hazard evaluation and risk assessment: Fogo Volcano, São Miguel, Azores. *Zeitschrift für Geomorphologie Suppl.* 140, 129-149.

6.3.2 Building vulnerability

Housing on São Miguel is vulnerable to high losses during seismic events and tephra-fall. Ten major earthquakes have affected the island since its settlement (i.e. 1522, 1638, 1713, 1810, 1811, 1848, 1852, 1932, 1935 and 1952), coupled with several episodes of seismic swarms associated with volcanic activity. Gomes *et al*. (2005) classified housing according to its vulnerability, examining the *freguesias* within the *concelho* of Ponta Delgada, which lie on the flanks or within the caldera of Sete Cidades using a scheme developed in collaboration with the European Macroseismic Scale (Grünthal, 1998). The classification identified the buildings at most risk from earthquakes (Classes A and B) which were constructed from *rubble-stone* and *simple-stone* (Table 6.4).[36] Prior to 1970s most dwellings were constructed of local materials, principally *rubble-stone*, with many buildings of two storeys in height, though many have subsequently been improved and strengthened with reinforced slabs and columns. Since the 1970s most buildings have been constructed using reinforced concrete frames and/or un-reinforced concrete blocks. Despite estimates that buildings in the Furnas *area* still consist of 80% old *rubble-stone* form (Pomonis *et al*., 1999), official data indicates that in Povoação and Lagoa *concelhos*, 41% of houses were built before 1971 and *ca*. 40% in Ponta Delgada *concelho* (INEP, 2002, pp. 18). Gomes *et al*, (2005) concluded that some 76% and 17% of houses belonged, respectively, to *vulnerability* Classes A and B. On Faial some 508 *rubble-stone* buildings were damaged and 273 destroyed during the two-day volcano-tectonic swarm in May 1958 associated with the Capelinhos volcanic eruption (Coutinho *et al*., 2008, 2010). In the *freguesias* of Praia do Notre and Ribeira do Cabo and the smaller settlements of Areeiro, Cruzerio (near Capelo) and Espalhafatos (Fig. 6.3), it is

---

[36] The European Macroseismic Scale (*EMS*) has classified building *vulnerability* into six classes (Classes A to F) based on the type of structure. In this classification Class A is the most vulnerable and Class F is the least (Grünthal, 1998).

estimated that some 1,037 homes were either destroyed or badly damaged, and 3,023 people rendered homeless (Lobão, 2008, pp. 50; Rosa and Pereira, 2008). Using the *European Macroseismic Scale* (*EMS*), Gomes *et al*. (2005) demonstrated that the maximum historic intensity reached on Sete Cidades volcano on São Miguel was IX and that this took place during the offshore eruptions of 1713 and 1811. Traditional housing is vulnerable to events with an *EMS* of IX or greater, and would cause between 57% and 77% of dwellings in the Sete Cidades *area* to be badly damaged or destroyed, currently representing between 2,480 and 3,350 homes.

The *vulnerability* of buildings on São Miguel to seismic activity and volcanic ash fall is known in some detail (e.g. Chester *et al*., 1999a; Pomonis *et al*., 1999; Gomes *et al*., 2005; Martins *et al*., 2012), however, in recent years much progress has also been made in researching building *vulnerability* on Faial. In order to mark the 200th anniversary of the Lisbon earthquake a symposium was held in 1955 and found that Portuguese buildings were highly vulnerable to earthquake losses and that a more comprehensive building code was urgently needed (Ordem dos Engenheiros, 1955). A code was published in 1958, which was both too late to have had an impact on hazard losses on Faial during the seismic crisis associated with Capelinhos and generally viewed to have been ineffective (Azevedo *et al*., 2009, pp. 561-562). In the 1980s revision of building codes dominated hazard planning (Oliveira and Pais, 1995), but the tectonic earthquake of 1980, which affected the islands of Graciosa, São Jorge and Terceira (Fig. 6.1), killed 60 people and rendered *ca*. 22,000 people homeless, highlighted a major problem with this approach. Whereas reinforced concrete buildings constructed to the most recent earthquake codes performed well, *ca*. 90% of traditional *rubble-stone* buildings were damaged (Carvalho, 1980; Degg and Doornkamp, 1994). A new code was introduced in 1983 (RSA, 1983). On July 9 1998 an earthquake, with an epicentre located 10 km off the northeast coast of Faial and having a Mercalli Intensity of 5-6, killed 8 people, injured 150, rendered 1,500 people homeless and damaged many buildings (Senos *et al*., 1998; Matias *et al*., 2007; Coutinho *et al*., 2008 – Fig. 6.7). It affected the whole island but caused widespread destruction in the *freguesias* of Salão, Ribeirinha, Flamengos and Pedro Miguel (Fig. 6.5). In fact, Melo (2008) concluded that public investment on housing alone amounted to 245 million Euros (*ca*. 360 million US dollars), with a further 16 million Euros (*ca*. 24 million US dollars) being spent on temporary pre- fabricated dwellings and *ca*. 42 million Euros (*ca*. 62 million US dollars) on the repair, reconstruction and/or rehabilitation of the health, education, communications and industrial infrastructure. One particular problem highlighted by the emergencies of 1957/8 and 1998 is what David Alexander has termed *residual un-ameliorated vulnerability*[37] (Alexander, 1997). In a detailed survey of 3,950 buildings affected by the 1998 tectonic-earthquake – known as '*Auto de Vistoria*' (i.e. reconnaissance survey), prepared by the *Regional Laboratory for Civil Engineering* in Ponta Delgada (São Miguel) and implemented by the *Centre for Reconstruction* (*CPR*) – a high proportion of traditional *rubble-stone* buildings were shown to be damaged. As argued above, in the Azores the principal cause for concern is not the relatively newly constructed structures, but houses and other heritage buildings that were erected before there were effective codes.

This text box is where the unabridged thesis included the following third party copyrighted material:

Centro de Vulcanologia e Avaliação de Riscos Geológicos (*CVARG*)

Fig 6.7: The church of São Mateus do Ribeirinha in the *freguesia* of Ribeirinha (Faial) partially collapsed due to the major earthquake in 1998. (copyright *Centro de Vulcanologia e Avaliação de Riscos Geológicos* (*CVARG*).

Pomonis *et al*. (1999) identified an additional feature of physical *vulnerability*. Even a small eruption would produce extensive tephra deposition and could affect towns and villages downwind of eruption sites, especially if phreatomagmatic activity featured in such an event. Higher magnitude eruptions would cause more extensive damage. In the villages examined by Pomonis *et al*. (1999) - Furnas, Ribeira Quente, Povoação and Ponta Garça (Fig. 6.4) - *ca*.

---

[37] *Residual un-ameliorated vulnerability* includes pre-code buildings and un-reinforced historical structures which are extremely vulnerable to seismic events and to a lesser extent volcanic eruptions.

Table 6.4: Examples of residential building types on São Miguel and Faial. (Based on information from: Grünthal, 1998; Pomonis *et al.*, 1999; Costa, 2002; Oliveira, 2003; Proença, 2012; Costa *et al*., 2012; Neves *et al*., 2012; Oliveira *et al*., 2012).

Type of structure	Characteristics
Traditional *rubble-stone*	Traditional construction in which stones are used as the basic building material, with poor quality mortar, typically up to two storeys in height. Floors are typically wooden, and provide no horizontal stiffening. Traditional *rubble-stone* buildings on São Miguel and Faial are extremely vulnerable to earthquake shaking, because they lack resistance to horizontal motions.
Traditional *simple-stone*	Traditional construction similar to *rubble-stone*, however, s*imple-stone* differs from *rubble-stone* because the building stones have undergone some dressing before use. These hewn stones are arranged in the construction of the buildings according to some techniques to improve the strength of the structure (i.e. using larger stones to tie in the walls at the corners).
Un-reinforced concrete blocks	Common construction introduced in the 1950s, in which concrete blocks are also used as the basic building material. Common as second-floor additions to traditional *rubble-stone* constructions. In recent construction concrete blocks are mixed with fine volcanic materials. Floors are typically wooden, and provide no horizontal stiffening. From the 1970s buildings on São Miguel and Faial have usually been constructed using reinforced concrete frames or un-reinforced concrete blocks.
Un-reinforced concrete blocks with reinforced concrete floors	Common construction similar in appearance to the traditional *rubble* and *simple-stone* structures, however, the floors are typically of reinforced concrete slabs, and provide some resistance to horizontal motions.
Reinforced concrete frames	Common construction in recent times on São Miguel and Faial, in which beams and columns are used in conjunction with beam-column joints to provide resistance to horizontal and vertical motions. *Vulnerability* of these structures is influenced by both the quality of construction and level of maintenance.

18% of buildings had roofs that were in poor condition and, hence, highly vulnerable to collapse as a result of tephra accumulation. More recently important research has been published on strengthening traditional Portuguese buildings generally (Pomonis *et al*., 1999; Oliveira, 2003; Murphey-Corella, 2009; Neves *et al*., 2012; see also Spence, 2007, Table 7, pp. 187) and Azorean housing in particular (Costa, 2002). Costa and Arede (2006) point out that *resilience* could be greatly improved by relatively simple measures including, *inter alia*: reinforcing walls and roofs by connecting structural elements together so as to improve rigidity; and ensuring that roofs are not only in good condition but also firmly connected to the walls.

6.3.3 Demographic and economic vulnerability

6.3.3.1 *Demographic vulnerability*

The characteristics of the population of the Azores in general and São Miguel and Faial in particular have been studied by many scholars (e.g. British Admiralty, 1945; Trindade, 1976; Bryson, 1988; Chapin, 1989; Fortuna, 1988; de Dilva, 1988/9; Rocha, 1988/9, 1990; SREA, 1993; INEP, 2002 – Table 6.5). Episodes of harsh economic conditions are a recurrent theme in the history of the Azores and from the eighteenth to the twentieth century's, emigration first to Brazil and later predominantly to the U.S.A., exerted a major influence on demography (Callender and Henshall, 1968; Williams, 1982). From the 1920s the population of the Azores increased rapidly due to the restriction placed on immigration by the United States government. By the 1950s it was estimated that there were some 250,000 people of Azorean origin living in the U.S.A., who were concentrated in New England and California, whereas at that time the population of the Azores was 318,449 (Callender and Henshall, 1968, pp.19; SREA, 1993). From 1960 emigration started to increase again to North America - especially to Canada - whilst changes in United States legislation in 1965 (i.e. the *Hart-Celler Act*[38]) ended the system of immigration quotas and further liberalized immigration policy. These long-term trends in population are reflected in the evolution of population in the Azores since 1900 (Table 6.5). Out-migration from the Azores in the nineteenth century kept population numbers around *ca*. 250,000 (British Admiralty, 1945), but by 1960 and the closure of the 'safety-valve' of out-migration, this had increased to an all-time high of over 327,000.

---

[38] The *Hart-Celler Act* 1965 (Public Law 89-236) ended the system of immigration quotas and replaced it with a preference system that focused on immigrants' skills and family relationships with citizens or residents of the United States.

Over the past fifty years the principal demographic characteristics of São Miguel have been out-migration to mainland Portugal and abroad, together with internal migration and commuting to the principal settlements of the island, particularly Ponta Delgada (Trindade, 1976; Williams, 1982; Fortuna, 1988; de Silvia, 1988/9; Rocha, 1988/9, 1990). In recent years out-migration has been less significant and the island's population increased by *ca*. 4% between 1991 and 2001 (INEP, 2002) and *ca*. 2% between 2001 and 2011, showing an annual rate of natural increase of 0.33% in 2009 compared to an average for the Azores of 0.24% (SREA, 2007, 2010, 2011b). Migrations have often been linked to natural disasters on the Azores (Dibben *et al*., 1999), however the relationship is not deterministic. For instance, after the 1957/8 Capelinhos eruption on Faial, 4,811 refugees emigrated to the United States under the *Azorean Refugee Act*[39] of 1958 (Williams, 1982). The *Azorean Refugee Act* allowed 1,500 families affected by the eruption and earthquake to enter the United States, in addition to those allowed entry under the *Immigration and Naturalization Act* of 1952. Under this act migrants needed a minimal education, no criminal record, a successful medical examination and a sponsor in the United States who was prepared to take financial responsibility for the first five years of an immigrant's life in the U.S.A. (Rogers, 2007, pp. 91; Silva, 2008). Costa (1998) studied the out-migration and demonstrated that although the three *freguesias* of Horta lost 14% of their population, in contrast the figures for more rural areas some of which received little damage in the emergency, were usually much higher (e.g. Capelo - 41%; Cedros - 25%; Pedro Miguel - 21%; Ribeirinha - 21%; Salão - 20% and Castelo Branco - 18%). It is argued by Costa (2008) that these data are strongly suggestive that many emigrants were in fact not *sinistrados* (i.e. victims) of the emergency, but economic migrants who made use of the legislation to re-settle in the U.S.A.[40] (Coutinho *et al*., 2010). After the 1980 earthquake in the Azores, a similar disaster related migration was apparent. There was an increase in migration from the island of Terceira in 1980 but in the following years the rate returned to the pre-1980 figure (Dibben *et al*., 1999). The indications are that disasters seem to facilitate rather than cause migration.

---

[39] The *Azorean Refugee Act 1958* is also known as the *Pastore-Kennedy-Walter Act* or just the *Pastore-Kennedy Act* (Public Law 85-892). The act under which an additional 500 visas were issued is the *Azorean Refugee Act* 1960 (Public Law 86-648). It is difficult to estimate how many people left Faial under the act and how many left later, because the 1958 Act also applied to the Dutch immigrants from Indonesia.

[40] The majority of migrants joined existing communities either in California (Chapin, 1989) - especially in and around San Jose, or on the East coast - where the principal communities are located in Massachusetts, Rhode Island, New Jersey, New York, Connecticut and Florida (de Sá, 2008a). The largest number of post-Capelinhos immigrants went to either New Bedford and Fall River in Massachusetts or to California (de Sá, 2008b).

Table 6.5: Population change on São Miguel and Faial since 1900. (Based on information from: SREA 1993, 2003, 2011b)

	1900	1950	1960	1970	1981	1991	2001	2011
AZORES	256,673	318,449	327,446	289,096	243,410	237,795	240,565	246,746
S. Miguel	122,169	165,156	168,687	151,454	131,908	125,951	131,530	137,830
(% of the Azores total)	(48)	(52)	(52)	(52)	(54)	(53)	(55)	(56)
Faial	22,075	23,923	20,281	17,068	15,489	14,920	15,063	14,994
(% of the Azores total)	(9)	(8)	(6)	(6)	(6)	(6)	(6)	(6)

Long-term features of out-migration and an historic lack of full-employment[41] are still present within the islands demographic profile, while internal migration and commuting is continuing. This means that in the late 1990s (Chester *et al*., 1999a) *dependency ratios* (i.e. % of the population under 15, plus % over 65) across the *Furnas area* ranged from 38-46%, and the proportion of the population classified as economically active was never greater than 36% in any *freguesia*. In addition older people were illiterate and rates exceeding 15% of the population occurred in 11 of the 15 *freguesias* that comprise the *Furnas area*. It was concluded by Chester *et al*. (1995) that, as a result of these long-standing demographic characteristics, a high proportion of the population would require assistance, especially in following instructions should an eruption-related emergency be declared.[42] More recent data show that high dependency, low levels of economic activity and poor educational attainment remain features of the islands demography. For instance in 2001 *dependency ratios* for the *concelhos* that comprise São Miguel ranged from 33% in Ponta Delgada to 43% in Ribeira Grande, the economically active population varied from 36% in Povoação to 44% in Ponta Delgada, while illiteracy was still 16% in Vila Franca do Campo and 7% in Ponta Delgada (INEP, 2002). In comparison in 2011 *dependency ratios* for the *concelhos* that comprise Faial ranged from 29% in Feteira to 31% in Horta (SREA, 2011b).

One feature of the population statistics for the Azores is that the *Serviço Regional de Estatítica dos Açores* (SREA) and the *Instituto de Estatítica de Portugal* publish data at different levels of detail. Data at the most detailed level of sub-division (i.e. the *freguesia*)

---

[41] In recent years employment opportunities in the Azores have been better than in Portugal as a whole. Data for 2009 show 9.5% unemployment in Portugal and 6.7% in the islands (SREA, 2010b). For the third quarter of 2011 figures were 12.4% for Portugal and 11.6% for the Azores (SREA, 2011c).

[42] Before the 1974 Portuguese Revolution many people did not receive even an elementary education.

are derived from the census. Although the *Serviço Regional de Estatítica dos Açores* has a policy of updating some sets of data and estimating others between censuses (see SREA, 2006, 2007, 2010a, 2011a, 2011b), statistics are only available for municipalities (i.e. *concelhos*) and in some cases for the whole of São Miguel. Another feature of demographic *vulnerability* identified by Chester *et al*. (1995), which is not captured by official statistics, is the transient nature of much of São Miguel and Faial's population. A census can only give a snapshot of population on a specific day, traditionally in Portugal in March or April in the first year of the decade, and as Chester *et al*. (1995) have shown in field surveys, many houses are often only occupied at weekends and/or in the summer. Hence the number of people who would have to be evacuated on, say, a Saturday in August would be far greater than on a weekday in January. Tourist numbers also vary over the year and, because data are only published on an individual island basis (SREA, 1993) and many people do not lodge in hotels, but with friends and in camp sites, it is not possible to specify just how many people are likely to require evacuation at different times of the year. For example, the number of nights spent on São Miguel by tourists more than tripled between 1993 and 2003 and reached a figure of over 70,000 in 2010 of whom *ca*. 40% were ordinarily resident of other areas of Portugal, with some 39% visiting in July, August and September (SREA, 2006a, 2006b, 2007, 2010, 2011c). In 2009 just over 5,200 people could be accommodated in hotels and other lodgings on any given night suggesting a total annual capacity of *ca*. nearly 2 million rooms, assuming each visitor only stayed one night. The average stay was, however, 3.5 nights and average occupancy only 37.5% implying that there are many visitors to the island who are effectively 'lost' from the official record (SREA, 2010a). From a hazard management perspective it is important to know:

1. where the excess population is accommodated; and
2. how many visitors are true tourists and, conversely, how many are expatriates returning to family homes that are either vacant or under-occupied for most of the year.

If civil protection and evacuation planning are to be effective, then a detailed study of this transient population is required.

6.3.3.2 *Economic vulnerability*

Spatially limited hazards (e.g. landslides, flooding and low intensity seismic activity), have economic impacts which often constrained to a small number of *freguesias*. Any major or moderate scale future eruption(s) could have severe impacts on the economies of São Miguel and Faial, leading to the closure of many enterprises and a period of widespread unemployment. Outside assistance from the Portuguese government and/or the European Union would be required. There is one major change, nevertheless, that has occurred in the economy of São Miguel and Faial in recent decades which had produced an important new area of *vulnerability*.

In the 1950s the economy of Portugal was comparable of other semi-industrialised nations of southern Europe and Latin America with: per capita incomes below $300 (US); low labour productivity; a pre-dominance of unskilled, often illiterate workers; a large proportion of the labour force employed in agriculture and other primary activities; and technological backwardness (Baklanoff, 1992). Policies advanced by the Portuguese government focused on maintaining a balanced budget, with limited investment and a degree of caution towards foreign creditors meant that rates of growth in *Gross Domestic Product* (*GDP*) were low in comparison with other western European countries, averaging *ca*. 1% per annum between 1934 and 1947 and just over 2% between 1948 and 1958 (Lains, 2003). In 2009 agriculture and fishing accounted for just under 13% of total employment (SREA, 2010b), a reduction from the 1970s when nearly 40% of the islands population worked in these sectors. The economic history of the islands has been dominated by the rise and fall of specific cash crops (i.e. tea, tobacco, bananas, lemons, oranges, pineapples, sugar cane, woad and archil). Dependence on a few major cash crops meant that when a number of diseases and pests invaded the islands in the mid-nineteenth century the economy was devastated. These diseases included: in 1835 the *Aspidiota conchiformis* bug which was imported from America and attacked the orange tree, in 1850 the potato rut affected the islanders stable diet and in 1853 the fungus *Oidium tuckeri* attacked the grape vine (Walker, 1886; Williams, 1982). Decline in agriculture employment has not been the only change in the economy of the Azores and over the past thirty years there has been a reduction in traditional subsistence agriculture and the production of export crops, and a rapid increase in cattle rearing (e.g. with a tripling of cattle between 1980 (36,000) and 1999 (108,000) – Langworthy, 1987; INEP, 2001). Some *freguesias* on São Miguel contain more cattle than people, with many cattle in the three volcanic *areas* this can have major implications for emergency planning (Langworthy, 1987; Bryson, 1988; INEP, 2001). On Faial cattle numbers are particularly high in the *concelhos*: Cedros, Salão and Ribeirinha (north coast); Castelo Branco and Feteira (south coast); and Pedro Miguel and Flamengos (east coast). Cattle (living and dead) in a volcanic emergency can block roads and hamper evacuation.

6.3.4 Social and cultural vulnerability

Previous studies examining hazard exposure on Furnas and Fogo volcanoes (Chester *et al*., 1995, 1999, 2002; Wallenstein *et al*., 2005), have shown aspects of social and cultural *vulnerability*. Comprehensive programmes of education developed since the 1974 revolution[43] coupled with inter-marriage have improved social mobility, but social-stratification is still recognisable (Williams, 1982; Chester *et al*., 1995). The people of São Miguel can normally be associated to one of four social groups (i.e. *Trabalhadores* (workers); *Proprietários* (proprietors); Established educated; New entrepreneurs), identified in the 1980s by research undertaken by the sociologist Francis Chapin (Chapin, 1989).

Two points emerge concerning hazard-based emergency planning. Firstly, social structure has important implications for emergency management. Initially disaster management planners should consider two particular societal groups for assistance when planning an evacuation; *proprietários* and members of the *established educated* (especially government officials, local doctors and school teachers), who often possess established leadership roles within the communities, in addition to elected officials (Chapin, 1989; Chester *et al*., 1995). Secondly, illiteracy is an issue, as is the strong attachment of *trabalhadores* (workers) to their property and land, with many potentially not following evacuation orders; these features are more evident in the rural areas, especially within the three volcanic *areas* on São Miguel. Prior experience in other volcanic areas has identified that attachment to land (i.e. place), property and, farming activities may prevent evacuation (Perry *et al*., 1979; Nolan, 1979; Blong, 1984, pp. 149-150; Chester *et al*., 1993, pp. 297-300) with greater success in evacuation occurring when whole families rather than individual members are moved. This behaviour reflects both social and cultural *vulnerability* and is discussed in section 6.3.5.

6.3.5 Behavioural vulnerability

Several factors affect an individual's susceptibility to risk (e.g. association with place, livelihood, practices and resources). Cannon (1994) also determined that an individual's susceptibility is influenced by the ability for self-protection, physiological *resilience* (e.g. age and psychological make-up) and perception of risk (Crosweller and Wilmshurts, 2013).

---

[43] Before 1974 the system of Government in Portugal was known as the *Estado Novo* (i.e. New State). This regime ruled Portugal for over forty years, being initiated in 1928 and continued until it was overthrown by the *Portuguese Revolution* of 1974. For a more detailed discussion on the policies and characteristics of the *Estado Novo* reference should be made to: Gallagher, (1981); Wheeler, (1981); Baklanoff, (1992); Birmingham, (1993); Pinto, (1995); Anderson, (2000); Lewis, (2002); Cairo, (2006) and Coutinho *et al*., (2010).

Christopher Dibben (1999) examined these features in the context of Furnas volcano through the use of in-depth interviews, in addition interviews were conducted with the Civil Defence authorities, local government officials and people affected by previous earthquakes. Five themes were covered by the interviews:

1. length of residence and reasons for moving to the village;
2. the respondent's attitude to the social and physical character of the village;
3. perceptions of volcanic and other hazards;
4. disaster preparation and
5. attitudes to measures for the mitigation of risks.

These interviews identify that 'issue of attachment to place' are important when discussed within the context of economic, social and cultural *vulnerabilities* (Dibben, 1999; Dibben and Chester, 1999). Place attachment is defined in the literature as the interaction of emotion, perception and practice in a local environment (Low and Altman, 1992), and often reflects stable long-term bonds between people their homes and communities (Fried, 1963; Cochrane, 1987; Rivlin, 1987; Dibben and Chester, 1999). Several of the inhabitants of Furnas recognised that the village was both a fine place to live and a potentially very dangerous one. The belief in two mutually incompatible explanations, or holding one view but acting in opposition is often termed *parallel practice* and this has been discussed in detail in Chapter 4.

Responses to the interviews by Christopher Dibben (1999) illustrated further aspects of *vulnerability*, which include:-

1. No residents had prepared themselves for a future eruption, either mentally or physically, even though they generally knew that the volcano was active (Dibben and Chester, 1999).
2. Many people felt they would have no warning and did not know to whom to turn for advice.
3. Many believed they had no control over future events (i.e. hazards being '*Acts of* God').
4. Little or no evidence of economic or social marginalisation (i.e. all socio/economic groups being equally ill-informed).
5. Risk of CO_2 seepage into buildings and the broader health-related risks posed by volcanic gases (Baxter *et al.*, 1999, 2005) are poorly understood. There is a significant lung cancer risk to those who live in CO_2 exposed buildings (i.e. those that live in houses that are in zones of high seepage, with floors that readily allow seepage and have poor ventilation), or whose employment involved working in hollows or cellars. Small children are particularly vulnerable because of their limited height and patterns of play.

The Furnas attitude survey was undertaken over a decade ago and needs to be repeated and expanded to include other villages to assess behavioural features and how they may influence *vulnerability*.

6.3.6 Educational and informational vulnerability

A considerable body of research has been undertaken on a wide range of natural hazards across the Azores. Particular attention has been given to reconstructing volcano and volcano related hazards (e.g. earthquakes caused by magma movement - Silveira *et al*., 2003; Wallenstein *et al*., 2005, 2007; Gomes *et al*., 2006) and providing these within the context of future risks. These may occur before or during a volcanic events, whilst others render São Miguel dangerous even when its volcanoes are not erupting (Malheiro, 2006; Wallenstein *et al*., 2007). A number of these hazards have been examined, including:-

a. climatic and geomorphological hazards, particularly flooding and landslides (Louvat and Alleger, 1998; Chester *et al*., 1999a; Duncan *et al*., 1999; Valadão *et al*., 2002; Gomes *et al*., 2005; Marques *et al*., 2005, 2006, 2007, 2008; Wallenstein *et al*., 2005, 2007).

b. Tsunamis generated by earthquakes and/or collapses into the Atlantic Ocean (Andrade *et al*., 2006).

c. Health impacts on the population, especially CO_2 seepage into dwellings (Baxter *et al*., 1999, 2005; Hansell *et al*., 2006; Viveiros *et al*., 2009, 2010).

Human *vulnerability* has also been studied and research has concentrated not only on detailing the threats faced by the population of São Miguel, but also on how people would cope in the event of a future eruption or volcano-related emergency (Dibben, 1999; Dibben and Chester, 1999 - section 6.3.5). It is clear that several aspects of *vulnerability* that have been identified have to be taken into account if civil defence policies are to be successful. In order to investigate disaster preparation on São Miguel three in-depth interviews were undertaken by the present author. It should be noted that for reasons of confidentiality the names and offices held by the respondents remain confidential, all are scientifically trained to doctoral level and all have been involved in earth science research, civil defence as “responders” and in the development of policy at a senior level. They are listed in Appendix 6 as respondents 1 - 3.

Educational and policy priorities have now become more focused on providing suitable leadership, reliable information and confidence to those living on the three volcanoes. Respondent 2 identified the move towards the provision of greater engagement with school children by bringing them to the *Centro de Vulcanologia e Avaliação de Riscos Geológicos (CVARG*), where they view the seismic network. The flow of hazard information from the Civil Protection Authorities (*Serviço Regional de Protecção Civil e Bombeiros dos Açores - SRPCBA*) to *concelhos* and *freguesias* has been greatly improved with clearer routes of dialogue between scientists and non-scientists. The scientific capacity of *CVARG* has been improved, providing dynamic hazard scenarios and scientific support for the *SRPCBA*.

Responses to the interviews illustrated further aspects of *vulnerability*. Risk communication on small islands where most, if not all, of the population may live within range of a potential hazard and where the only 'safe-area' may be off island, is particularly important; an issue identified by McGuire *et al*. (2009). Solana *et al*. (2008) identified that the potential for poor communication is especially high at volcanoes that have not erupted for several generations. The media have a critical role to play during an emergency. To help educate the media, *CVARG* provide training courses on the history of the volcanoes, their activity and style of eruption and monitoring methods and specialised terminology used (respondent 1). Effective communication between scientists, officials and the public can make the difference between a successful and unsuccessful response (McGuire *et al*., 2009). In the Azores, administrative responsibility for civil protection functions as a cascade. Minor and localized problems are dealt with within the individual *freguesia* larger-scale problems are successively the responsibility of: the *concelho*; the Azores Autonomous Region and a minister within the national government. Each *freguesia* is responsible for its own emergency plan (respondent 2 and 3).

6.4 CONCLUSIONS: MOVING FORWARD

In summary the major findings in the assessment of *vulnerability* and *resilience* on São Miguel and Faial are that the inhabitants of the islands are exposed to volcanic and volcano-related hazards in the following ways:-

1. Locational (see section 6.3.1). There is significant locational *vulnerability* because of isolation. This is expressed as both the isolation of the islands, which are located some 900 km from the Portuguese mainland and, with respect to Faial, the fact that any eruption with a higher magnitude than the 1957/8 event would require inter-island evacuation.
2. Buildings (see section 6.3.2). The exposure of buildings is a classic example of *residual un-ameliorated vulnerability* and is the major threat to the people of the Azores.

3. Demographic (see sections 6.3.3). Significant exposure occurs because of two circumstances. First on both islands, particularly on São Miguel, there is an issue of isolated settlement and the difficulties posed for evacuation. Secondly, much relevant demographic information is not captured in official figures. This relates, *inter-alia*, to expatriate Azoreans who return to family homes at holiday times and the growing number of tourists who have no disaster experience. More detailed study is required into these transient population cohorts.
4. Cultural (i.e. social, educational, behavioural - see sections 6.3.4, 6.3.5, 6.3.6). Major issues relate to: illiteracy (of the aged population), a problem that is being reduced with the passage of time; high dependency ratios and attachment to place, farm and pedigree livestock.

As evidenced throughout this chapter, *resilience* is both embedded in the social and cultural responses to volcano and volcano-related hazards and within each of the identified areas of *vulnerability*.

Chapter 7

DISCUSSION AND CONCLUSION: MOVING FORWARD

The purpose of this Chapter is to summarise the main findings of this thesis.

7.1 INTRODUCTION: MEETING THE RESEARCH AIMS AND OBJECTIVES

The main aims of this thesis as outlined in Chapter 1 are to: [1] assess the *vulnerability* and *resilience* of traditional societies and those on the threshold of modernisation to volcanic and volcano-related disasters, and [2] to evaluate whether historical events and their associated responses may inform future policies of disaster management. In order to do this, three objectives were identified. Firstly, to test two methodologies that have the potential to reveal how traditional societies and those on the threshold of modernisation have coped in the past with volcanic and volcano-related disasters; secondly, to identify traditional strategies of coping and survival in *pre-industrial* or *folk* societies in three case-study areas and, finally, to assess the potential use of this information in the development of future plans for disaster management. The degree to which each of these objectives has been satisfied is discussed in sections 7.2 to 7.5.

7.2 EVALUATION OF MAJOR THEMES: KEY CONCLUSIONS

This section considers the key findings of the thesis for each case study area.

7.2.1 Mount Etna, Sicily, Italy: Human adjustments and responses

A detailed study of major eruptions of Etna occurring during the *pre-industrial* era (i.e. from the classical period to 1923) and in 1928, shows the region to be socially resilient and one that is not just able to survive but to prosper. Indeed in the period from the 1792/3 eruption to 1928, when much land was sterilised and Mascali and two smaller settlements were destroyed, the region managed to increase its population both in absolute terms and relative to other regions of Sicily and remained a successful agricultural region. Apart from the seventeenth-century, when the region's *resilience* was almost overwhelmed by its *vulnerability*, when, in less than 25 years, the combined impacts of the largest historic eruption in 1669 and the major earthquake in 1693 (maximum intensity 10-11 MCS) destroyed Catania and delayed the re-development of the city and its hinterland until the eighteenth century, there were no instances of *vulnerability* overwhelming the *resilience* of the region. In the *pre-industrial* era eruptions were managed at three levels: through limited State involvement; by mutual support within village communities, in which religious belief and explanations for losses provided both a social cement – the church often providing leadership and pastoral support – and a context in which losses could be explained and by family and extended family groups. Today, the major challenges which face the Etna region are: an increase in population, especially within what is now officially described as the Metropolitan Area (*Area Metropolitana*) (Anon, 2012c); i.e. the commuter zone around Catania; and an increasing number of people are divorced from the land and traditional culture, being less aware of the vulnerabilities of location than their forebears (Dibben, 2008); e.g. partial loss of *folk* memory. In addition, although the Etna region has been fortunate that only minor damage occurred in many nineteenth century eruptions from volcano-related earthquakes (i.e. 1865), the threat clearly remains (i.e. 2002). Although modern buildings are more resistant to earthquakes, the city of Catania and most towns and villages are still dominated by traditional buildings constructed using lava blocks and rubble stone, which remain highly susceptible to earthquake-induced failure**.** Buildings are, moreover, often constructed on debris from previous eruptions and loose soil. Finally, State-based policies have boosted overall *resilience* and today a major disaster would probably see far less human distress, mortality and morbidity than was the case in the past. Indigenous deep-seated *resilience*, which was so characteristic of *pre-industrial* times has, however, been reduced, these trends being exacerbated by a break-down in the centuries old 'Sicilian way of life'.

7.2.2 Mount Vesuvius, Italy: Looking to the future

It is clear from the study of the 1944 and 1906 eruptions that, for present-day policies of volcanic-hazard management to be successful, plans need to consider the local cultural *mileau* of the region. In particular the loss of '*folk*' memory is particularly germane in the context of Vesuvius. In 1995 a comprehensive hazard evaluation and evacuation plan was published (*Dipartimento della Protezione Civile*, 1995), based on a *1631 A.D. eruption scenario* (Barberi *et al.*, 1990). It predicts that some 700,000 people will need to be evacuated following a 7-day warning period. The rationale is that before the 1631 eruption, earthquakes were felt for at least 15 days. The scientific commission identified three major hazard zones based on the type and size of phenomena potentially affecting them:-

1. The Red Zone (*Zona Rossa*) covers an area *ca*. 250 km^2 and could be subject to nearly total destruction due to pyroclastic flows and surges, and very heavy basaltic fallout.
2. The Yellow Zone (*Zona Gialla*) covers an area *ca*. 1,800 km^2 and could be affected by heavy ash and lapilli fallout, as well as by mud fall and flows.
3. The Blue Zone (*Zona Blu*) covers an area *ca*. 370 km^2 and could be affected by mudflows and floods.

Since it first appeared the evacuation plan has been the subject of much controversy, not just within the Italian volcanological and political communities, but also amongst the people who live on the flanks of the volcano. Some of the criticisms relate to the eruption scenario and centre upon whether an eruption can be predicted within 20 days, the accuracy of the *1631 A.D. eruption scenario*, the durability of seismic monitoring stations in the days leading up to an eruption (Masood, 1995) and the justification for assuming that prevailing winds from the west will be the actual winds at the time of eruption. The plan's success depends critically on the interpretation of precursory phenomena.

As discussed in Chester *et al*. (2001) the publication in 1994 of an alternative eruption scenario by Flavio Dobran produced a rift in the Italian earth sciences community, with Dobran and his colleagues arguing that both the largest eruption of Vesuvius (i.e. 79 A.D.), which destroyed Pompeii and Herculaneum, and medium-scale events, such as the eruption of 1631, have the potential to develop extremely quickly, which would place up to 1 million people at risk, with less than 15 minutes warning (Dobran *et al*., 1994; Baxter *et al*., 1998; Dobran, 2000). Whether the evacuation plan is logistically possible is also debatable (Rolandi, 2010). It requires the evacuation of more than 600,000 people in just one week, with the use of just 81 ships, 4,000 cars and 40 trains each day (Valentine and Heiken, 1995; Newhall, 1996; Matthews, 1998). In addition 16,500 people would be required to physically manage the evacuation. It should be noted however, that the published evacuation plan is just a draft document and is continually revised by its principal author, Professor Lucia Civetta (Director of the Vesuvius Volcano Observatory), based on comments from interested parties. A limited trial evacuation has successfully been carried out. Despite a local culture, in which scientists are having to deal with severe problems of unplanned and often illegal urban growth with a lack of respect for planning laws, a long-standing denial by much of the population that Vesuvius poses any threat at all, organised crime – a symptom of a 'delinquent society' (Alexander, 2000) – and a long-established suspicion of authority particularly that embodied by the State, the evacuation plan at least tackles difficult issues that have long been recognised and are only now being adequately addressed. Despite this the plan shows little awareness of *vulnerability* or *resilience,* and there is no local 'ownership' of policy. In fact, this may be an example of policy being part of the problem rather than the solution. The loss of '*folk*' memory is clearly a major contemporary issue.

7.2.3 The Islands of São Miguel and Faial, the Azores, Portugal: Volcano and Volcano-related hazard vulnerability and resilience

In the Azores and in contrast to Vesuvius, civil defence policies are driven by an awareness of the local culture. In short, hazard management policies are 'bottom up' and to a much lesser extent 'top down'. There are nevertheless, problems of putting these policies into practice. First, with the passage of time there is a rapidly decreasing number of people on the islands who have direct experience of either volcanic eruptions or seismic events, despite the 1980 and 1998 earthquakes which both affected limited areas. Although much smaller losses have been caused by a range of hazards, these are related to extreme weather events, there is a lack of experience of large-scale geological events affecting many people. There is one positive countervailing trend, however, that scientists are closely involved with hazard management on a day-to-day basis and, indeed one prominent scientist from the *Universidade dos Açores* is a former government minister and another a former senior civil servant. Scientists are notably aware of policies of natural disaster reduction at the international level. The interchange of personnel between government and academia is a possible lesson for other volcanic areas and is an example of good practice. Finally, there is also still a strong rural ethos on the islands of the Azores, which are embedded in traditional experiences. This has been largely been lost on the slopes of Vesuvius and in metropolitan Catania.

7.3 EVALUATION OF COMMON THEMES: KEY CONCLUSIONS

There are three common features which emerge from this study, which are:

1. Volcano-related earthquakes are an understated and under-planned hazard. This is not, only an example of '*residual un-ameliorated*' *vulnerability* (Alexander, 1997), but is also, without major infrastructure investment, intractable.

2. Rapid, recent urban development affects long-term *adjustments* by increasing the potential for future impacts and increasing overall *vulnerability*. This points to the need to better integrate development and disaster planning.

3. *Popular Catholicism* (i.e. the practice of liturgies of divine propitiation) does not inhibit responses based on scientific knowledge and/or civil defence planning. Hence, the resources of the church, its priests and local plant in the form of church buildings, have the potential to be used as valuable community resources, through the dissemination of the information and the provision of practical and spiritual support, without compromising planning goals.

7.4 REVIEW OF THE METHODOLOGIES: HISTORICAL RECONSTRUCTION AND VULNERABILITY AND RESILIENCE ANALYSIS

In Chapter 3 two methodological approaches were introduced: the historically-based approach (i.e. historical reconstruction) and one based on the analysis of *vulnerability* and *resilience*. The former was used for Etna, and tested on Vesuvius. The latter was used for the islands of São Miguel and Faial. The case studies show that for Etna and the Azores the chosen approaches worked well and allowed, not only the details of *pre-industrial* loss bearing to be revealed, but also enabled relevant points to be made about present, and future, issues in disaster management. It should be noted, however, that in order to maximise the effectiveness of the use of an historically-based approach then considerastion needs to be placed on the interpretation of source materials (i.e. the linguistic skills of the researcher). As mentioned in Chapter 1, the use of more reliable translation software (e.g. *Systrans* and *Google Translate*) has facilitated the development of non-language speakers developing a greater knowledge of social and cultural responses beyond just the details of the physical event; recent research grants (e.g. STREVA – *Strenthening Resilience in Volcanic Areas*) extend this through the development of multi-disciplinary teams including language specific specialists, for work in remote regions where knowledge of local dialects is required, thus removing the limitations of language skills through collaboration. In the case of the study of Vesuvius, the situation is problematic. In contrast to Etna, rapid urbanisation of the area since its *final* eruption in 1944 and the influx of people into the region without any first-hand knowledge means that the traditional '*folk*' memory of events, which is so much a feature of Etna, has been largely lost. The combination of urbanisation and period of inactivity have resulted in the reduction of '*folk*' memory. In addition future events and their eruptive styles are more uncertain than those on Etna. A major conclusion from this research is that for Vesuvius and other volcanoes with these characteristics, a *vulnerability* and *resilience* type methodology is preferred.

7.5 FUTURE WORK

Future work involves the application of a *vulnerability* and *resilience* based methodology grounded within both historical and contemporary contexts. Vesuvius would represent an ideal case study for such an investigation, focusing on the interrogation of local and regional archives. More generally, both approaches (i.e. historical reconstruction and *vulnerability* and *resilience* analysis) need to be tested in societies with non-European cultures, across volcanoes with differing styles of activity and with contrasting levels of economic development. The use of archival sources written in non-European languages is virtually un-researched in the hazards field and is probably a fruitful line of enquiry.

7.6 CONCLUDING REMARKS

One final implication of this research is that it highlights the possibility, indeed the desirability, of including links to a variety of historical data sources within international and global volcanological data-bases. Such data-bases include: *The Smithsonian Global Volcanism Program* and the *Volcanic Global Risk Identification and Analysis Project* (VOGRIPA – http://www.bgs.ac.uk/vogripa). In short, the research undertaken points towards the need for a more integrated *vulnerability* and *resilience* based approach; supplemented with historical reconstruction.

BIBLIOGRAPHY

Abatino, E. 1989. *Vesuvius. A volcano and its history*. Carcavallo Publishing, Napoli.

Alfano, G.B., 1924. *Le eruzioni del Vesuvio fra il 79 e il 1631 (studio bibliografico)*. Scuola Tipografica Pontificia, Valle di Pompei, pp. 58.

Alfano, G.B., Friedlander, I. 1929. *La Storia Del Vesuvio Illustrata Dai Documenti coevi*. Napoli, pp. 1-69.

Alessi, G. 1829-1835. Storia critica delle eruzioni del-l'Etna. Atti della Accademia gioenia di scienze naturali Catania, Series 1, 3-9.

Alexander, D. 1993. *Natural Disasters*. New York: Chapman and Hall.

Alexander, D. 1995. A survey of the field of natural hazards and disaster studies. In: Carrara, A., Guzzetti, F. (Eds.). *Geographical Information systems in assessing natural hazards*. Dordrecht, Kluwer, pp. 1-19.

Alexander, D. 1997. The study of natural disasters, 1977-1997: Some reflections on a changing field of knowledge. *Disasters* 21, 4, 284-304.

Alexander, D. 2000. *Confronting Catastrophe*. Terra Publishing, Harpenden.

Anderson, J.M. 2000. *History of Portugal*. Greenwood, Westport CT, pp. 222.

Andrade, C., Borges, P., Freitas, M.C., 2006. Historical tsunami in the Azores archipelago (Portugal). *Journal of Volcanology and Geothermal Research* 156, 172-185.

Annen, C., Wagner, J-J. 2003. The Impact of Volcanic Eruptions During the 1990s. *Natural Hazards Review* 4, 4, 169-175.

Anon, 1669. 'An answer to some inquiries concerning the eruptions of Mt. Aetna, 1669, communicated by some inquisitive merchants now residing in Sicily'. *Philosophical Transactions of the Royal Society of London* 4, 1028-34.

Anon, 1809a. The eruption of Mount Etna. Caledonian Mercury, October 30, Issue 13707.

Anon, 1809b. Eruption of Mount Etna. *The National Intelligencer and Washington Advertiser*, October 6, Issue 1403, column B.

Anon, 1843a. News. *Essex Standard and General Advertiser for the Eastern Counties*, December 8, page 1.

Anon, 1843b. Bronte Insieme – L’eruzione del 1843 (http://www.bronteinsieme.it/2st/eruzione_1843.html) – last accessed 25/07/11.

Anon, 1843c. The late eruption of Etna. *The Times* (London), December 10, page. 5, column C.

Anon, 1843d. The eruption of Mount Etna. *The Times* (London), December 10, page 5, column C.

Anon, 1844. The eruption of Etna. *The Times* (London) January 1, p. 6. column C.

Anon, 1852a. The eruption of Etna. *The Times* (London), September 24, page 8, column F.

Anon, 1852b. Italy: The eruption of Mount Etna. *The Ripley Bee* (Ripley OH), November 6, Issue 24, column E.

Anon, 1865a. The eruption of Etna. *The Times* (London), February 24, page. 7, column E.

Anon, 1865b. The earthquake at Catania. *The Times* (London) August 2, p. 11, column C.

Anon, 1879a. The eruption of Mount Etna. *The Evening's New and Pall Mall Gazette* (London), May 30, Issue 4452.

Anon, 1879b. The eruption of Etna. *The Sheffield and Rotherham Independent* (Sheffield), June 9, Issue 7713.

Anon, 1879c. The eruption of Etna. *Illustrated London News*, June 21, page 575, Issue 2088.

Anon, 1879d. The eruption of Etna - Earthquake shocks. *The Sheffield and Rotherham Independent* (Sheffield), June 5, Issue 7710.

Anon, 1879e. The Eruption of Mount Etna. *The Derby Mercury* (Derby), June 18, Issue 8581.

Anon, 1879f. The losses by Etna’s Eruption. *Frank Leslie’s Illustrated Newspaper* (New York), June 22, page 19.

Anon, 1879g. Floods in Italy. *The Standard* (London) June 5, Issue 17120.

Anon, 1879h. Etna's fury wanes; lava flow checked. Castiglione is now the only town in imminent danger from volcano. Mussolini directs relief. *New York Times*, June 22, page 19.

Anon, 1879i. Southern Italy. *The Times* (London) June 10, page 4, column E.

Anon, 1883a. News in Brief. *The Times* (London), March 22, page 3, column B.

Anon, 1883b. The eruption of Etna. *The Times* (London), April 2, page 8, column C.

Anon, 1883c. Southern Italy. *The Times* (London), April 6, column A.

Anon, 1883d. Report. *The Leeds Mercury* (Leeds), March 30, Issue 14032.

Anon, 1883e. Italy. *The Times* (London), March 27, page. 3, column B.

Anon, 1883f. The eruption of Etna. *Aberdeen Weekly Journal* (Aberdeen), March 26, Issue 8772.

Anon, 1883g. Italy. The Times (London), March 23, page 3, column C.

Anon, 1886a. The eruption of Mount Etna. *The Pall Mall Gazette* (London), May 22, Issue 6609.

Anon, 1886b. Mount Etna. *The Standard* (London), May 25, Issue 193202, 19th Century British Library Newspapers: Part II.

Anon, 1886c. The Mount Etna Eruption. *St. Louis Globe – Democrat* (St. Louis), May. 28, Issue 5, Column D.

Anon, 1886d. The eruption of Etna. *The Standard* (London), June 4, Issue 19311.

Anon, 1886e. Southern Italy. *The Times* (London), June 5, page 6, column F.

Anon, 1886f. The Mount Etna eruption, *Liverpool Mercury* (Liverpool) May 29, Issue 11977.

Anon, 1886g. The eruption of Mount Etna. *Aberdeen Weekly Journal*, June 1, Issue 9768.

Anon, 1886h. London Letter. The Ipswich Journal (Ipswich), May 25, Issue 8389.

Anon, 1892a. Threatens two cities, Eruption of Etna becomes alarming, people praying. Milwaukee Sentinel July 11, column F.

Anon, 1892b. The eruption of Mount Etna. *The Times* (London), July 13, page 5, column A.

Anon, 1892c. The eruption of Etna. *The Times* (London) July 12, p. 5, column B.

Anon, 1892d. Mount Etna in eruption. *Illustrated London News,* August 6, page 163.

Anon, 1892e. The eruption of Mount Etna. *The Times* (London) July 18, page 5, column B.

Anon, 1892f. The eruption of Etna. *The Times* (London), August 17, page 4, column A.

Anon, 1906a. Vesuvius causes terror. Loud detonations and frequent earthquakes – villages flee. *New York Times*, April 6, page 1.

Anon, 1906b. Ruin by Vesuvius: Terror in Naples. Two severe earthquake – Fumes make breathing difficult. Big towns evacuated. *New York Times*, April 9, page 1.

Anon, 1906c. Vesuvius threatens destruction of towns. Bosco Trecase abandoned – panic in other places. 1,000 foot column of fire. Lava advancing at the rate of 21 feet a minute – Stones weighing a ton each ejected. *New York Times* (New York), April 17, page 1.

Anon, 1906d. Ashes from Vesuvius overwhelm a town. Bosco Trecase Destroyed – Ottajano being evacuated. Lava razing homesteads. Duke of Aosta and Cardinal Prisco try to comfort the peasants. Earthquakes grow stronger. *New York Times* (New York), April 8, page 1.

Anon, 1906e. Volcanic victims may number 500. *New York Times* (New York), April 10, page 1.

Anon, 1906f. Pompeii in Peril; Ottajano a ruin. *New York Times* (New York), April 11, page 1.

Anon, 1906g. Ash fall in Naples greater than ever. *New York Times* (New York), April 13, page 1.

Anon, 1906h. The eruption of Vesuvius: A Reassuring Report. *The Times* (London), April 13, page 3, column E.

Anon, 1906i. Eyes of the world on hero of Vesuvius. *New York Times* (New York), April 15, page SM4.

Anon, 1906j. The eruption of Vesuvius. *The Times* (London) April 17, page 4, column C and D.

Anon, 1906k. Lava still hot in Bosco Tre Case, forty-five days after the eruption of Vesuvius. *New York Times* (New York), June 24, page SM2.

Anon, 1911a. Havoc from Etna Volcano. Lava destroying everything in its path, railway threatened. *New York Times* (New York), September 13, page. 4.

Anon, 1911b. 20,000 homeless by Etna's eruption, Inhabitants of Catiglione and Francavilla flee before advancing flood of lava. *New York Times* (New York), September 15, page 3.

Anon, 1923a. Etna in eruption. Three villages destroyed. *The Times* (London), June 19, page. 14, column C.

Anon, 1923b. The threat of Etna. Many villages submerged. Grave outlook. *The Times* (London), June 20, page 14, column C.

Anon, 1923c. The threat of Etna. Many villages submerged. Grave outlook. *The Times* (London), June 20, page. 14, Issue 43372, column C.

Anon, 1923d. Mount Etna Disaster. Lava stream a mile wide. *The Times* (London), June 21, page 14, column A.

Anon, 1923e. A double stream of lava. *The Times* (London), June 20, page 14, column C.

Anon, 1923f. Peasants' heavy losses. Millions of vines destroyed. *The Times* (London), June 23, column C.

Anon, 1923g. King's visit cheers Mount Etna refugees. Mussolini's departure for the scene of the eruption also gives confidence. *New York Times* (New York), June 21, page 21.

Anon, 1923h. Etna's fury wanes; lava flow checked. Castiglione is now the only town in imminent danger from volcano. Mussolini directs relief. *New York Times* (New York), June 22, page 19.

Anon, 1923i. Mount Etna eruption. Peril abated, threatened town saved, slower flow of lava. *The Times* (London), June 22, page 13, column A

Anon, 1923j. Etna eruption ending. Crater still active. Trainloads of sightseers. *The Times* (London), June 26, page 12, column C.

Anon, 1923k. Mount Etna quiet. Danger exaggerated. *The Times* (London), June 27, page 12, column D.

Anon, 1923l. Foreign News: Etna eruption. *The Times* (London), July 2.

Anon, 1928a. Eruption of Etna; the lava flow abating. *The Times* (London) Nov. 13, pg. 16. Issue 45049.

Anon, 1928b. Etna Havoc Spreading; More villages Desolate-thousands homeless. *The Times* (London) Nov. 9, pg. 16. Issue 45046.

Anon, 1928c. The eruption of Etna; New Outbreak; Doubtful Fate of Villages. *The Times* (London) November 10, pg. 12. Issue 45047.

Anon, 1928d. Eruption of Etna; Scene at New Crater. *The Times* (London) November 12, pg. 16. Issue 45048.

Anon, 1928e. *Corriere della Sera*. 6th November, Catania.

Anon, 1928f. *Giornale dell'Isola*. 7th November, Catania.

Anon, 1928g. Eruption of Etna; The lava flow abating. *The Times* (London) November 13, pg 16, Issue 45049.

Anon, 1928h. Etna Eruption; Loss estimated at £2,000,000; Moving Religious Spectacle. *The Times* (London) November 14, pg 16, Issue 45050.

Anon, 1944a. *Report on eruption of Vesuvius, March 1944. Effect in Respect of certain Royal Air Force Units, and action taken by Royal Air Force.* Manuscript, Department of Research and Information Service, Royal Air Force Museum: Hendon.

Anon, 1944b. *The Manchester Guardian*. 22 March. 5g.

Anon, 1944c. Report. *The Manchester Guardian*. 23 March. 5f.

Anon, 1944d. *New York Times*, March 24, 5d.

Anon, 1994. A World Safe from Natural Disasters: The Journey of Latin America and the Caribbean. *Pan-American Health Organisation*, Washington DC, pp. 112.

Anon, 2010b. I Grandi Disastri in Italia Anno 1910 (http://cronologia.leonardo.it/storia/a1910.htm) – Last accessed 8/8/11.

Anon, 2010c. Nicolosi. Comuni di Sicilia. (http://isapordisicilia.com/comunisicilia/comuni/nicolosi.htm) – Last accessed 8/8/11.

Anon, 2010d. SCUTS entram na fase final. Açores 9 Outubro 2010 (Ano 6, no. 52) (http://www.jornalacores9.com/Scut.html - last accessed May 27 2011).

Anon, 2011b. The Etnean Observatory of the INGV. (http://www.ct.ingv.it/index.php?option=com_content&view=article&id=355) – Last accessed 20/9/11.

Anon, 2011c. Measuring worth. (http://www.measuringworth.com/index.php) – Last accessed 9/8/11.

Anon, 2012a. *Provincia Regionale di Catania. Informazione* (http://translate.google.co.uk/translate?hl=en&sl=it&u=http://www.provincia.ct.it/servizi/sportelli_informativi/comuni/area_metropolitana/trecastagni/default.aspx&prev=/search%3Fq%3Dtrecastagni%2B1408%26hl%3Den%26biw%3D1024%26bih%3D567%26prmd%3Dimvns&sa=X&ei=zWcKUOiMGYmb1AX4w4TtCg&ved=0CGEQ7gEwBAe) – Last accessed 23/7/12.

Anon, 2012b. *Nicolosi: Le Vicende dal 1669 al 1766*.

Anon 2012c. *Provincia Regionale di Catania*. Informazione (http://translate.google.co.uk/translate?hl=en&sl=it&u=http://www.provincia.ct.it/servizi/sportelli_informativi/comuni/area_metropolitana/trecastagni/default.aspx&prev=/search%3Fq%3Dtrecastagni%2B1408%26hl%3Den%26biw%3D1024%26bih%3D567%26prmd%3Dimvns&sa=X&ei=zWcKUOiMGYmb1AX4w4TtCg&ved=0CGEQ7gEwBAe) – Last accessed 3/1/13.

Anon 2012c. *Provincia Regionale di Catania*. Informazione (http://translate.google.co.uk/translate?hl=en&sl=it&u=http://www.provincia.ct.it/servizi/sportelli_informativi/comuni/area_metropolitana/trecastagni/default.aspx&prev=/search%3Fq%3Dtrecastagni%2B1408%26hl%3Den%26biw%3D1024%26bih%3D567%26prmd%3Dimvns&sa=X&ei=zWcKUOiMGYmb1AX4w4TtCg&ved=0CGEQ7gEwBAe) – Last -accessed 3/1/13.

Arnò, V., Principe, C., Rosi, M., Santacroce, R., Sbrana, A., Sheridan, M.F. 1987. Eruptive History. In: Santacroce, R. (Ed.), *Somma-Vesuvius*, CNR Quaderni de la Ricerca Scientifica 114, Roma, pp. 53-103.

Ávila, J.I., Mendonça, L. 2008. Azorean emigration: Causes, waves and destinations. A brief historical summary. In Goulart, T (Ed.) 2008. *Capelinhos, a volcano of Synergies. Azorean Emigration to America*. San Jose CA: Portuguese Heritage Publications of California, 17-24.

Avvisati, C., Casale, A. 2006. *Vesuvio 1906. Il drama di un popolo.* Centro Studi Archeologici di Boscoreale, Boscoreale.

Azevedo, J., Serrano, S., Oliveira, C.S., 2009. The next 1755 – myth and reality; Priorities and actions to develop in case of an earthquake in the Lisbon Metropolitan area. In: L.A. Mendes-Victor, C.S. Oliveira, J. Azevedo, J., A. Ribeiro (Eds.), *The 1755 Lisbon Earthquake revisited.* Springer, Berlin (Geotechnical, Geological and Earthquake Engineering vol. 7), pp. 559-579.

Azzaro, R., Barbano, M.S., Moroni, A., Mucciarelli, M., Stucchi, M. 1999. The seismic history of Catania. *Journal of Seismology* 3, 235-252.

Baedeker, K. 1930. *Southern Italy and Sicily with Excursions to Sardinia, Malta, Tripoli and Corfu*. Karl Baedeker, Leipizig, George Allen and Unwin, London.

Bandiera, O. 2003. Land reform, the market for protection and the origins of the Sicilian mafia: Theory and Evidence. *Journal of Law, Economics and Organisation* 19 (N1), 218-243.

Baklanoff, E.N. 1992. The political economy of Portugal’s Estado Novo: a critique of the stagnation thesis. *Luso-Brazilian Review* 20, 1, 1-17.

Bankoff, G. 2001. Rendering the world unsafe: ‘Vulnerability’ as western discourse. *Disasters* 25, 1, 19-35.

Bankoff, G. 2012. *Mapping Vulnerability: Disasters, Development and People*. Routledge, pp. 256.

Baratta, M. 1897. *Il Vesuvio e le sue Eruzioni*. Società Editrice Dante Alighieri, Roma, pp.203.

Barberi, F., Le Guern, F., Villari, L. 1984. Lava Diversion Efforts During the 1983 Etna Eruption: Planning, Execution and Results. *Bulletin of Volcanology* 47, 4, 1070-1096.

Barberi, F., Macedonia, G., Pareschi, M.T., Santacroce, R. 1990. Mapping the tephra fallout risk: an example from Vesuvius, Italy. *Nature* 344, 142-144.

Barberi, F. Carapezza, M.L. Valenza M., Villari L. 1993. The control of lava flow during the 1991-2 eruption of Mt Etna. *Journal of Volcanology and Geothermal Research*, 56, 1-34.

Barberi, F., Carapezza, M.L. 2004. The control of lava flows at Mt. Etna. In: Bonaccorso, A., Calvari, S., Coltelli, M., Del Negro, C., Falsaperla, S. 2004. Mount Etna: Volcano Laboratory. American Geophysical Union, Geophysical Monograph Series Washington DC.

Barbaro, P. 2009. Explanation of the Earth’s features and origin in pre-Meiji Japan. In: Kölbl-Ebert, M. (Ed.) *Geology and Religion: A history of harmony and hostility*. The Geological Society of London, Special Publication 310, 25-36.

Barrows, H.H. 1923. Geography as Human Ecology. *Annals of the Association of American Geographers* XIII, 1, 1-14.

Barry, J.M. 1998. *Rising Tide: The Great Mississippi Flood of 1927 and How it Changed America*. London: Simon and Schuster, pp. 528.

Baxter, P.J. Neri, A., Todesco, M. 1998. Physical modelling and human survival in pyroclastic flows. *Natural Hazards* 17, 2, 163-176.

Baxter, P.J., Baubron, J.C., Coutinho, R. 1999. Health hazards and disaster potential of ground gas emission at Furnas Volcano, São Miguel, Azores**.** *Journal of Volcanology and Geothermal Research* 92 1-2, 95-106.

Baxter, P.J., 2005. Human impacts of volcanoes. In: Marti, J., Ernst, G. J. (Ed.), *Volcanoes and the Environment.* Cambridge, Cambridge University Press, pp. 273-303.

Behncke, B., Neri, M., Nagay, A. 2005. Lava flow hazard at Mount Etna (Italy): new data from a GIS-based study. In: Manga. M., Ventura, G. (Eds.) Kinematics and Dynamics of Lava Flows, *Geological Society of America*, *Special*, vol. 396, pp. 189-209.

Behncke, B. 2011. Can lava flows at Etna be diverted. (http://boris.vulcanoetna.it/ETNA_diversion.html) – Last accessed 22/8/11.

Benjamin, S. 2006. *Sicily: Three thousand years of human history*. Steerforth Press, Hanover New Hampshire, pp. 498.

Bentley, H., Gregory, J.R. 1944. *Final Report on the Vesuvius Emergency Operation*, Headquarters Naples Province (Allied Control Commission).

Birmingham, D. 1993. *A Concise History of Portugal*. Cambridge University Press, Cambridge, pp. 209.

Blaikie, P., Cannon, T., Davis, I., Wisner, B. 1994. *At risk. Natural hazards, people's vulnerability and disasters.* Routledge, London.

Blong, R.J. 1982. *The time of darkness, local legends and volcanic reality in Papua New Guinea*. University of Washington Press, Seattle/Australian National University Press, Canberra.

Blong, R.J. 1984. *Volcanic Hazards*. Academic Press, Sydney.

Bonaccorso, A., Ferrucci, F., Patnè, D., Villari, L. 1996. Fast deformation processes and eruptive activity at Mount Etna *(Italy*). *Journal of Geophysical Research* 101, B8, 17467-17480.

Bonaccorso, A., Calvari, S., Coltelli, M., Del Negro, C., Falsaperla, S. 2004. Mount Etna: Volcano Laboratory. American Geophysical Union, Geophysical Monograph Series Washington DC.

Booth, B., Walker G.P.L., Croasdale R. 1978. A quantitative study of thousand years of volcanism on Sao Miguel, Azores. *Philosophical Transactions of the Royal Society of London*, 228, 271-319.

Booth, B., Croasdale, R.. Walker, G.P.L. 1983. Volcano hazard on Sao Miguel, Azores. In: Tazieff H Sabroux, J-C. (Eds.) *Forecasting Volcanic Events*. Amsterdam, Elsevier, 99-109.

Borelli, G.A. 1670. *Historia et Meteorologia Incendii Aetnaei Anno 1669 ac Responsio ad Censuras Honoratti Fabri contra Librum de Vi Percussions*. Regio Julio.

Bousquet, J-C., Lanzafame, G., Paquin, C. 1998. Tectonic stresses and volcanism: in-situ stress measurements and neotectonic investigations in the Etna area (*Italy*). *Tectonophysics* 149, 3-4, 219-231.

Bowker, J. 1970. *Problems of Suffering in the Religions of the World*. Cambridge University Press, Cambridge, pp. 318.

Bracker, M. 1944. Vesuvius lava flow slackens. *New York Times* (New York), March 23.

Branca, S., Del Carlo, P. 2004. *Eruptions of Mt. Etna during the past 2,200 years: A revised compilation integrating the historical and stratigraphic records*. In: Bonaccorso, A., Calvari, S., Coltelli, M., Del Negro, C., Falsaperla, S. (Eds.), Mount Etna: Volcano Laboratory. American Geophysical Union, Washington D.C., Geophysical Monograph Series, 143, pp. 1-27.

Branca, S., Del Carlo, P. 2005. Types of eruptions of Etna volcano AD 1670-2003: Implications for short-term eruptive behaviour. *Bulletin of Volcanology* 67, 732-742.

Branca, S., Del Carlo, P. 2008. Types of eruptions of Etna volcano AD 1670-2003: Implications for short-term eruptive behaviour. *Bulletin of Volcanology* 67, 732-742.

Branca, S., Coltelli, M., De Beni, E., Wijbrans, J. 2008. Geological evolution of Mount Etna volcano (Italy) from the earliest products until the first central volcanism (between 500 and 100 ka ago) inferred from geochronological and stratigraphic data. *International Journal of Earth Sciences*, Geol. Rundsch 97, 135-152.

Branca, S., Coltelli, M., Groppelli, G., Lentini, F. 2012. Geological map of Etna volcano, 1:50,000 scale. *Italian Journal of Geosciences* **(**Bollettino della Società Geologica Italiana e del Servizio Geologico d'Italia) 130, 265-291.

Branca, S., De Beni, E., Proiette, C. 2013. The large and destructive 1669 AD eruption at Etna volcano: reconstruction of the lava flow field evolution and effusion rate trend. *Bulletin of Volcanology* 75, 694, 1-16.

British Pathè, 1923. Film clip (http://www.britishpathe.com/record.php?id=20071) - Last Accessed 25/7/11.

British Admiralty, 1945. Spain and Portugal: Volume IV The Atlantic Islands. London, Naval Intelligence Division.

Bryant, E. 2005. *Natural Hazards*: *Second Edition*. Cambridge University Press: Cambridge.

Bryson, T. 1988. The Azores: going it alone in the Atlantic. *The Geographical Magazine* 55, 9, 30-35.

Burton, I., Kates, R.W., White, G. 1978. *The Environment as Hazard*. Oxford University Press, New York, pp. 240.

Burton, I., Kates, R.W., White, G. 1993. *The Environment as Hazard*. Second Edition. Oxford University Press, New York, pp. 290.

Calado, H., Borges, P., Phillips, Ng, K., Alves, F. 2011. The Azores archipelago, Portugal: improved understanding of small island coastal hazards and mitigation measures. *Natural Hazards* 58, 427-444.

Callender, J.M., Henshall, J.D. 1968. The land use of Faial in the Azores. In: Cook, A.N. (Ed.), Four Island Studies. The World Land Use Survey. Monograph 5, Geographical Publications, Bude, Chapter 11, pp. 367-395.

Cannon, T. 1994. Vulnerability Analysis and the Explanation of Natural Disasters. In: Varley, A. (Ed.), Disasters, Development and Environment. Wiley, Chichester, pp. 13-30.

Cannon, T. 2008. Reducing people's vulnerability to natural hazards communities and resilience. *Research paper/UNU-WIDER, No. 2008.34*.

Cairo, H. 2006. Portugal is not a small country: Maps and propaganda in the Salazar regime. *Geopolitics* 11, 367-395.

Carafa, G. 1632. *In opusculum de novissima Vesuvvi conflagration: epistola isagogica*. Naples: Egidio Longo.

Carrera P. 1636. II Mongibello descritto in tre libri, G. Rossi, Catania pp. 204.

Carroll, R.P., 1990. Cognitive Disssonance. In: R.J. Coggins, J.L. Houlden (Eds.), *A Dictionary of Biblical Interpretation*. SCM, London pp. 123-124.

Carta, S., Figari, R., Sartoris, G., Sassi, E., Scandone, R. 1981. A statistical model for Vesuvius and its volcanological implications. *Bulletin of Volcanology* 44, 2, 130-151.

Carvalho, A.G.S., Sampaio, J.M.F. Pluviometria na ilha de S. Miguel (nótula descritiva). – pp. 120, Instituto Universitário dos Açores, Secção de Geografia.

Chapin, F.W., 1989. Tides of migration: A study of migration decision making and social progress in São Miguel. New York. AMS Press.

Chester, D.K., Duncan, A.M., Guest, J.E., Kilburn, C.R.J. 1985. *Mount Etna: The Anatomy of a Volcano*. Chapman and Hall, London, pp. 442.

Chester, D.K. 1993. *Volcanoes and Society*. Edward Arnold, London, pp. 351.

Chester, D.K. 1998. The Theodicy of natural disasters. *Scottish Journal of Theology* 51, 485-505.

Chester, D.K., Dibben, C., Coutinho, R., 1995. Report on the Evacuation of the Furnas District, São Miguel, Azores. Image Centre University College, University of London, Open File Report, CEC Environment/ESP Laboratory Volcano Furnas Azores.

Chester, D.K., Dibben, C., Coutinho, R., Duncan, A.M., Cole, P.D., Guest, J.E., Baxter, P.J., 1999a. Human adjustments and social vulnerability to volcanic hazards: The case of Furnas Volcano, São Miguel, Açores. In: Firth, C.R., McGuire, W.J. (Eds.), Volcanoes in the Quaternary. London, Geological Society of London Special Publication 161, pp. 189-207.

Chester, D.K., Duncan, A.M., Dibben, C., Guest, J.E., Lister, P.H. 1999b. Mascali, Mount Etna region Sicily: An example of fascist planning during the 1928 eruption and its continuing legacy. *Natural Hazards* 19, 1, 29-46.

Chester, D.K., Duncan, A.M., Guest, J.E., Johnston, P.A., Smolenaars, J.J.L. 2000. Human responses to Etna Volcano during the Classical Period. In: McGuire, B., Griffiths, D., Stewart, I. (Eds.), *The Archaeology of Geological Catastrophes*. Geological Society of London Special Publication 171, 179-188.

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

Chester, D.K., Dibben, C., Duncan, A.M. 2002. Volcanic hazard assessment in western Europe. *Journal of Volcanology and Geothermal Research* 115, 3-4, 411-435.

Chester, D. K., 2005. Volcanoes, Society and Culture. In: Marti, J., Ernst, G. J. (Eds.), Volcanoes and the Environment. Cambridge, Cambridge University Press, pp. 404-439.

Chester, D.K., Duncan. A.M., Guest, J.E. 2005. Responses to Eruptions of Etna from the Classical Period to 1900. In: Balmurth, M.S., Chester, D.K., Johnston, P.A. (Eds.), *Cultural Responses to the Volcanic Landscape: The Mediterranean and Beyond*. Colloquia and Conference Papers 8, Archaeological Institute of America, Boston, pp. 93-108.

Chester, D.K., Duncan, A.M. 2007. Lieutenant-Colonel Delmé-Radcliffe's report on the 1906 eruption of Vesuvius, Italy. *Journal of Volcanology and Geothermal Research* 166, 204-216.

Chester, D.K., Duncan, A.M., Wetton, P., Wetton, R. 2007. Responses of the Anglo-American military authorities to the eruption of Vesuvius, March 1944. *Journal of Historical Geography* 33, 168-196.

Chester, D.K., Duncan, A.M. 2008. Geomythology, theodicy and the continuing relevance of religious worldviews on responses to volcanic eruptions. In: Grattan, J., Torrence, R. (Eds.). *Living Under the Shadow,* Walnut Creek, CA: Left Coast Press, 203-224.

Chester, D.K., Duncan, A.M., Dibben, C. 2008. The importance of religion in shaping volcanic risk perception in Italy, with special reference to Vesuvius and Etna. *Journal of Volcanology and Geothermal Research* 172, 216-228.

Chester, D.K., and Duncan, A.M. Escape from Vesuvius, 1944. *Historical Geography* 59, 8, 43-49.

Chester, D.K., Duncan, A.M., James, P.A. 2010. Mount Etna, Sicily: Landscape evolution and hazard responses in the pre-industrial era. In: Martini, P., Chesworth, W. Panizza, M. (Eds.), *Landscapes and Societies*. Springer, Berlin, pp. 235-255.

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

Cioni, R., Marianelli, P., Santacroce, R., Sbrana, A. Plinian and subplinian eruptions. In: Sigurdsson, H., Houghton, B., McNutt, S.R., Rymer, H., Stix, J. (Eds.). *Encyclopedia of Volcanoes*. Academic Press, London, pp. 477-494.

Cioni, R., Bertagnini, A., Santacroce, R., Andronico, D. 2008. Explosive activity and eruption scenarios at Somma-Vesuvius (Italy): Towards a new classification scheme. *Journal of Volcanology and Geothermal Research* 178, 3, 331-346.

Clapperton, C.M. 1972. Patterns of physical and human activity on Mount Etna. *Scottish Geographical Magazine* 88, 160-167.

CMTE Working Group, 2008. Catalogo Macrosismico dei Terremoti Etnei, 1832-2008.

Coutinho, R., Pimentel, A., Pacheco, J.M., 2008. Na Rota dos Vulcões – Guia Geológico da Ilha do Faial. Secretaria Regional do Ambiente e do Mar. ADELIAÇOR, Horta.

Cole, P.D., Queiroz, G., Wallenstein, N., Gaspar, J.L., Guest, J.E. 1995. An historic subplinian/phreatomagmatic eruption: the 1630 AD eruption of Furnas volcano, Azores. *Journal of Volcanology and Geothermal Research* 69, 117-135.

Cochrane, T. 1987. Place, people and folklore: an Isle Royale case study. *Western Folklore* 46, 1–20.

Cole, P.D., Guest, J.E., Queiroz, G., Wallenstein, N., Pacheco, J.M., Gaspar, J. L., Ferreira, T., Duncan, A.M., 1999. Styles of volcanism and volcanic hazards on Furnas volcano, São Miguel, Azores. *Journal of Volcanology and Geothermal Research* 92, 1-2, 39-53.

Cole, P.D., Pacheco, J.M., Gunasekera, R., Quiroz, G., Conçalves, P., Gaspar, J.L., 2008. Contrasting styles of explosive eruption at Sete Cidades, São Miguel, Azores, in the last 5000 years: Hazard implications from modelling. *Journal of Volcanology and Geothermal Research* 178, 574-591.

Comfort, L.K. 2006. Cities at risk: Hurricane Katrina and the drowning of New Orleans. *Urban Affairs Review* 41, 501-516.

Corrêa, J., 1924. *Leituras sobre a História do Valle das Furnas. Oficina de Artes Graficas, S. Miguel, Açores*, pp. 217.

Corsaro, R.A, Cristofolini, R., Patane, L.. 1996. The 1669 eruption at Mount Etna: chronology, petrology and geochemistry, with inferences on the magma sources and ascent mechanisms. *Bulletin of Volcanology* 58, 348-358.

Costa, A. 2002. Determination of mechanical properties of traditional masonry walls in dwellings of Faial Island, Azores. *Earthquake Engineering and Structural Dynamics* 31, 1361-1382.

Costa, A. Arêde, A., Oliveira, C.S. 2012. Out-of-plane behaviour of existing stone masonry buildings: experimental evaluation. *Bulletin of Earthquake Engineering* 10, 93-111.

Costa, R.M.M. 1998. Impacto Demográfico da Erupção Vulcânica dos Capelinhos. In: *O Faial e a Periferia Açoriana nos Séculos XV a XX*. Núcleo Cultural da Horta, pp. 339-351.

Costa, R.M.M. 2008. A brief introduction to the settlement of the Azores and a historical outline of the island of Faial. In: Goulart, T. (Ed.) *Capalinhos, a Volcano of Synergies. Azorean Emigration to America*, Portuguese Heritage Publications of California, San Jose CA, pp. 3–16.

Costa, R. M. M., 2008. A brief introduction to the settlement of the Azores and a historical outline of the island of Faial. In: T. Goulart (Editor), Capalinhos, a Volcano of Synergies. Azorean Emigration to America. Portuguese Heritage Publications of California, San Jose CA, pp. 3-16.

Costa, A., Arêde, A. 2006. Strengthening of structure damaged by the Azores earthquake of 1998. *Construction and Building Materials* 20, 252-368.

Coutinho, R. Pimentel, A., Pacheco, J.M., 2008. Na Rota dos Vulcões – Guia Geológico da Ilha do Faial. Secretaria Regional do Ambiente e do Mar. ADELIAÇOR, Horta.

Coutinho, R., Chester, D.K., Wallenstein, N., Duncan, A.M. 2010. Responses to, and the short and long-term impacts of the 1957/1958 Capelinhos volcanic eruption and associated earthquake activity on Faial, Azores. *Journal of Volcanology and Geothermal Research* 196, 265-280.

Crandell, D.R. 1984: United States. In: Crandell D.R., Booth, B., Kusumadinata, K., Shimozuru, D., Walker, G.P.L., Westerkamp, D. (Eds.). *Source Book for Volcanic-Hazards Zonation*. Paris: UNESCO, 72-91.

Cristofolini, R. 1973. Recent trends in the study of Etna. *Philosophical Transactions of the Royal Society of London* 274A, 17-35.

Cristofolini, R., Ghisetti, F., Scarpa, R., Vezzani, L. 1985. Character of the stress field in the Calabrian Arc and Southern Apennines (Italy) as deducted by geological, seismological and volcanological information. *Tectonophysics* 117, 39-58.

Cronin, S.J., Neall, V.E. 2000. Impacts of volcanism on pre-European inhabitants of Tavenui, Fiji. *Bulletin of Volcanology* 62, 199-213.

Cronin, S.J., Cashman, K.V. 2008. Welcoming a monster to the world: Myths, oral tradition, and modern societal response to volcanic disasters. *Journal of Volcanology and Geothermal Research* 176, 3, 407-418.

Crosweller, H.S., Wilsmhurts, J. 2013. Natural hazards and risk: the human perspective. In: Rougier, J., Sparks, J.S., Hill, L. (Eds.). *Risk and Uncertainty Assessment for Natural Hazards*. Cambridge University Press.

Cullotto, S. and Barbera, G. 2011. Mapping traditional cultural landscapes in the Mediterranean area using a combined multidisciplinary approach: Method and application to Mount Etna (Sicily; Italy). *Landscape and Urban Planning* 100, 98-108.

Cunha, A. 2003. The October 1997 landslides in São Miguel Island, Azores. In: Javier, H. (Ed.) Lessons learnt from landslide disasters in Europe. European Commission Joint Research Centre, ISPRA, Doc. 20558EN.

Cutter, S.L. 1993. *Living with risk*. London: Edward Arnold.

Cutter, S.L. 2006. *Hazards, Vulnerability and Environmental Justice*. Earthscan: London and Sterling, pp. 418.

Cucuzza –Silvestri, S. 1989. *Carlo Gemmellaro, La Vulcanologia dell' Etna. La topografia, la geologia, la storia delle sue eruzioni, la descrizione e lo esame de'fenomeni vulcanici*. G. Maimone, Catania.

Darley, G. 2011. *Vesuvius: The most famous volcano in the world*. Profile Books: London, pp. 245.

Dazzi, C. 2007. Environmental features and land use of Etna In: Arnalds, O., Bartoli, F., Buurman, P., Oskarsson, H., Stoops, G., Garcia-Rodeja, E. (Eds.), *Soils of Volcanic Regions in Europe*, 629-644. Berlin, Springer.

Degg, M., Doornkamp, J.C. 1994. Earthquake Hazard Atlas 7. Iberia (Portugal and Spain), including the Azores, Balearics, Canary and Madeira Islands. London Insurance and Reinsurance Market Association, London, pp.58.

Degg, M., Homan, J. 2005. Earthquake vulnerability in the Middle East. *Geography* 90, 1, 54-66.

Della Torre, G.M. 1755. *Storia e fenomeni del Vesuvio*. Raimondi, Napoli, pp.159.

Delmè-Radcliffe, Sir. C. 1906. Report by Lt. Col. Delmè-Radcliffe on Conditions Following the Eruption of Vesuvius in 1906. British Foregin, H.M.S.O., London. (report 14404 pp.1-9).

Della Torre, G.M. 1761. *Supplemento alla storia del Vesuvio ove si descrive I'incendio del 1760*. Raimondi, Napoli, pp.15

De Bottis, G. 1768. Ragionamento istorico intorno ai Nuovi vulcani comparsi alla fine del 1760 nel territorio di Torre del Greco. Stamperia Simoniana, Napoli.

de Sá, M. da Glória Pires, 2008a. The Portuguese in the United States Census of 2000. In: T. Goulart (Editor). Capelinhos, a volcano of Synergies. Azorean migration to America. Portuguese Heritage Publications of California, San Jose CA, pp. 87-97.

de Sá, M. da Glória Pires, 2008b.The Azorean community on the east coast. In: T. Goulart (Editor). Capelinhos, a volcano of Synergies. Azorean Emigration to America. Portuguese Heritage Publications of California, San Jose CA pp. 159-170.

de Silva, J.M.M., 1988/89. Questões Açorianas: A questão demográfica. Arquipélago (Revista da Universidade dos Açores, Ciêcias Socialis), 3/4, 57-75.

der Heide, E.A. 2004. Common misconceptions about disasters: Panic, the "Disaster Syndrome," and looting, in M. O' LEARY, M. (Ed.), *The First 72 Hours: A Community Approach to Disaster Preparedness*. Lincoln, Nebraska, Universe Publishing, 340-380.

Dewey, J. 1895-98. Ethical principles underlying education. In: Boydston, J. (ed.). *The early works*. Carbonale: Southern Illinios University press, pp. 54-83.

Dewey, J. 1910. How we think. Reprinted In: Archambault, R.D. (Ed.). 1964. *John Dewey on education*. Chicago: University of Chicago Press, pp. 242-260.

Dewey, J. 1916. Democracy and education. Reprinted In: McDermott, J.J. (Ed.). 1981. *The philosophy of John Dewey*. Chicago: University of Chicago Press, pp. 483-506.

Dewey, J. 1925. *Experience and Nature*. New York: Dover.

Dewey, J. 1934. *Art as experience*. New York: Dover.

Dias, U.M. 1936. *História do valle das Furnas*. Empressa Tip Lda. Vila Franca do Camp, pp. 159.

Dibben, C.J.L. 1999. Looking beyond eruptions for an explanation of volcanic disasters: Vulnerability in volcanic environments. Ph.D. Thesis, University of Luton.

Dibben, C.J.L. 2008. Leaving the city for the suburbs - The dominance of 'ordinary' decision making over volcanic risk perception in the production of volcanic risk on Mt Etna, Sicily. *Journal of Volcanology and Geothermal Research* 172, 3-4, 288-299.

Dibben, C., Chester, D.K. 1999. Human vulnerability in volcanic environments: The case of Furnas Volcano, São Miguel, Azores. Journal of Volcanology and Geothermal Research 92, 133-150.

Dickie, J. 2000. Darkest Italy. The Nation and Stereotypes of the Mezzogiorno, 1860–1900. Macmillan, London.

Dickie, J. 2011. Blood brotherhoods. The Rise of the Italian Mafias. Hodder, London.

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

Dobran, F. 2000. Mitigation of volcanic disasters in densely populated areas. (http://www.2.ios.com/~dobran/publ.htm) – Last accessed 1/03/13.

Dolomieu, D. 1792. *Precis d'un voyage fait a l'Etna en Juin 1781. Description de l' eruption de l' Etna en juillet 1787. Sur l'eruption de l'Etna en 1792*. De Drée, Paris.

Dow, K. 1992. Exploring differences in our common future(s): the meaning of vulnerability to global environmental change. *Geoforum* 23, 417-436.

Dull, R.A., Southon, J.R. Sheets, P.D. 2001. Volcanism, ecology and culture: a reassessment of the Volcán Ilopango TBJ eruption in the southern Maya Realm. *Latin American Antiquity*, 12, 25-44.

Duncan, A.M., Chester, D.K., Guest, J.E. 1981. Mount Etna Volcano : Environmental Impact and Problems of Volcano Prediction. *The Geographical Journal* 147, 2, 164-178.

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

Duncan, A.M., Gaspar, J., Guest, J., Wilson, L. 1999. Introduction: Special Issue Furnas Volcano, São Miguel, Azores. *Journal of Volcanology and Geothermal Research* 92, vii-ix.

Duncan, A.M., Chester, D.K., Guest, J.E. 2005. Eruptive Activity of Etna before A.D. 1600, with Particular Reference to the Classical Period. In: Balmurth, M.S., Chester, D.K., Johnston, P.A. (Eds.), *Cultural Responses to the Volcanic Landscape: The Mediterranean and Beyond*. Colloquia and Conference Papers 8, Archaeological Institute of America, Boston, pp. 57-69.

EM-DAT – The OFDA/CRED International Disaster Database – (http://www.emdat.be) – Last accessed 31/01/13.

Fazzello T. 1558. *De Rebus Siculis decades duae, nunc primum in lucem editae, his accessit totis operis index locupletissimus*. Folio Panormi.

Finley, M.I., Mack-Smith, D., Duggan, C.J.H. 1986. *A History of Sicily*. London.
Filoteo, A. 1590. *Aetna topografia atque ejus incrediorum istoria*. Venetis Muschius exc. pp. 32.

Fernandes, R.M.S., Bastos, L., Miranda, J.M., Lourenço, N., Ambrosius, B.A.C., Noomen, R., Simons, W. 2006. Defining the plate boundaries in the Azores region. *Journal of Volcanology and Geothermal Research* 156, 1-9.

Ferlito, C., Viccaro, M., Nicotra, E., Cristofolini, R. 2012. Regimes of magma recharge and their control on the eruptive behaviour during the period 2001-2005 Mt. Etna volcano. *Bulletin of Volcanology* 74, 2, 533-543.

Ferrara, F., 1818. *Descrizione dell' Etna con Soils of Volcanic Regions in Europe la storia delle eruzioni e il catalogo dei prodotti*. Press Lorenzon Dato, Palermo.

Ferreira, M.A. 2008. Classificação dos danos no edificado com base na EMS-98. Sismo de 1998 - Açores.

Ferreira, M.A., Oliveira, C.S. 2008. Overall impact of July 9, earthquake. Ten years later. *Azores 1998 - International Seminar on Seismic risk and rehabilitation of stone masonry housing*. pp.9.

Filson, J.R. 1987. Geological hazards: Programs and research in the U.S.A. *Episodes* 10, 4, 292-295.

Finetti, I., Morelli, C. 1794. Esplorazione sismica a riflessione nei golfi di Napoli e Pozzuoli. Boll Geof. Teor. Appl. 16, 175-222.

Fisher, R.J., Heiken, G., Hulen, J.B. 1997. *Volcanoes: Crucibles of Change*. Princeton University Press: Princeton, New Jersey.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C.S., Walker, B., Bengtsson, J., Berkes, F., Colding, J. 2002. *Resilience and sustainable development: building adaptive capacity in a world of transformations*. Scientific Background Paper on Resilience presented for the process of The World Summit on Sustainable Development. The Environmental Advisory Council to the Swedish Government, Stockholm.

Fortuna, M.J.A., 1988. A população activa dos Açores e a sua distribuição sectorial. Arquipélago (Revista da Universidade dos Açores, Economia) 1, 41-59.

Frazzetta, G., Villari, L. 1981. The feeding of the eruptive activity of Etna volcano. The regional stress field as a constraint to magma uprising and eruption. *Bulletin Volcanologique* 44, 3, 269-282.

Freeth, S.J. 1993. On the problems of translation in the investigation of the Lake Nyos disaster. *Journal of Volcanology and Geothermal Research* 54, 353-356.

Fried, M. 1963. Grieving for a lost home, In: Duhl, L.J. (Ed) *The Urban Condition*. Basic Books, New York, pp. 151–171.

Furchheim, F. 1897. Bibliografia del *Vesuvio. Napoli, pp.297.*

Gaillard, J-C., 2007. Resilience of traditional societies in facing natural hazards. *Disaster* Prevention and Management 16, 4, 522-544.

Gaillard, J-C., Texier, P. 2008. Natural hazards and disasters in Southeast Asia: Guest editorial. *Disaster Prevention and Management* 17, 3, 346-349.

Gallagher, T. 1981. Portugal's Beria: General Santos Costa and the 1926-1974 dictatorship. History Today 32, 2, 42-46.

García-Acosta, V. 2002. Historical Disaster Research. In: Hoffman, S.M. and Oliver-Smith, A. (Eds.), *Catastrophe and Culture.* James Currey, Oxford, pp. 49-66.

Garonna, P. 2011. *The importance of insurance for disaster risk reduction policies: Lessons from the crisis*. Associazione Nazionale fra le Impresse Assicuratrici, Roma.

Gaspar, J.L., Wallenstein, N., Coutinho, R., Ferreira, T., Queiroz, G., Pacheco, J., Guest, J., Tryggvason, E., Malheiro, A. 1997. Considerações sobre a ocorrência dos movimentos de massa registados na madrugada de 31 de Outubro de 1997 na ilha de S. Miguel, Açores. Universidade dos Açores, Centro de Vulcanologia, Relatório Técnico-Cientifico 14/DGUA/97.

Gaspar, J.L., Goulart, C., Queiroz, G., Silveira, D., Gomes, A., 2004. Dynamic structure and data sets of a GIS database for geological risk analysis in the Azores volcanic islands. *Natural Hazards and Earth System Sciences* 4, 233-242.

Gaspar, J.L., Queirós, G., Ferreira, T. 2007. Geological hazards at the Azores region. *Volcanic Rocks - Proceedings of the International Workshop on Volcanic Rocks, Workshop W2 - 11th Congress ISRM*, 11-18.

Garonna, P., 2011. The importance of insurance for disaster risk reduction policies:
Lessons from the crisis. Associazione Nazionale fra le Impresse Assicuratrici, Roma
(http://www.protezionecivile.gov.it/resources/cms/documents/Hyogo_paolo_garonna.pdf).

Gemmellaro, M., 1809. Memoria dell'eruzione dell' Etna avvenuta nel-l'anno 1809. Giovanni del Nobolo, Messina.

Gemmellaro, C., 1858. *La vulcanologia dell' Etna. La topografia, la geologia, la storia delle sue eruzioni, la descrizione e lo esame de'fenomeni vulcanici.* Accademia Gioenia di Catania, Catania.

Gemmellaro, G.G. 1885a. *Carta Geologica d'Italia alla scala 1:100.000: Bronte*. Roma, C. Virano.

Gemmellaro, G.G. 1885b. *Carta Geologica d'Italia alla scala 1:100.000: Monte Etna*. Roma, C. Virano.

Gentile-Cusa, B. 1886. *Sulla eruzione dell' Etna di Maggio-Giugno 1886.* Catania, Tipografia Francesco Martinez.

Giocomelli, L., Pesaresi, C. (undated). *La Struttura e la storia eruttiva dell' Etna*. Gruppo Nazionale per la Volcanologica, Instituto Nazionale di Geofisica e Vulcanologia.

Gomes, A., Gaspar, J.L., Goulart, C., Queiroz, G., 2005. Evaluation of landslide susceptibility of Sete Cidades Volcano (S. Miguel Island, Azores). *Natural Hazard and Earth System Sciences* 5, 251-257.

Grünthal, G. 1998. European Macroseismic Scale 1998. Luxenbourg, Conseil de L'Europe Cahiers du Centre Européen de Géodynamique et de Séismologie vol. 15.

Guest, J. E., Gaspar, J. L., Duncan, A. M., Queiroz, G, Cole, P. D., Wallenstein, N., Ferreira, T. 1994. *Preliminary report on the volcanic geology of Furnas Volcano, Sao Miguel, The Azores.* Open File Report 1, CEC Environment: ESF Laboratory Volcano, Furnas, Azores, Planetary Image Centre, University College, London.

Guest, J.A., Gaspar, J.L., Cole, P.D., Queiroz, G., Duncan, A.M., Wallenstein, N., Ferreira, T., Pacheco, J-M. 1999. Volcanic geology of Furnas Volcano, São Miguel, Azores. *Journal of Volcanology and Geothermal Research* 92, 1-29.

Guest, J.E., Cole, P., Duncan, A.M., Chester, D.K. 2003. Volcanoes of Southern Italy. Geological Society, London.

Hamilton, Sir. W. 1768-72. Observations on Mount Vesuvius, Mount Etna, and other Volcanoes: In a series of letters, addressed to the Royal Society to which are added Explanatory Notes by the author, hitherto unpublished. *Philosophical Transactions Royal Society London* 57 - 61.

Hamilton, Sir. W. 1771. Account of a journey to Mount Etna in a letter to Matthew Maty. *Philosophical Transactions Royal Society London* 60, 1-20.

Hamilton, Sir. W. 1772. *Observations on Mount Vesuvius, Mount Etna and Other Volcanoes of the Two Sicilies*. London.

Hamilton, Sir. W. 1776. *Campi Phlegraei. Observations on the Volcanoes of the Two Sicilies*. Naples.

Hamilton, Sir. W. 1779. *Supplement to Campi Phlegraei being an account of the great eruption of Vesuvius in the month of August*. Naples.

Hamilton, Sir. W. 1795. An Account of the Late Eruption of Mount Vesuvius in a Letter to Sir Joseph Banks. *Philosophical Transactions Royal Society London* 73-116.

Hamilton, R. 1999. Natural Disaster Reduction in the 21st Century. In: Ingleton, J. (Ed.). *Natural Disaster Management*. Leicester, 304-307.

Hansell, A.L., Horwell, C.J., Oppenheimer, C. 2006. The health hazards of volcanoes and geothermal areas. *Occupational and Environmental Medicine*, 63: 149-156.

Harris, S.L. 2000. Archaeology and volcanism. In: Sigurdsson, H., Houghton, B., Mc Nutt, S.R., Rymer H., Stix, J. (Eds.). *The Encyclopedia of Volcanoes*, San Diego: Academic Press, 1301-1314.

Hass, J.E., Kates, R.W., Bowden, M.J. 1977. *Reconstruction Following Disasters*. MIT Press: Cambridge, Mass.

Hazlett, R.W., Buesch, D., Anderson, J.L., Elan, R., Scandone, R. 1999. Geology, failure conditions and implications of seismogenic avalanches of the 1944 eruption at Vesuvius, Italy. *Journal of Volcanology and Geothermal Research* 47, 249-264.

Hewitt, K. 1980. Review: The Environment as Hazard. Annals Association of American Geographers 70, 2, 306-311.

Hewitt, K. (Ed.) 1983a. *Interpretations of Calamity*. Allen and Unwin, London, pp.304.

Hewitt, K. 1983b. *The idea of calamity in a technocratic age*. In Hewitt, K. (Ed.), Interpretations of Calamity, Allen and Unwin, London, 3-30.

Hewitt, K. 1997. Regions of Risk: A Geographical Introduction to Disasters. Longman, Harlow Essex, pp. 389.

Hewitt, K. 2012. Environmental disasters in social context: toward a preventive and precauionary approach. *Natural Hazards*, 1-12.

Hinshaw, R.E. 2006. *Living with Nature's Extremes: The Life of Gilbert Fowler White*. Boulder, Co: Johnson Books, pp. 339.

Hodge, D., Sharp, V., Marts, M. 1979. Contemporary responses to volcanism: Case studies from the Cascades and Hawaii. In: Shetts, P.D., Grayson, D.K. (Eds.). *Volcanic Activity and Human Ecology*. New York: Academic Press, pp. 221-227.

Hood, A.N. 1915. *Sicilian Studies*. George Allen and Unwin, London.

Hooke, J.M., Kain, R.J.P. 1982. Historical change in the physical environment: a guide to sources and techniques. In: Gregory, K.J. (Ed.), *Studies in Physical Geography,* Butterworth Scientific, London.

Hornblower, S. 2011. *The Greek World 479-323 B.C.* Taylor & Francis: London.

Hughes, J.W., Guest, J.E., Duncan, A.M., 1990. Changing styles of effusive eruption on Mount Etna since AD 1600. In: Ryan, M.P. (Ed.), Magma transport and storage. John Wiley, Chichester, 385-406.

Hurt, D.R. 1981. *An Agricultural and Socail History of the Dust Bowl*. Chicago: Nelson Hall, pp. 214.

Hutton, J. 1788. Theory of the Earth: or an investigation of the laws observable in the composition, dissoultion and restoration of land upon the globe. *Transactions of the Royal Society of Edinburgh* 1, 209-304.

Hyde, W.W. 1916. The volcanic history of Etna. *Geographical Review* 1, 401-418.

Imbò, G. 1928. Osservazione a richerch in relaziobe all'eruzione etnea 2-20 November 1928. *Bulletin Volcanologique* 15–18, 89–119.

Imbò, G. 1951. Attivita eruttiva vesuviana e relative osservasioni dell'intervallo intereruttivo 1906-1944 ed in particolare del parossismo del Marzo 1944. *Annali Osservatorio Vesuviano Napoli* (*unico celebrativo del centenario dell'Osservatorio Vesuviano*) 5, 185-380.

INEP, 2001. Recenseamento geral da Agricultura Açores 1999. Lisboa, Instituto National de Estastistica, Lisboa.

INEP, 2002. Censos 2001: XIV Recenseamento Gerald a População, IV Recenseamento Geral da Habitação. Lisboa, Instituto National de Estastistica.

Istituto Nazionale di Statistica (ISTAT), 2011.

Istituto Nazionale di Geofisca e Vulcanologia, Catania (http://www.ct.ingv.it/ufs/macro/).

Jaggar, T. A. 1928a, Eruption of Etna, *The Volcano Letter*, No. 202.

Jaggar, T. A. 1928b, The eruption of Etna, *The Volcano Letter*, No. 204.

Jaggar, T. A. 1929, More about Etna, *The Volcano Letter,* No. 211.

Johnston, R.J. 1979. *Geography and Geographers: Anglo-American Human Geography since 1945*. Edward Arnold, London.

Johnston-Lavis, H.J. 1891. *The Southern Italian Volcanoes*. Naples, Furchheim.

Johnston-Lavis, H.J. 1909. The eruption of Vesuvius in April 1906. *Scientific Transactions of the Royal Dublin Society of London*, London. pp.283.

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

Kauahikaua, J., Camara, B. 2000. The most recent eruptions of Haulālai volcano, Hawai'i: geological evidence from the historical record. In: McCoy, F., Heiken, G. (Eds.). *Geological Hazards and Antiquity*. Geological Scoeity of America Special Paper, vol. 345, pp. 25-32.

Kauahikaua, J., Cashman, K.V., Clague, D.A., Champion, D., Hagstrum, J.T. 2002. Emplacement of the most recent lava flows on Haulālai Volcano, Hawai'i. *Bulletin of Volcanology* 64, 229-253.

Kennedy, F. 2001. Sicilian pray as technology fails to stop lava. *The Independent* (London), 10 July, page 30.

Kilburn, C., McGuire, B. 2001. *Italian Volcanoes*. Harpenden: Terra Publishing.

Kilpatrick, F.P. 1957. Problems of perception in extreme situations. *Human Organization* 16, 2, 20-22.

King, R. 1971. Mediterranean island in torment. *Geographical Magazine* 44, pp. 178-185.

King, R. 1973. Sicily. David and Charles, Newton Abbot.

King, R., Strachan, A. 1978. Sicilian agro-towns, Erdkunde, 32, 110-123.

Kircher A. 1678. Mundus Subterraneus, in XII libros degustus, 3rd edition (2 vols), (1st edition in Amsterdam in 1664-5).

Kirsch, J.P., 1907-14. Agatha. In: Hebermann, C.B., Pallen, C.B., Shahan, T.J., Wynn, J.J. (Eds.), *Catholic Encyclopedia: An International Work of Reference on the Catholic Church, vol. 1*. The Encycopedia Press, New York, pp. 203–204.

Knight, F. 1921. *Risk, uncertainty and profit*. Boston, Houghton Mifflin Co.

Kozák, J., Čermák, V. 2010. *The Illustrated History of Natural Disasters*. Springer: London.

Krause, D., Watkins, N. 1970. North Atlantic crustal genesis in the vicinity of the Azores. *Geophysical Journal. Royal Astronomical Society* 19, 261-283.

Lacroix, A. 1906. *L'eruption du Vésuve en 1906.* Revue Générale des Sciences, 20 and 21 (20 October et 14 Novembre – A. Colin, Paris), no page numbers.

Lacroix, A. 1908. *La Montagne Pelée après ses eruptions, avec observations sur les eruptions du Vésuve en 79 et en 1906*. Masson, Paris, pp. 138.

Langworthy M. 1987. Dairying in the Azores. In: Pearson, S.R., Avillez, F., Bentley, J.W., Finan, T.J., Fox, R., Josling, T., Langworthy M. Monke E., Tangerman S., *Portuguese agriculture in transition*. Itheca, Cornell University Press, 124-140.

Lains, P. 2003. Portugal's growth paradox 1870-1950. Investigação – Trabalhos em Curso (Faculdade de Economia do Porto), pp. 135.

Lechet, M.F. 1990. The International Decade for Natural Disaster Reduction: Background and objectives. *Disasters* 14, 1, 1-6.

Leibniz, G.W von 1712. Essais de Théodicée sur la bonté de Dieu, a la liberté de l'homme et l'origine du mal. Microfilm Research Publications, New Haven, microfilm (1973).

Leibniz, G.W. von 1952. *Theodicy*. Routledge and Kegan Paul, London (edited by Austin Farrer, English translation by E.M. Huggard), pp. 448.

Leighton, R. 1999. Sicily before history: an archaeological survey from the Palaeolithic to the Iron Age. Duckworth, London.

Lewis, D.J., Smith, R. 1980. *American sociology and pragmatism: Mead, Chicago sociology and symbolic interaction*. Chicago, University of Chicago Press.

Lewis, P.H. 2002. *Latin Fascist Elites*. Praeger, Westport CT, pp. 209.

Ligresti, D. 2002. *Dinamiche Demografiche nelle Sicilia Moderna (1505-1806).* Milano, Franco Angeli.

Lirer, L., Chirosca, M.C., Nunno, R., Petrosino, P., Grimaldi, M. 2005. *Il Vesuvio Ieri, Oggi, Domani*. Regione Campania, Napoli, pp.150.

Lobão, C.M.G. 2008. Capelinhos, fifty years later. The chronology of the eruption. In: Goulart, T. (Ed.), Capelinhos, a Volcano of Synergies. Azorean Emigration to America. Portuguese Heritage Publications of California, San Jose CA, pp.45-52.

Lourenço, N., Miranda, J.M., Luis, J.F., Ribeiro, A., Mendes Victor, L., Madeira, J., Needham, D. 1998. Morphotectonic analysis of the Azores Volcanic Plateau from a new bathymetric compilation of the area. *Marine Geophy. Res*. 20, 141-156.

Louvat, P., Allègre, C.J. 1998. Riverine erosion rates on São Miguel volcanic island, Azores archipelago. *Chemical Geology* 148, 177-200.

Low, S.M., Altman, I. 1992. Place Attachment: A Conceptual Inquiry. In: Altman, I., Low, S.M. (Eds.), *Place Attachment*. Plenum, New York, pp. 1–12.

Luhr, J. F., Simkin, T. 1993. Parícutin: The Volcano Born in a Mexican Cornfield. Geoscience Press, pp. 427.

Luongo, G. Cubellis, E., Obrizzo, F., Petrazzuoli, S. 1991. A physical model for the origin of volcanism of the Tyrrhenian margin: the case of the Neapolitan area. *Journal of Volcanology and Geothermal Research* 48, 173-86.

Lyell, C. 1830. *Principles of geology, being an attempt to explain the former changes of the Earth's surface, by reference to causes now in operation*. vol. 1. London: John Murray.

Lyell, C. 1835. *Principles of Geology, vol. 3*. Fourth Edition. John Murray and Co., London.

Lyell, C., 1858. On the structure of lavas which have consolidated on steep slopes; with remarks on the Mode of Origin of Mount Etna, and on the Theory of “Craters of Elevation.” *Philosophical Transactions of the Royal Society of London* 148, 703-86.

Macdonald, G.A. 1972. *Volcanoes*. New Jersey: Prentice Hall.

Macdonald, N., Chester, D.K., Sangster, H., Todd, B., Hooke, J. 2012. The significance of Gilbert F. White’s paper ‘Human adjustments to floods’ in the development of risk and hazard management. *Progress in Physical Geography* 36, 1, 125-133.

Machado, F. 1959. Submarine pits of the Azores plateau. *Bulletin of Volcanology*, 109-116 Série II, Tome XXI.

Machado, F., Parsons, W.H., Richards, A.F., Mulford, J.W. 1962. Capelinhos eruption of Fayal Volcano, Azores, 1957-1958. *Journal of Geophysical Research* 67, 9, 3519-3529.

Machado F., Forjaz V.H. 1968. *Actividade Vulcanica Do Faial 1957-67*. Ponta Delgardo.

Mack-Smith, D. 1968. *A History of Sicily: Vol. 2. Medieval Sicily 800-1713*. Chatto and Windus, London.

Madeira, J., Ribeiro, A. 1990. Geodynamic models of the Azores triple junction: a contribution from tectonics. *Tectonophysics* 184, 405-415.

Malheiro, A., 2006. Geological hazards in the Azores archipelago: Volcanic terrain instability and human vulnerability. *Journal of Volcanology and Geothermal Research* 156, 158-171.

Maniscalo, L. 2005. The prehistoric settlement near Salinelle di San Marco (Paterno, Catania Province, Sicily). In: Balmuth, M.S., Chester, D.K., Johnston, P.A. (Eds.), *Cultural Responses to Volcanic Landscape*, 127-142. Massachusetts, Archaeological Institute of America Colloquia and Conference Papers 9.

Manyena, S.B., O' Brien, G., O'Keefe, P. and Rose, J. 2011. Disaster resilience: a bounce back or bounce forward ability? Local Environment 16, 5, 417-424.

Martins, V.N., Sousa e Silva, D., Cabral, P. 2012. Social vulnerability to seismic risk using multicriteria analaysis: the case of Vila Franca do Campo (São Miguel Island, Azores, Portugal). *Natural Hazards* 62, 385-404.

Marques, R., Coutinho, R., Queiroz, G. 2005. *Considerações sobre a ocorrência dos movimentos de vertente desencadeados pelos sismos de 20 e 21 de Setembro de 2005 no Fogo-Congro (Ilha de São Miguel).* Caracterização e análise de cenários.Universidade dos Açores, Centro de Vulcanologia e avaliação de Riscos Geológicos. Relatório Técnico-Ciêntifico 27/CVARG/05. pp. 36.

Marques, R., Coutinho, R., Queiroz, G. 2006. *Landslides and erosion induced by the 2005 Fogo-Congro seismic crisis (S. Miguel, Azores).* European Geosciences Union, Geophysical Research Abstracts, Vol. 8, ECU06-A-06925, SRef-ID: 1029-7006.

Marques, R., Queiroz, G., Coutinho, R., Zêzere, J.L., 2007. Actividade geomorfológica desencadeada pela crise sísmica de 2005 no Vulcão do Fogo (S. Miguel, Açores): avaliação da susceptibilidade com recurso a regressão logistica. Publicações da Associação Portuguesa de Geomorfólogos 5, 47-61.

Marques, R., Zêzere, J., Trigo, R., Gaspar, J., Trigo, I., 2008. Rainfall patterns and critical values associated with landslides in Povoação County (São Miguel Island, Azores): relationships with the North Atlantic Oscillation. *Hydrological Processes* 22, 4, 478-494.

Marianelli, P., Metrich, N. and Sbrana, A. 1999. Shallow and deep reservoirs involved in magma supply of the 1944 eruption of Vesuvius. *Bulletin of Volcanology* 61, 48-63.

Maravigna, C. 1811. Tavole sinottiche dell’Etna che comprendono la Topografia, la Storia delle eruzioni, la descrizione delle materie eruttate, e di alquanti fenomeni di questo volcano dietro le recent fisico-chimiche scoverte. Catania.

Martins, V.N., Sousa e Silva, D. and Cabral, P. 2012. Social vulnerability to seismic risk using multicriteria analaysis: the case of Vila Franca do Campo (São Miguel Island, Azores, Portugal). *Natural Hazards* 62, 385-404.

Matias, L., Dias, N., Morais, I., Vales, D., Carrilho, F., Madeira, J., Gaspar, J., Senos, L., Silveira, A. 2007. The 9th of July 1998 Faial Island (Azores, North Atlantic) seismic sequence. *Journal of Seismology*, 11, 3, pp. 275-298.

Masood, E. 1995. Row erupts over evacuation plans for Mount Vesuvius. *Nature*, 377, 471.

Matteucci, R.V. 1891. Sulla fase eruttiva del Vesuvio cominciata nel giugno 1891. *Atti R. Accad. Sci. Fis. Mat., Serie II*, 5-2, pp.594.

Mascolo, G. B. 1633. *De Incendio Vesuvii excitato XVII. Kal. Ianuar. anno trigesimo primo saeculi Decimiseptimi Libri X cum Chronologia superiorum incendiorum et Ephemeride ultimi*. Officina Roncalioli S., Naples, Italy.

Matthews, R. 1998. The Vesuvius Dilemma. *Sunday Telegraph*, (London), April 12, p.21.

McGuire, W.J. 1995a. Monitoring active volcanoes: An introduction. In: McGuire, W.J, Kilburn, C., Murray, J. (Eds.), *Monitoring Active Volcanoes*. UCL Press, London, 1-31.

McGuire, W.J. 1995b. Prospects for volcano surveillance. In W. J. McGuire, C. Kilburn, and J. Murray (Eds.) Monitoring Active Volcanoes. London, University College London Press, pp. 403-410.

McGuire, W.J. 1998. Volcanic hazards and their mitigation. In: Maund, J.G., Eddlestone, M. (Eds.). *Geohazards in Engineering Geology*. Geological Society London, Engineering Geology Special Publications 15, 79-95.

McGuire, W.J. 2002. *Natural Hazards and Environmental Change*. Arnold: London.

McGuire, W.J., Burton, P., Kilburn, C., Willetts, O. 2004. *World Atlas of Natural Hazards*. Arnold: London.

McGuire, W.J., Solana, M.C., Kilburn, C.R.J., Sanderson, D. 2009. Improving communication during volcanic crises on small, vulnerable islands. *Journal of Volcanology and Geothermal Research* 183, 63-75.

Mecatti, G.M. 1754. *Discrosi storico-filosofici sopra il Vesuvio*. De Simone, Napoli.

Mecatti, G.M. 1759. *Narrazione istorica di quell che è occorso al Vesuvio nel 1754-55-56-57-58-59.* Del Simone, Napoli, pp.270.

Melo, L.F. 2008. Sismo de 9 de Julho de 1998 - O investimento public associado ao processo de reconstrução e as suas fonts e formas de financiamento. In: Oliveira, C.S., Costa, A., Nunes, J.C (Eds.), Sismo 1998 - Açores uma década depois. Governo dos Açores, Ponta Delgada, pp.679-683.

Mercalli, G. 1883. Vulcani e fenomeni vulcanici in Italia. Milan (reprint, Sala Bolognese, Italy, 1981).

Milone, F. 1960. Sicilia: La natura e l’uomo. Paulo Boringhieri, Torino.

Miranda, J.M., Luis, J.F., Abreu, I., Mendes Victor, L.A., Galdeano, A., Rossignol, J.C. 1991. Tectonic framework of the Azores triple junction. *Geophys. Res. Lett*. 18 8, 1421–1424.

Mitchell, B. 1989. *Geography and Resource Analysis*. Burnt Mill, Harlow, Longman.

Mitchell, J.K. 1989. Hazard research. In: Gaile, G.L., Willmott, C.J. (Eds.), *Geography in America*. Columbus, OH: Merrill, 471-480.

Mitchell, J.K. 1990. Human dimensions of environmental hazards. In: Kirby, A. (Ed.). *Nothing to Fear: Risks and Hazards in American Society*. Tuscon, University of Arizona.

Monticelli, T. 1841. *Alcune escursioni fatte al Vesuvio dal 1823 al 1829*. Napoli.

Monticelli, T., Covelli, N. 1823. *Storias dei fenomeni del Vesuvio avvenuta negli anni 1821, 1822 e parte del 1823*. Giorn. Arcad., Roma, 327-337.

Moore, R.B., 1990. Volcanic geology and eruption frequency, São Miguel, Azores. *Bulletin of Volcanology* 52, 602-614.

Moore, R.B. 1991a. Geologic map of São Miguel, Azore. U.S. Geol. Surv. Misc. Invest. Ser. Map I — 2007, Scale 1:50,000.

Moore, R.B., 1991b. Geology of three late quaternary stratovolcanoes on São Miguel, Azores. US. Geol. Survey Bull. 1900.

Needham, H.D. Francheteau J. 1974. Some characteristics of rift valley in Atlantic Ocean near 36˚48' North. *Earth and Planetary Science Letters* 22, 29-43.

Neves, F., Costa, A., Vicente, R., Oliveira, C.S., Varum, H. 2012. Seismic vulnerability and characterisation of the buildings on Faial Island, Azores. *Bulletin of Earthquake Engineering* 10, 27-44.

Newhall, C.G., Self, S. 1982. The Volcanic Explosivity Index (VEI): An estimate of the explosive magnitude for historical volcanism. *Journal of Geophysical Research* 87 ©, 1231-1238.

Newhall, C. G. 1996. IAVCEI/International Council of Scientific Unions' Decade Volcano Projects: Reducing Volcanic Disaster. Status Report, US Geological Survey, Washington, D.C.

Nolan, M.L. 1979. Impact of Parıcutin on five communities. In: Sheets, P.D., Grayson, D.K. (Eds.), *Volcanic Activity and Human Ecology*. Academic Press, New York, pp. 293–338.

Nunn, P.D. 2001. On the convergence of myth and reality: examples from the Pacific Islands. *The Geographical Journal*, 167, 125-138.

O' Keefe, P., Westgate, K., Wisner, B. 1976. Taking the naturalness out of natural disaster. *Nature* 260, 566-7.

Magnus, O. 1555 History of the Nordic Peoples (Historia de Gentibus Septentrionalibus). Antwerp.

Oliveira, C.S. and Pais, I. 1995: Technical approaches for earthquake emergency planning: Recent applications to the city of Lisbon. In Horlick-Jones, T., Amendola, A. and Casale, R., editors, Natural risk and civil protection. London: E. and F.N. Spon, 58–72.

Oliveira, C.S., 2003. Seismic vulnerability of historical constructions: a contribution. *Bulletin of Earthquake Engineering* 1, 27-82.

Oliveira, C.S., Ferreira, M.A., Mota de Sá, F. 2012. The concept of a disruption index: application to the overall impact of July 9, 1998 Faial earthquake (Azores Islands). *Bulletin of Earthquake Engineering* 10, 7-25.

Ordem dos Engenheiros, 1955. Actas do Simpósio sobre a acção dos sismos. Ordem dos Engenheiros Lisboa. no page numbers.

Palm, R.I. 1990. *Natural Hazards: An Integrated Framework for Research and Planning*. Baltimore, Johns Hopkins Press.

Palmieri, L. 1859. Cronache del Vesuvio dal 1855 al 1859. *Annals Osservatorio Vesuviana*, Anno II, 46-78.

Palmieri, L. 1862. Cronache del Vesuvio dal 1852 al 1862. *Annals Osservatorio Vesuviana*, Anno II, 1-19.

Palmieri, L. 1865. Cronache del Vesuvio dal 1862 al 1865. *Annals Osservatorio Vesuviana*, Anno III, 71-73.

Palmieri, L. 1870. Ultime fasi della conflagrazione vesuviana del 1868. *Annals Osservatorio Vesuviana*, Anno IV, 25-38.

Palmieri, L. 1874. L'incendio Vesuviano del 26 aprile 1872. *Annals Osservatorio Vesuviana*, Anno I, 5-103.

Palmieri, L. 1895. Il Vesuvio dal 1875 al 1895. *Atti R. Accad. Sc. Fis. Mat., Serie II, VIII* 5, pp.18.

Paragallo, G. 1705. *Istoria Naturale del Monte Vesuvio*. Stamperia di Giacomo Raillard, Napoli, pp.428.

Pecora, A. 1968. *Sicilia.* Torinese Tipografico Editrice.

Perret, F.A. 1924. *The Vesuvius Eruption of 1906. Study of a Volcanic Cycle*. Carnegie Inst. Pub. 339. Washington, D.C.

Pesce, A. and Rolandi, G. 1994. *Vesuvio 1944: L' ultima eruzione*. S. Sebastiano al Vesuvio: Private Publication.

Pelling, M. 2001. Natural disaster? In: Castree, N., Braun, B. (Eds.), *Social Nature: Theory, practice and politics*. Blackwell: Oxford. pp. 170-188.

Pelling, M. 2003. *The Vulnerability of Cities: Natural Disasters and social resilience*. London: Earthscan.

Pelluzza, F (Monsignor): *Santi Fratelli Martiri Alfio, Fidadelfo e Cirino - Storia del 3 Novembre 1928.* Tipo. La Rocca, Giarre. (Brotherhood of Martyrs: Saints Alfio, Filadelfo and Cirino - History of the November 3, 1928).

Perry, R.W., Greene, M.R., Lindell, M.K. 1980. Enhancing evacuation warning compliance: suggestions for emergency planning. *Disasters* 4, 433–449.

Pinto, A.C. 1995. *Salazar's dictatorship and European Fascism. Problems of Interpretation. Social Science Monographs*. Columbia University Press, New York, pp. 223.

Pomonis, A., Spence, R., Baxter, P., 1999. Risk assessment of residential buildings for an eruption of Furnas Volcano, São Miguel, the Azores. *Journal of Volcanology and Geothermal Research*, 92, 107-131.

Principe. C., Tanguy, J-C., Arrighi, S., Paiotti, A., Le Goff, M., Zoppi, U. 2004. Chronology of Vesuvius' activity from A.D. 79 to 1631 based on archeomagnetism of lavas and historical sources. *Bulletin of Volcanology* 66, 703-724.

Proença, J., Gago, A.S., Cardoso, J., Paula, R. 2012. Development of an innovative seismic strengthening technique for traditional load-bearing masonry walls. *Bulletin of Earthquake Engineering* 10, 113-133.

Quarantelli, E.L. 1988. Disaster crisis management: A summary of research findings. *Journal of Management Studies* 25, 4, 373-385.

Quarantelli, E, L. (Ed.). 1998. *What is a Disaster?: Perspectives on the Question*. Routledge, London and New York, pp. 326.

Quarantelli, E.L. 1999. The Sociology of Panic, Disaster Research Centre, University of Delaware.

Querioz, G., Gaspar, J.L., Cole, P.D., Guest, J.E., Wallenstein, N. Duncan, A.M., Pacheco, J. 1995. Erupoções vulcanicas no vale das Furnas (Ilha de S. Miguel, Azores) na primeira metade do Seculo XV. *Açoreana* 8, 159-165.

Queiroz, G., Pacheco, J.M., Gaspar, J.L., Aspinall, W.P., Guest, J.E., Ferreira, T. 2008. The last 5000 years of activity at Sete Cidades volcano (São Miguel Island, Azores): implications for hazard assessment. *Journal of Volcanology and Geothermal Research* 178, 562-573.

Radice, B. 1928. Memorie storiche di Bronte. Stabilimento Tipografico Sociale, Bronte, vol.1.

Radice, B. 1936. Memorie storiche di Brotne. Stabilimento Tipografico Sociale, Bronte, vol.2.

Radice, B. 1969. *The Letters of the Younger Pliny*. Penguin, Harmondsworth.

Rampino, M. R., Self S. 1992. Volcanic winter and accelerated glaciations following the Toba supereruption. *Nature* 359, 50–52.

Reclus, J.E. 1865. Le Monte Etna et l'eruption de 1865. Revue des Deux Mondes 58, 110-138 (1 July 1865).

Recupero, G. 1815. Storia Naturale E Generale Dell'Etna. Dalla Stamperia Della Regia Università, Catania, 2 vols.

Reichhardt, T., Check, E., Marris, E. 2005. After the flood. *Nature* 437, 174-176.

Reisner, M. 1993. *Cadillac Desert: The American West and its Disappearing Water*. London, Penguin, pp. 608.

Ricciardi, G.P. 2009. *Diario del Monte Vesuvio: Venti Secoli Di Immagini e Cronache Di Un Vulcano Nella Città. Tomo III, XX seolo*. Institutio Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, pp. 651-894.

Rittmann, A. 1973. Structure and evolution of Mount Etna. *Philosophical Transactions of the Royal Society of London* 274A, 5-16.

Rivlin, L.G. 1987. The neighborhood, personal identity, and group affiliations. In: Altman, I., Wandersman, A. (Eds.), *Neighborhood and Community Environment*. Erlbaum, Hillsdale, HJ, pp. 441–488.

Rocha, G.P.N., 1988/89. Emigração e população Açoriana. Arquipélago (Revista da Universidade dos Açores, Ciêcias Socialis) 3/4, 29-43.

Rocha, G.P.N., 1990. A tranisição demográfica nos Açores. Arquipélago (Revista da Universidade dos Açores, Ciêcias Socialis) 5, 125-168.

Rochefort, R, 1961. *Le travail en Sicile Etude de Geographie Sociale*, Presses Universitaires de France, Paris.

Rodwell, G.F., 1878. *Etna: A History of the Mountain and of its eruptions*. Kegan Paul, London.

Rogers, M. 2007. The Portuguese in San Jose. Images of America, Arcadia, San Francisco, pp127.

Rolandi, G., Barrella, A.M., Borelli, A. 1993. The 1631 eruption of Vesuvius. *Journal of Volcanology and Geothermal Research* 58, 183-201.

Rolandi, G., Petrosino, P., McGeehin, J. 1998. The interplinian activity at Somma-Vesuvius in the last 3500 years. *Journal of Volcanology and Gethermal Research* 82, 19-52.

Rolandi, G., Munno, R., Postiglioni, R.I. 2004. The A.D. 472 eruption of the Somma volcano. *Journal of Volcanology and Geothermal Research* 129, 291-319.

Rolandi, G. 2010. Volcanic hazard at Vesuvius: An analysis for the revision of the current emergency plan. *Journal of Volcanology and Geothermal Research* 189, 347-362.

Romano, R. Sturiale, C., 1982. *The historical eruptions of Mt. Etna (volcanological data)*. In: Romano, R. (Ed.). Mount Etna Volcano, a Review of the Recent Earth Science Studies. Memorie Della Società Geologica Italiana 23, 75-97.

Rosa, M.E., Pereira, J.F. 2008. Capelo and Praia do Notre, before during and after the volcano 1957-1958. In: Goulart, T. (Ed.), Capelinhos, a Volcano of Synergies. Azorean Emigration to America. Portuguese Heritage Publications of California, San Jose CA, pp.53-66.

Rosi, M., Principe, C., Vecci, R. 1993. The 1631 eruption of Vesuvius reconstructed from the review of chronicles and study of deposits. *Journal of Volcanology and Geothermal Research* 58, 151-182.

RSA, 1983. Regulamento de Segurança e Acções para Estruturas de Edifícios e Pontes. Casa da Moeda, Imprensa Nacional, Dec-Lei 349-C/83 de 30 de Julho.

Rucker, D. 1969. *The Chicago pragmatists*. Minneapolis, University of Minnesota.

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

Sangster, H., Duncan, A.M., Chester, D.K. 2012. Religions and Hazards. In: Bobrowsky, P. (Ed.), *Encyclopedia of Natural Hazards*. Springer, Heidelberg.

Santacroce, R. 1987. Somma-Vesuvius. Consiglio Nazionale delle Ricerche, Quaderni de ‘La Ricerca Scientifica’, Roma, 114,8, (includes a geological map).

Santacroce, R., Cioni, R., Marianelli, P., Sbrana, A. 2005. Understanding Vesuvius and Preparing for Its Next Eruption. In: Balmurth, M.S., Chester, D.K., Johnston, P.A. (Eds.), *Cultural Responses to the Volcanic Landscape: The Mediterranean and Beyond*. Colloquia and Conference Papers 8, Archaeological Institute of America, Boston, pp. 27-55.

Sartorius Vön Waltershausen's, W., 1880. *Der Aetna*. W. Engelmann, Leipzig, 2 vols.

Scacchi, A. 1850. Relazione dell’incendio accaduto al Vesuvio nel mese di febbraio 1850, seguita dai giornalieri cambiamenti osservati in questo Vulcano dal 1840 sin’ora. *Rend. R. Accad. Sci. Fis. Mat*., IX, 13-48.

Scandone, R., Cortini, M., 1982. Il Vesuvio: un volcano ad alto rischo. Le Scienze, 162, 92-105.

Scandone, R., Giacomelli, L., Gasparini, P. 1993. Mount Vesuvius: 2000 years of volcanological observations. *Journal of Volcanology and Geothermal Research* 58, 5-25.

Scandone, R., Giacomelli, L., Speranza, F.F. 2008. Persistent activity and violent strombolian eruptions at Vesuvius between 1631 and 1944. *Journal of Volcanology and Geothermal Research* 170, 167-180.

Scarth, A. 2002. *La catastrophe: Mount Pelée and the destruction of Saint-Pierre, Martinique*. Harpenden : Terra.

Scarth, A. 2009. *Vesuvius: A biography*. Princeton University Press, Princeton and Oxford, pp. 342.

Schmincke, H-U. 2004. *Volcanism*. Berlin; New York: Springer.

Scifoni, S., Coltelli, M., Marsella, M., Proietti, C., Vicari, A., Del Negro, C., Cappello,A. 2010. *Mitigation of lava flow invasion hazard through optimized barrier configuration*. Cities on Volcanoes 6, Conference, Puerto de la Cruz, Tenerife, Canary Islands, pp. 161.

Scott, W.E. 1989. Volcanic and related hazards. In: Tilling, R.I. (Ed.). *A short Course in Geology, vol. 1, Volcanic Hazards*. Washington, D.C. American Geophysical Union, pp. 9-29.

Scrope, G. P. 1825. *Considerations on Volcanos: The probable causes of their phenomena, the laws which determine their march, the disposition of their products, and their connexion with the present state and past history of the globe; leading to the establishment of a new theory of the earth*. W. Phillips, London.

Searle, R., 1980. Tectonic pattern of the Azores spreading centre and triple junction. *Earth Planet. Sci. Lett.* 51, 415-434.

Senos, M.L., Gaspar, J.L., Cruz, J., Ferreira, T., Nunes, J.C., Pacheco, J., Alves, P., Queiroz, G., Dessai, P., Coutinho, R., Vales, D.E., Carrilho, F. 1998. O terramoto do Faial de 9 de Julho de 1998. Proceedings do 1 Simpósio de Meteorologia e Geofisca da APMG, Lagos Algarve, pp.61-68.

Serao, F. 1738. *Istoria dell'incendio del Vesuvio accaduto nel mese di maggio dell'anno 1737, scritta per I'Accademia delle Scienze*. De Bonis, Napoli, pp.122.

Siebert, L., and Simkin, T. 2010. Volcanoes of the World: an Illustrated Catalogue of Holocene Volcanoes and their Eruptions; Smithsonian Institution, Global Volcanism Program Digital Information Series. (http://www.volcano.si.edu/gvp/world).

Sigurdsson, H. 1999. *Melting the Earth: The History of Ideas on Volcanic Eruptions*. Oxford University Press, New York.

Sigurdsson, H. *Encyclopedia of Volcanoes*. Academic Press.

Simkin, T., Siebert, L. 1994. *Volcanoes of the World, 2nd edition*. Geoscience Press, Tucson, pp. 349.

Simon, H.A. 1957. *Administrative Behaviour*. Macmillan, New York.

Simon, H.A. 1959. Theories of decision making in economic and behavioural science. *American Economic Review* 49, 253-283.

Simonetti, P. 1983. *Il Vesuvio San Giorgio e le Feste*. Napoli.

Silvaggio M. 1542. *Descriptio montis Aetnei cum suis horrendis ignibus. Opus de tribus peregrinis. Venetiis anno virginei partus MDXLII*. Bibl. Nazionale di San Marco, Venice, pp. 154–161.

Silveira, D., Gaspar, J.L., Ferreira, T., Queiroz, G., 2003. Reassessment of the historical seismic activity with major impact on S. Miguel Island (Azores). *Natural Hazards and Earth System Sciences* 3, 615-625.

Silvestri, O. 1886. *Le recente eruzione dell" Etna.* Nuovo Antol. Ser. 3, 4, 22-36 (Nuova Antologia di Scienze Lettere ed Arti. Firenze).

Silva, J.L.M.P. 2008. The arrival of the immigrants and how they were received: In: Goulart, T. (Ed.), Capelinhos, a Volcano of Synergies. Azorean Emigration to America. Portuguese Heritage Publications of California, San Jose CA, pp. 137-144.

Smith, K. 2013. *Environmental Hazards: Assessing Risk and Reducing Disasters*. Sixth Edition. Taylor and Francis, Routledge, London.

Smolenaars, J.J.L. 2005. Earthquakes and Volcanic Eruptions in Latin Literature: Reflections and Emotional Responses: In: Balmurth, M.S., Chester, D.K., Johnston, P.A. (Eds.), *Cultural*

Responses to the Volcanic Landscape: The Mediterranean and Beyond. Colloquia and Conference Papers 8, Archaeological Institute of America, Boston, pp. 311-329.

Solana, C. M., Kilburn, C.R.J., Rolandi, G. 2008. Communicating eruption and hazard forecasts on Vesuvius, Southern Italy. *Journal of Volcanology and Geothermal Research* 172, 308-314.

Solana, C.M. 2012. Development of unconfined historic lava flow fields in Tenerife: implications for the mitigation of risk from a future eruption. *Bulletin of Volcanology 74,* 2397-2413.

Somekh, B., Lewin, C. (Eds.). 2005. *Research methods in the social sciences*. Sage, London.

Sorrentino, I. 1734. *Istoria del Monte Vesuvio*. Severini, Napoli, pp. 224.

Spence, R., 2007. Saving lives in earthquakes: Successes and failures in seismic protection since 1960. *Bulletin of Earthquake Engineering* 5, 139-251.

Speranza, F., Branca, S., Coltelli, M., Caracciolo, F., Vigliotti, L. 2006. How accurate is “paleomagnetic dating”? New evidence from historical lavas from Mount Etna. *Journal of Geophysical Research*, 111, B12S33.

Speranza, F., Di Chiara, A., Rotolo, S.G. 2012. Correlation of welded ignimbrites on Pantelleria (Strait of Sicily) using paleomagnetism. *Bulletin of Volcanology* 74, 341–357.

SREA, 1993. XII Recenseamento geral da população. III Recenseamento geral da Habitacção 1991. Açores, Serviço Regional de Estatística dos Açores.

SREA, 2003. Principais Resultados Definitivos dos Censos 1991 e 2001. Serviço Regional Estatística dos Açores, Angra do Heroísmo, Açores.

SREA, 2006a. Os Açores em números 2005. Açores, Serviço Regional de Estatística dos Açores.

SREA, 2006b. Séries Estatísticas 1995-2005. Açores, Serviço Regional de Estatística dos Açores.

SREA, 2007. Os Açores em números 2006. Açores. Serviço Regional de Estatística dos Açores.

SREA, 2010a. Os Açores em números 2009. Açores. Serviço Regional de Estatística dos Açores.

SREA, 2010b. Anuário Estatístico da Região Autónoma dos Açores 2009. Açores, Serviço Regional de Estistí SREA, 1993. XII Recenseamento geral da população. III Recenseamento geral da Habitação 1991. Açores, Serviço Regional de Estatística dos Açores.

SREA, 2011a. Estimativas da População Residente. Açores. Serviço Regional de Estatístca dos Açores http://estatistica.azores.gov.pt:81/ReportServer/Pages/ReportViewer.aspx?%2fDemografia%2fEstimativas+da+Popula%c3%a7%c3%a3o+Residente&rs:Command=Render - Last accessed 20/5/11.

SREA, 2011b. Censos 2011: Resultados Preliminares. Açores. Serviço Regional de Estatístíca dos Açores.

SREA, 2011c. Dormidas segundo os Países de Residência, na Hotelaria Tradicional: São Miguel. http://estatistica.azores.gov.pt/upl/%7Bca1006ab-43b0-463e-826b-eb34e3b97ea1%7D.htm - Last accessed 28/5/11.

Starr, C. 1969. Social Benefit versus technological risk. *Science* 165, 1232-1238.

Stieglitz, A., 1990. *Landscapes of the Azores (Sao Miguel): A Countryside Guide*. Hodder, Australia, pp. 64.

Steinmetz, L., Hirn, A., Sapin, M., Whitmarsh, R., Moreira, V. 1976. Zone of P wave attenuation beneath the crest of Mid-Atlantic Ridge. *Bulletin of the Geological Society of France*, 4.

Stoddart, D.R. 1987. To reclaim the high ground: Geography for the end of the century. *Transactions of the Institute of British Geographers*, 12, 327-336.

Stommel, H.M., Stommel, E. 1983. *Volcano Weather: The Story of 1816, the Year Without a Summer*, Simon & Schuster, London pp. 177.

Stothers, R.B., Rampino, M.R. 1983. Volcanic Eruptions in the Mediterranean Before A.D. 630 From Written and Archaeological Sources. *Journal of Geophysical Research: Solid Earth*, 88, B8, 6357-6371.

Susman, P., O'Keefe, P.,Wisner, B. 1983. Global disasters, a radical interpretation. In: Hewitt, K. (Ed.), Interpretations of Calamity. Boston, Allen and Unwin, pp. 263-283.

Swanson, D.A. 2008. Hawaiian oral tradition describes 400 years of volcanic activity at Kilauea. *Journal of Volcanology and Geothermal Research* 176, 427-431.

Tazieff H., Sabroux J. C. 1983. *Forecasting volcanic events*. Elsevier, London pp. 635.

Tanguy, J-C. 1981. Les eruptions historiques de l’Etna: Chronologie et localisation. *Bulletin of Volcanology* 44, 586-640.

Tanguy, J-C., Ribière, Ch., Scarth, A., Tjetjep, W.S. 1998. Victims from volcanic eruptions: a revised database. *Bulletin of Volcanology* 60, 137-144.

Tanguy, J-C., Condomines, M., Le Goff, M., Chillemi, V., La Defa, S., Patanè, G., 2007. Mount Etna eruptions of the last 2,759 years: revised chronology and location through archeomagnetic and ^{226}Ra-^{230}Th dating. *Bulletin of Volcanology* 70, 55-83.

Tanguy, J-C., Condomines, M., Branca, S., La Delfa, S., Coltelli, M. 2012. *Italian Journal of Geosciences* 131, 2, 241-257.

Tilling, R.I. 1989. Volcanic hazards and their mitigation: Progress and problems. *Reviews of Geophysics* 27, 237-67

Tilling, R.I., Lipman, R.W. 1993. Lessons in reducing volcanic risk. *Nature* 364, 277-280.

Tilling, R.I. 2004. Volcano hazards. In: Martí, J., Ernst, G.G.J. (Eds.), *Volcanoes and the Environment*. Cambridge University Press: Cambridge, pp. 55-89.

Timmerman, P. 1981. *Vulnerability, resilience and the collapse of society*. Environmental Monograph 1. Toronto: Institute for Environmental Studies.

Tonini, R., Armigliato, A., Pagnoni, G., Zaniboni, F., Tinti, S. 2011. Tsunami hazard for the city of Catania, Eastern Sicily, Italy, assessed by means of Worse-case Credible Tsunami Scenarion Analysis (WCTSA). *Natural Hazards and Earth System Sciences* 11, 1217-1232.

Trindade, M.J.L., 1976. Portuguese emigration from the Azores to the United States during the nineteenth century. In: Studies in honour of the Bicentennial of American Independence. Lisboa, Luso-American Educational Commission and the Calouste Gulbenkian Foundation, pp. 237-295.

Uchrin, G. 1990. Olympiodorus's eruption of Mount Etna: A possible date of A.D. 417. *Eos, Transactions American Geophysical Union* 71, 11, 329-334.

United Nations, 1987. Resolution 42/169 (International Decade for Natural Disaster Reduction).

United Nations, 1990. *A Safer world in the twenty-first century: Risk and Disaster Reduction*.

United Nations, 1995. *Yokohama Strategy for a Safer World*.

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

United Nations, 2002. Living with Risk. Geneva, United Nations.

United Nations, 2005. Report on the World Conference on Disaster Reduction, Kobe, Hyogo, Japan, 18-22 January 2005. United Nations, Geneva GE.05-61029.

United Nations, 2011. Hyogo Framework for Action 2005-2015.
(http://www.unisdr.org/we/coordinate/hfa) – Last accessed 04/06/11.

Valadão, P., Gaspar, J.L., Queiroz, G. ,Ferreira, T. 2002. Landslide density map of S. Miguel Island, Azores archipelago. *Natural Hazards and earth System Sciences* 2, 51-56.

Valentine, G., Heiken, G. 1995. Volcanoes in Town, 27-30 September 1995. *IAVCEI Community Newsletter* 27, pp. 3-4.

Varone, S. 1634. *Vesuviani Incendii Historiae: Libri tres, Francisci Savii* Typogr. Naples, Italy.

Vinassa de Regny, P.A. 1911. *Visite ed osservazioni*. Accademia Gioenia di Scienze Naturali in Catania series 5, vol. V, Mem. XX, 23-37.

Viveiros, F., Ferreira, T., Cabral Vieira, J., Silva, C., Gaspar, J.L. 2008. Environmental influences on soil CO_2 degassing at Furnas and Fogo volcanoes (São Miguel Island, Azores archipelago). *Journal of Volcanology and Geothermal Research* 177, 4, 883-893

Viveiros, F., Cardellini, C., Ferreira, T., Catarina, S. 2012. Contribution of CO_2 emitted to the atmosphere by diffuse degassing from volcanoes: The Furnas Volcano case study. *International Journal of Global Warming (IJGW), 4, 3/4, 287-304.*

Vogt, P.R., Jung, W.Y. 2004. The Terceira Rift as hyper-slow hotspot-dominated oblique spreading axis: A comparison with other slow-spreading plate boundaries. *Earth and Planetary Science Letters* 218, 1-2, 77-90.

Wadge, G. 1977. The storage and release of magma on Mount Etna. *Journal of Volcanology and Geothermal Research* 2, 361-384.

Walker, G.P.L. 1974. Volcanic hazards and the prediction of volcanic eruptions. In: Funnell, B.M. (Ed.), *Prediction of Geological Hazards*. Geological Society of London, Miscellaneous Paper 3, pp. 23-41.

Walker, G.P.L. 1982. Volcanic hazards. *Interdisciplinary Science Reviews* 7, 2, 148-157.

Wallenstein, N., Duncan, A.M., Almeida, H., Pacheco, J. 1998. *A erupção de 1563 do Pico do Sapateiro, S. Miguel, Azores*. Espanha, I Asamblea Hispano-Portuguesa de Geodesia y Geofisica. Almeria.

Wallenstein, N., 1999. Estudo da histótia recente e do comporamento eruptivo do Vulcão do Fogo (S.Miguel, Açores). Avaliação preliminary do hazard. Tese de doutoramento no ramo de Geologia, especialidade de Vulcanologia. Universidade dos Açores, Depertamento de Geociêcias.

Wallenstein, N., Chester, D.K., Duncan, A.M. 2005. Methodological implications of volcanic hazard evaluation and risk assessment: Fogo Volcano, São Miguel, Azores. *Zeitschrift für Geomorphologie Suppl.* 140, 129-149.

Wallenstein, N., Duncan, A., Chester, D., Marques, R. 2007. Fogo Volcano (São Miguel, Azores): a hazardous edifice Le volcan Fogo, un édifice générateur d’aléas indirects. *Géomorphologie: relief, processus, environnement* 3, 259-270.

Wallenstein, N., Silva, R., Riedel, C., Lopes, C., Ibáñwz, J., Silveria, D, Montalvo, A. 2009. Recent developments in seismic studies in the Fogo-Congro area, São Miguel Island (Azores). In: Bean, C.J., Braiden, A.K., Lokmer, I., Martini, F., O'Brian, G.S. I (Eds.), The VOLUME Project: Volcanoes: Understanding subsurface mass movement. University of Dublin, School of Geosciences, pp. 207-216.

Warrick, R.A. 1979. Volcanoes as hazard: An overview. In: Sheets, P.D., Grayson, D.K. (Eds.), Volcanic Activity and Human Ecology. Academic Press, New York, 161-189.

Wescoat Jr, J.L. 1992. Common themes in the work of Gilbert White and John Dewey: A pragmatic appraisal. *Annals of the Association of American Geographers* 82, 4, 587-607.
Weston, F. 1964. List of recorded volcanic eruptions in the Azores with brief reports. *Bol. Mus. Lab. Min. Geol. Fac. Ciencias de Lisboa* 10, 3–18, 1964.

White, G.F. 1942. Human adjustments to floods. Unpublished Ph.D, Department of Geography, University of Chicago.

White, G.F. 1945. Human adjustments to floods. Research Paper 29. Department of Geography, University of Chicago, pp. 225.

White, G.F. 1972. Geography and public policy. *The Professional Geographer* 24, 101-104.

White, G.F., 1973. Natural hazards research: concepts, methods and policy implications. In: White, G.F. (Ed.), *Natural Hazards: Local, National, Global*. Oxford University Press, New York, pp. 3-16.

Whittow, J. 1980. *Disasters: The Anatomy of Environmental Hazards*. Pelican: Harmondsworth.

Whittow, J. 1987. Hazards-adjustment and mitigation. In: Clark, M.J., Gregory, K.J., Gurnell, A.M. (Eds.), Horizons in Physical Geography. Macmillan, London, 307-319.

Wheeler, D.L. 1981. "Nightmare Republic" Portugal 1910-1926. *History Today* 31, 9, 5-10.

Wijkman, A., Timberlake, L. 1984. *Natural Disasters: Acts of God or Acts of Man?* London and New York: Earthscan, International Institute for Environment and Development.

Williams, J.R., 1982. And Yet They Come: Portuguese Immigration from the Azores to the United States. Centre for Migration Studies, New York.

Winchilsea, Earl, 1669. *An exact relation of the famous earthquake and eruption of Mount Etna, or Mont-Gibello, A.D. 1669: Being one of the greatest recorded in history; now reprinted from a scarce pamphlet, containing a letter from the Earl of Winchilsea to His Majesty King Charles the second; together with a more particular narrative, collected from several other authentic materials. To which also is now added a genuine letter, written to a late noble peer, purposing to describe the last great eruption, as well as a journey to the very summit of Mount Etna in the year 1766.* J. Wilkie, St. Paul's Churchyard, London and E. Easton, Salisbury, 1775.

Wisner, B., Blaikie, P., Cannon, T. & Davis, I. 2004. *At Risk: Natural hazards, people's Vulnerability and Disasters*. Routledge, London.

Wolfe, E.W. 1992. The 1991 Eruptions of Mount Pinatubo, Philippines: Earthquakes and Volcanoes.

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

Zaman, M.Q. 1999. Vulnerability, disaster and survival in Bangladesh: three case studies. In: Oliver-Smith, A. and Hoffman, S. (Eds). *The Angry Earth: Disaster in anthropological perspective*. Routledge, London, pp. 192-212.

Zonno, G., Oliveira, C.S., Ferreira, M.A., Musacchio, G., Meroni, F., Mota-de-Sá, F., Neves, F. 2010. Assessing seismic damage through stochastic simulation of ground shaking: the case of the 1998 Faial earthquake (Azores Islands). *Surveys in Geophysics* 31, 361-381.

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

Zbyszewski, G., Veiga Ferreira, O. 1959. Rapport de la deuxiéme mission géologique sur le volcanisme de L'' Ille de Faial. *Serviços Geológicos de Portugal 4 (new series)*, 29-55.

Zbyszewski, G. 1961. Etude Geologique de l'ile de São Miguel (Açores). *Communications de la Service Geologique de* Portugal 45, pp. 5–79.

APPENDICES

The text and formatting presented in the Appendices are those applied within the final published papers and have not been standardised for the rest of this thesis, this reflects the pre-published content most closely.

APPENDIX 1

The significance of Gilbert F. White's 1945 paper 'Human Adjustment to Floods' in the development of risk and hazard management – paper published in *Progress in Physical Geography*. Miss Sangster wrote sections relating to natural hazards and was involved in the revision of draft editions of the paper.

Macdonald N., Chester D., Sangster H., Todd B. & Hooke J.

Abstract

Few publications may claim to have transcended the original field in which they were written, by shaping a wide range of research areas and philosophies. In this short paper we reflect on the manner in which Gilbert F. White's 1945 publication, *Human Adjustment to Floods*, has not only shaped how we study and perceive flooding, but has also had a significance beyond its original aims, revolutionising the ways in which hazard and risk are conceptualised more generally. Before considering the impact of *Human Adjustment to Floods*, we briefly review academic understanding of floods in the decades leading up to the 1940s and later place the 1945 paper in the context of White's subsequent contributions to research which both developed and built on his ideas.

Keywords Risk, Hazard, Gilbert F. White, Flood Management

Submitted 03/2011

Published 01/2012

This text box is where the unabridged thesis included the following third party copyrighted material:

Macdonald, N., Chester, D.K., Sangster, H., Todd, B., Hooke, J. 2012. The significance of Gilbert F. White’s paper ‘Human adjustments to floods’ in the development of risk and hazard management. *Progress in Physical Geography* 36, 1, 125-133.

This text box is where the unabridged thesis included the following third party copyrighted material:

Macdonald, N., Chester, D.K., Sangster, H., Todd, B., Hooke, J. 2012. The significance of Gilbert F. White's paper 'Human adjustments to floods' in the development of risk and hazard management. *Progress in Physical Geography* 36, 1, 125-133.

This text box is where the unabridged thesis included the following third party copyrighted material:

Macdonald, N., Chester, D.K., Sangster, H., Todd, B., Hooke, J. 2012. The significance of Gilbert F. White’s paper ‘Human adjustments to floods’ in the development of risk and hazard management. *Progress in Physical Geography* 36, 1, 125-133.

This text box is where the unabridged thesis included the following third party copyrighted material:

Macdonald, N., Chester, D.K., Sangster, H., Todd, B., Hooke, J. 2012. The significance of Gilbert F. White’s paper ‘Human adjustments to floods’ in the development of risk and hazard management. *Progress in Physical Geography* 36, 1, 125-133.

This text box is where the unabridged thesis included the following third party copyrighted material:

Macdonald, N., Chester, D.K., Sangster, H., Todd, B., Hooke, J. 2012. The significance of Gilbert F. White's paper 'Human adjustments to floods' in the development of risk and hazard management. *Progress in Physical Geography* 36, 1, 125-133.

This text box is where the unabridged thesis included the following third party copyrighted material:

Macdonald, N., Chester, D.K., Sangster, H., Todd, B., Hooke, J. 2012. The significance of Gilbert F. White's paper 'Human adjustments to floods' in the development of risk and hazard management. *Progress in Physical Geography* 36, 1, 125-133.

This text box is where the unabridged thesis included the following third party copyrighted material:

Macdonald, N., Chester, D.K., Sangster, H., Todd, B., Hooke, J. 2012. The significance of Gilbert F. White's paper 'Human adjustments to floods' in the development of risk and hazard management. *Progress in Physical Geography* 36, 1, 125-133.

This text box is where the unabridged thesis included the following third party copyrighted material:

Macdonald, N., Chester, D.K., Sangster, H., Todd, B., Hooke, J. 2012. The significance of Gilbert F. White's paper 'Human adjustments to floods' in the development of risk and hazard management. *Progress in Physical Geography* 36, 1, 125-133.

This text box is where the unabridged thesis included the following third party copyrighted material:

Macdonald, N., Chester, D.K., Sangster, H., Todd, B., Hooke, J. 2012. The significance of Gilbert F. White's paper 'Human adjustments to floods' in the development of risk and hazard management. *Progress in Physical Geography* 36, 1, 125-133.

APPENDIX 2

Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning – paper published in *Journal of Volcanology and Geothermal Research*. The history of Mount Etna's activity and how the inhabitants coped in the period from 1792/3 until 1923 has been reconstructed jointly by Dr. David Chester, Prof. Angus Duncan and the present author and has been summarised as part of Chapter 4. One-third of the bibliographic research and primary data collection carried out in the field and the revision of draft editions of the paper reflects the contribution from the present author.

David K Chester, Ph.D; Angus M Duncan, Ph.D; Heather Sangster, B.Sc

Abstract:

This paper summarises: the characteristics of eruptions that occurred between 1792/3 and 1923; the ways in which human responses evolved during the period and the lessons this history holds for the management of present-day volcanic and volcano-related disasters. People responded to eruptions at three levels: as members of a family and extended family; through the mutual support of a village or larger settlement and as citizens of the State. During the study period and with the exception of limited financial aid and preservation of law and order, the State was a minor player in responding to eruptions. Families and extended families provided shelter, accommodation and often alternative agricultural employment; while supportive villages communities displayed a well-developed tendency to learn from experience (e.g. innovating techniques to bring land back into cultivation and avoiding the risks of phreatic activity as lava encountered water and saturated ground) and providing labour to enable household chattels and agricultural crops to be salvaged from land threatened with lava incursion. Eruptions were widely believed to be 'Acts of God', with divine punishment frequently being invoked as a primary cause of human suffering. Elaborate rituals of propitiation were performed to appease a supposed angry God, but this world-view did not produce a fatalistic attitude amongst the population preventing people coping with disasters in a generally effective manner. Despite present day emergencies being handled by the State and its agencies, some features of nineteenth century responses remain in evidence, including salvaging all that may be easily removed from a building and/or agricultural holding, and explanations of disaster which are theistic in character. Lessons from eruptions that occurred between 1792/3 to 1923 are that the former should be encouraged, while the latter does not prevent people acting to preserve life and property or obeying the authorities. Earthquakes are one category of hazard that caused major damage during, or associated with, several historic eruptions especially those of 1865, 1883 and 1911. This study highlights the vulnerability of the Etna region to this hazard which remains largely un-ameliorated. Attempts to divert lava flows occurred during the 1832, 1879 and 1923 eruptions.

Highlights

Innovative use of archival data sources

Detailed reconstruction of eruptions 1792/3 to 1923

Detailed analysis of human responses during the study period

Implications of this historical study for present-day hazard planning

Submitted 12/2011

Published 5/2012

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

This text box is where the unabridged thesis included the following third party copyrighted material:

Chester, D.K., Duncan, A.M., Sangster, H. 2012. Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. *Journal of Volcanology and Geothermal Research* 225-226, 65-80.

APPENDIX 3

Mount Etna, Sicily: Vulnerability and Resilience during the Pre-Industrial Era – paper submitted as part of the conference proceedings of LaPaDiS (Laboratory for Past Disaster Science: Volcanic eruptions and prehistoric culture change).

Heather Sangster, B.Sc; David K Chester, Ph.D; Angus M Duncan, Ph.D

Abstract:

Mount Etna is one of the world's few continually active continental volcanoes and its frequent flank eruptions have been recorded since classical times. These studies have generated a vast literature which, not only enables the impact of eruptions, recovery from them and aspects of human vulnerability and resilience to be brought into focus, but also provides information that allows an assessment to be made of the interplay between environmental, economic and social forces which has shaped this area into Sicily's most distinctive region. In this paper we argue that a unique agriculturally-based society, largely developing indigenously and without significant outside assistance, evolved during a long pre-industrial era, which stretched from late antiquity until the 1950s. In terms of loss-bearing, responses were also typically pre-industrial, with the 1923 eruption denoting the close of this period. Responses were managed with relatively little outside help or intervention. The 1928 eruption marked a transition, after which responses involved progressively greater State intervention. In the pre-industrial era eruptions were managed at three levels: through limited State involvement; by mutual support within village communities, in which religious belief and explanations for losses provided both a social cement - the church often providing leadership and pastoral support - and a context in which losses could be explained; and by family and extended family groups. Finally we argue that these indigenous mechanisms of coping hold important lessons about how disasters on Etna may be managed today.

Key Words: Mount Etna, vulnerability, resilience, pre-industrial era, agriculture, eruptions

Submitted: 12/2012

Published: tbc 2013

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Chester, D.K., Duncan, A.M. 2013. *Mount Etna Sicily: Vulnerability and Resilience during the Pre-Industrial Era*. University of Aarhus, Denmark, Aarhus pp no page numbers.

APPENDIX 4

Religions and Hazards – paper published in *The Encyclopedia of Natural Hazards*. Bobrowsky, P.T. (Ed.) 2013, Springer, London, pp. 1135.

Heather Sangster, Angus M. Duncan and David K. Chester

Submitted: 1/2010
Published: 5/2013

This text box is where the unabridged thesis included the following third party copyrighted material:

Sangster, H., Duncan, A.M., Chester, D.K. 2012. Religions and Hazards. In: Bobrowsky, P. (Ed.), *Encyclopedia of Natural Hazards*. Springer, Heidelberg.

APPENDIX 5

FAIAL ROAD SURVEY 1999

This text box is where the unabridged thesis included the following third party copyrighted material:

Faial Road Survey (unpublished) undertaken by Professor Rui Coutinho.

This text box is where the unabridged thesis included the following third party copyrighted material:

Faial Road Survey (unpublished) undertaken by Professor Rui Coutinho.

This text box is where the unabridged thesis included the following third party copyrighted material:

Faial Road Survey (unpublished) undertaken by Professor Rui Coutinho.

This text box is where the unabridged thesis included the following third party copyrighted material:

Faial Road Survey (unpublished) undertaken by Professor Rui Coutinho.

This text box is where the unabridged thesis included the following third party copyrighted material:

Faial Road Survey (unpublished) undertaken by Professor Rui Coutinho.

This text box is where the unabridged thesis included the following third party copyrighted material:

Faial Road Survey (unpublished) undertaken by Professor Rui Coutinho.

This text box is where the unabridged thesis included the following third party copyrighted material:

Faial Road Survey (unpublished) undertaken by Professor Rui Coutinho.

This text box is where the unabridged thesis included the following third party copyrighted material:

Faial Road Survey (unpublished) undertaken by Professor Rui Coutinho.

This text box is where the unabridged thesis included the following third party copyrighted material:

Faial Road Survey (unpublished) undertaken by Professor Rui Coutinho.

This text box is where the unabridged thesis included the following third party copyrighted material:

Faial Road Survey (unpublished) undertaken by Professor Rui Coutinho.

This text box is where the unabridged thesis included the following third party copyrighted material:

Faial Road Survey (unpublished) undertaken by Professor Rui Coutinho.

APPENDIX 6

Interviews with scientists working at the Departimento de Geociencias, Universidade dos Açores

This text box is where the unabridged thesis included the following third party copyrighted material:

Interviews undertaken with scientists working at the Departimento de Geociencias, Universidade dos Açores by the present author.

This text box is where the unabridged thesis included the following third party copyrighted material:

Interviews undertaken with scientists working at the Departimento de Geociencias, Universidade dos Açores by the present author.