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Abstract: 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

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Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning

By

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1. Introduction

One of the many enduring contributions made by Gilbert F. White (1974, pp. 5) to the literature on hazards was his introduction of the three-fold classification: *pre-industrial* (or *folk*); *industrial* and *post-industrial* (or *comprehensive*), to describe the characteristic ways in which human responses are related to levels of economic development. The transition from *pre-industrial* to *industrial* (Table 1) may be sequential, but this is not normally the case because the characteristics of both types of response may be seen at the same time within different social groups in disaster prone regions (White, 1974; Chester et al., 2005). In our previously published work (Chester et al., 2007; Coutinho et al., 2010) we have argued that in the relatively poor countries of Southern Europe this transition generally occurred later than was the case in Northern Europe and North America. In Southern Italy and Sicily State control over disaster management may be dated to 1908, as exemplified by the Messina earthquake (Dickie, 2000), and 1928 in the case of volcanic eruptions, when the Fascist government led by Benito Mussolini acted in a purposeful manner when faced with a major flank eruption of Etna which destroyed the large agricultural village of Mascali (Fig. 1). Some *pre-industrial* elements, for example the use of religion to explain disaster losses were present, however, within this and many subsequent eruptions (Duncan et al., 1976; Chester et al., 1999, 2008). Conversely in earlier eruptions isolated examples of State involvement in, rather than control over, responses may be instanced from the classical era onwards and included: the Roman authorities granting a 10-year moratorium on the payment of taxes by the city of Catania following the eruption of 122 BC (Rodwell, 1878, pp. 82); and, during the largest historic eruption in 1669, the Spanish Viceroy sending troops to restore order and provided limited money to aid recovery (Mack-Smith, 1968). Limited State involvement also occurred throughout the nineteenth and early twentieth centuries (see section 4.1.3).

Since Gilbert White wrote nearly four decades years ago, the term *pre-industrial* has become well established in the hazard research literature (e.g. Helbling, 2007; Junela and Mauelshagen, 2007) and archival research now allows the impacts of Etna's eruptions between 1792/3 and 1923, a period we term the *long nineteenth century*[1], to be assessed using this framework. Many detailed contemporary and near contemporary accounts of eruptions are now readily available electronically, with examples including: Sicilian scientific journals, in particular the *Atti della Accademia gioenia di scienze naturali* (*Catania*); major research volumes, for instance Mario Gemmellaro's (1809) *Memoria dell'eruzione dell' Etna avvenuta nel-l'anno 1809* and Francesco Ferrara's (1818) *Descrizione dell' Etna con la storia delle eruzioni e il catalogo dei prodotti*; and international newspapers of record, especially the *New York Times* and the *Times* (London) both of which reported nineteenth century eruptions in considerable detail often using both their own correspondents and lengthy accounts from expatriates. In addition English language provincial newspapers often published accounts of eruptions and these are available electronically for the nineteenth century for both the U.S.A. and U.K.[2] Some important 19th century reference works are available as reprints, most notably

[1] The widely used term the *Long Nineteenth Century* was introduced by the British historian Eric Hobsbawm (1962) to describe the period between the start of the French Revolution in 1789 and the beginning to the First World War in 1914. In this paper it is extended to include the 1923 eruption, because responses had more in common with earlier eruptions than they had with the subsequent flank event which occurred in 1928.

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

Carlo Gemmellaro's (1858) *La Vulcanologia dell' Etna* (Cucuzza-Silvestri, 1989), whilst others may be obtained from copyright libraries. Particularly useful sources are Sartorius von Waltershausen's (1880) *Der Aetna* and late nineteenth century geological maps, especially the *Carta Geologica 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). In addition evidence about the destruction caused by these eruptions and responses to them was collected in the field by visiting historic lava flows and the *comuni* (i.e. municipalities) which were affected by them.

The aim of this paper is threefold: first, to summarise the characteristics of eruptions which occurred between 1792/3 and 1923 and the ways in which responses evolved during the *long nineteenth century*; secondly to reconstruct their impacts; and finally to assess the important lessons this history holds for the management of disaster planning within the twin contexts of White's *comprehensive* approach and Italian policies of civil protection.

2. Eruptions during the *long nineteenth century*

2.1 A summary of the volcanic history of Etna

Mount Etna rises to over 3000 m, dominates eastern Sicily, covers an area of *ca.* 1750 km^2 and is continually active. Activity commenced 300-400 ka years ago in a marine gulf (Chester et al., 1985; Bonaccorso et al., 2004) and the last major caldera forming eruption occurred *ca*. 15 ka years ago with the close of the *Ancient Mongibello* stage, which was marked by caldera collapse and eruption of trachytic pyroclastic flows

(Guest et al., 2003). Since then activity in the *Recent Mongibello* stage has been basaltic and has comprised persistent activity at the summit, punctuated by larger-scale strombolian flank eruptions which have produced voluminous lava flows (Chester et al., 1985).

Records of eruptions became reasonably complete from the beginning of the fifteenth century, are reliable from 1669 (Branca and Del Carlo, 2005) and document the devastation of: Trecastagni and Pedara (Fig. 1) in 1408; Nicolosi in 1537; in 1646 several small settlements on the north flank were destroyed; the most damaging historical eruption in 1669 eruption laid waste to Belpasso, Comporotondo, Mascalucia, Misterbianco, Nicolosi, S. Giovanni de Gelermo, S.Pietro Clarenza, much of Catania and fourteen smaller settlements; and a number of small villages in the vicinity of Macchia were destroyed in 1689 (Fig. 1 - Chester et al., 2005). Widespread distress followed in the wake of these eruptions.

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 followed by a pause from flank eruptions and significant activity was only re-established from the middle of the eighteenth century. After 1750 the output of lava by flank eruptions was lower than in the previous century, with the mean eruption rate falling to 0.18 m^3s^{-1}. Branca 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 output. They 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 eruption (e.g. 1792/93 eruption); and *Class B*, where vigorous explosive activity persists throughout most of an eruption (e.g. 1886 eruption). As pointed out by Branca and Del Carlo (2004, 2005), the complexity of eruptive behaviour since 1750 is reflected in the fact that there were no *Class B* flank eruptions in the twentieth century, but there have already been two in the twenty-first (i.e. 2001 and 2002/3).

Another system may be used to classify lava flow fields on Etna (Hughes et al. 1990, pp. 392-3). A *Type A* flow field is narrow when compared with its length, whereas a *Type B* flow is wide when compared with its length. The former are notable for their higher average effusion rates and shorter duration**.** Since 1750 *Type B* flows developed from long duration eruptions have characterised the East and South East sectors of the volcano, whereas *Type A* have typically occurred on the Northern and Western flanks. The possible reasons for these contrasts between *Type A* and *Type B* flows are beyond the scope of the present paper, are more fully considered by Hughes et al. (1990) and have implications for hazard management which are discussed in section 5.0.

2.2 Eruptions from 1792/3 to 1923

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); in addition there were two minor events (i.e. 1802 and 1918) and two larger eruptions in 1811-12 and 1819 (Anon, 1819a, 1819b), whose effects were largely confined to the Valle del Bove (Fig. 1). Only the first group has been selected for detailed study because it is these that have presented major threats to human settlements and livelihoods. The following sections (2.2.1 to 2.2.13) summarise this activity and utilizes information from Romano and Sturiale (1982) and Branca and del Carlo (2004), together with the contemporary source materials that are cited.

2.2.1 The 1792/93 Eruption Following precursory earthquakes (Anon, 2010a) and activity at the central crater the eruption began at *ca.*1000 m on May 23 from the western wall of the Valle del Bove and produced a flow which extended to beyond Monte Calanna (Fig. 1). The fissure then extended towards the South East, new vents opened between 2000 and 1900 m on the southern outer slopes of the Valle del Bove and produced the principal lava flow of the eruption (Romano and Sturiale, 1975). This *Type B* eruption lasted just over a year (*ca.* 380 days) and its flow field extended 6.5 km to *ca.*600 m o.s.l. and within 1 km of the centre of Zafferana (Fig. 1). The average effusion rate was *ca.* 2.5 m^3s^{-1} (Romano and Sturiale, 1982) but, in line with typical long-lasting (i.e. *~~Class~~ B*) eruptions of Etna, during the initial channel forming phase the rate was probably higher. The maximum length of the flow field was established during this phase and in early August Zafferana was threatened. The distal parts of the flow field divided into five branches which destroyed much fertile land and caused considerable anxiety among the local population; the advance of the flow stopped in vineyards close to Zafferana (Recupero, 1815, pp. 153-154). Subsequently, as the effusion rate decreased and although the eruption continued for another ten months, further activity saw the development of a compound flow field that grew and spread in the proximal zone.

2.2.2 The 1809 Eruption The principal contemporary academic witness to this eruption was Mario Gemmellaro (Gemmellaro, 1809) and, after earthquakes were felt in Castiglione and Linguaglossa (Fig. 1 and 2) and caused some people to abandon their homes, this *Type A* eruption began on March 27 when a fissure opened on the North Northeast 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. On March 28 fissures opened progressively down-slope along the North East Rift and lavas were erupted from vents ranging from *ca.* 1500 m to *ca.* 1400 m in altitude (Anon, 1809a). At the vent lava moved at a velocity of *ca.* 6.5 km h^{-1}, in the medial part of the flow it fell to *ca.*2.5 km h^{-1} and at the flow front at only a rate of a few tens of metres per hour (Anon, 1809a). This was a short-lived eruption lasting only 13 days and generated a simple *Type A* flow-field that extended downslope 8 km, to an altitude of 670 m causing much damage to the cultivated area and almost reaching the village of Rovittello (Fig. 1). The average effusion rate has been calculated at 31.5 $m^3 s^{-1}$ by Romano and Sturiale (1982), and this high rate is characteristic of an eruption that was of limited volume and ceased before it progressed to the 'waning-stage', which is a typical feature of long-lived eruptions on Etna (Hughes et al., 1990). Powerful explosions occurred in the Central Crater, and up to 10 cm of tephra was deposited between Linguaglossa and Piedimonte (Fig. 1), with ash being recorded as far as Messina: some 67 km away (Anon 1809a; Cavallaro, 1987). Much of the 1809 flow-field is now covered by twentieth century lavas (Fig. 2). The eruption was witnessed by British army officers who were based in Sicily, and a letter from one to friends in Scotland relates that near to the flow front Baron Carri's villa was threatened with destruction. A procession took place and people were in a state of considerable distress, beating their breasts, tearing their hair in penance, with a priest preaching a sermon telling the people that the eruption was a judgment on their sins (Anon, 1809a). The villa was spared but agricultural land was destroyed.

2.2.3 The 1832 Eruption This *Type A* eruption started on 30 October from a vent at *ca.* 3000 m high on the SE flank. Lava from this vent threatened the Casa Inglese[3] and reached the Valle del Bove. An eruptive fissure then opened on the west flank from 2650 to 1700 m a.s.l., formed the Monte Nunziata cone and generated a lava flow that extended 10.5 km and reached an altitude of 950 m. The lava came to a halt only 2 km from Bronte (Fig. 3) causing extensive damage to agricultural land. The eruption had a relatively high average effusion rate of 22.4 $m^3 s^{-1}$. Earthquakes occurred before, during and after the eruption and caused some houses in Bronte to collapse (Alessi, 1829-1835; Radice, 1928, 1936).

2.2.4 The 1843 Eruption This was a short-lived, *Type A*, eruption of 11 days, started on November 17 and had a high average effusion rate of 58 $m^3 s^{-1}$. Eruptive vents were aligned along a West Northwest – East Southeast fissure stretching from 2375 m to 1830 m a.s.l. on the Western flank and generated a simple flow field that extended for 13.5 km, down to an altitude of 540 m. Much crop land, a paper-making factory and some rural housing were destroyed (Anon, 1843e), and a phreatic blast at the flow front near Bronte (Fig. 3) killed 59 people (see section 4.1.1). Earthquakes were felt on the western flank

[3] The Casa Inglesi (English house) was a three room construction built in 1811 by British soldiers who were occupying Sicily during the Napoleonic Wars. In 1879 it was incorporated into the astronomical observatory, and in the early twentieth century became a volcanological observatory. It was destroyed in 1971 (Chester et al., 1985, pp. 10).

before, during and after the eruption and between December 1 and December 10, an eruption column from the central crater produced ash which fell on Catania.

2.2.5 The 1852/53 Eruption This *Type B* eruption started on August 20 without any precursory earthquakes (Rodwell, 1878), though seismic activity occurred later during the eruption. Its onset was witnessed by a party of British tourists and their guides who were making an ascent of the volcano (Anon, 1852c), and it occurred within the Valle del Bove along a West Northwest - East Southeast trending fissure at a height of between 1950 and 1700 m. Strombolian activity built the Mt. Centenari cinder cones. By August 30 two streams of lava - with a maximum length of 8 km and descending to 510 m a.s.l. - had flowed from the Valle del Bove, one approaching Milo, the other Zafferana, and much agricultural land including valuable orchards were destroyed (Fig. 1: Anon, 1852a). Within two weeks (i.e. by early September) the villages of Zafferana, Ballo (a northern suburb of Zafferana), Caselle and Milo (Fig. 1) were threatened by lava. At different stages in the eruption ash fell both to the South East on Catania and Syracuse (81 km distant) and North East towards Taormina and Messina (67 km away) This eruption lasted 280 days and, although the average effusion was only 5.3 m^3s^{-1}, during the first few weeks it is likely to have been much higher as is typical of *Type B* event**s** (Hughes et al, 1990).

2.2.6 The 1865 Eruption This eruption, with *Type B* character, began on the night January 30 and was preceded by earthquakes (Anon, 1865f). A fissure opened on the North East flank (*ca.* 1825-1625 m) just below M. Frumento (Fig. 1). The Sartorius cinder cones were formed (Carveni et al., 2011a) and a rapidly moving lava flow advanced towards the towns of Linguaglossa, Mascali and Piedimonte (Fig. 1), causing extensive damage to agricultural land and some properties (Anon, 1865a). The lava advanced quickly covering more than 6 km in 2-3 days (Anon, 1865f), finally attaining a length of 7.4 km and, although the eruption continued for another 147 days, the lava extended little further building up a complex flow field (Hughes et al., 1990). Severe earthquakes were felt before, during and after the eruption, especially on the Eastern flank.

Three weeks after the end of the 1865 eruption, on July 19, there was an earthquake at Fondo di Macchia on the lower eastern flank of the volcano about 5.5 km West South West of Giarre (Azzaro, 2004). This earthquake was caused by movement of the Moscarello Fault, which is part of the Timpe fault system. Though this was a tectonic earthquake which occurred after the eruption it may have been triggered by the magmatic event. The un-buttressed eastern flank of the volcano is subject to gravitational instability (Montalto et al., 1996) and the vent of the 1865 eruption is located within this unstable zone. Magma injection may have led to movement to the east and Montalto et al. (1996) argue that gravitational sliding causes movement within shallow tectonic structures such as the Timpe fault system. The 1865 event was one of the most damaging earthquakes on the eastern flanks of Etna in the last 150 years (Azzaro, 2004) and, although having a modest estimated magnitude of *ca.*4.5, its shallow depth (< 2 km) meant that it had a high estimated EMS-98 Intensity (Grünthal, 1998) of XI near to its epicentre at Fondo di Macchia (Carveni et al., 2011b). The village of Fondo di Macchia was reduced to ruins and houses were destroyed in the adjacent villages of S. Venerina, Monacella and

Mangano (Fig. 1). A report in *The Times* of London (Anon, 1865b) refers to 150 houses in Fondo di Macchia being destroyed with 61 people killed and 45 wounded, some mortally, with aid being provided to the stricken area (see section 4.1.3). The area was struck by another earthquake on October 15 1911 following an eruption in the previous month which had a similar damage profile to 1865, though there were probably only around 12 victims[4] (see section 3.2.12). Fondo de Macchia was once again destroyed and today there is little evidence of the village.

2.2.7 The 1879 Eruption Weak earthquakes were felt before and during the eruption, and became strong and numerous after its close, with damage being noted in S. Venerina and Guardia (Fig. 1- Anon, 1879c, 1879d). The eruption started on May 26 with a North/South fissure opening on the North flank between 2250 and 1900 m, with lava issuing from its lower part and producing a 9 km flow which reached *ca.*550 m a.s.l. (Fig. 2). Lava almost touched the Alcantara River and cut the Randazzo to Linguaglossa road, damaging crops, threatening Passopisciaro and Moio Alcantara. It was reported that farm workers erected barriers to impede the progress of the lava (Anon, 1879i). One proprietor, a father of nine, saw everything he possessed destroyed, including houses, barns, cabins, olive trees, corn and vineyards (Anon, 1879f). Concern was expressed that the flow could dam the river (Anon, 1879b). A small 2 km-long lava flow was also generated on the upper South West flank, from a vent at 2680 m. The 1879 eruption was a short-lived (i.e. *Type A*) eruption of just 12 days and the main flow from the northern

[4] There is a vagueness in the literature about the number of people killed and/or injured. Two sources agree, however, that there were a 'dozen victims' (Azzaro and Camassi, 2006; *Istituto Nazionale di Geofisica e Vulcanologica* INGV, 2011).

flank had a high average effusion rate of just 35.3 m^3s^{-1} (Romano and Sturiale, 1982). A considerable area of agricultural land was destroyed by lava and black ash covered the leaves of trees and shrubs and 'peasants' were observed shaking the ash off trees as it was recognized as damaging to their productivity (Anon, 1879e). Ashes were distributed as far away as Messina, 67 km distant (Anon, 1879a).

2.2.8 The 1883 eruption This was a short lived event that started on 22 March but only lasted 3 days and, though the effusion rate was high, it only produced a short lava flow of a few hundred metres in length at about 1100 m asl on the south flank of the volcano (Romano and Sturiale, 1982). It is a classic example of a volume limited flow. There was strong earthquake activity before, during and after the eruption, which is attributed to forceful injection of magma into a dyke extending in a southwards direction from the summit region of the volcano (Azzaro and Barbano, 1996). Although in 1883 this dyke fed only a small lava flow it gave rise to much larger eruptions in 1886 and 1892. It was seismic activity that caused the most significant impact of this eruption (see section 5), with earthquakes being felt in towns across Etna: from Linguaglossa in the north; Aci Reale in the east; Bronte in the west as well as towns on the southern flank (Anon, 1883a). Damage was reported in Nicolosi, Belpasso and Zafferana (Anon, 1883a, 1883b, 1883c).

2.2.9 The 1886 eruption On the May 18 there was explosive activity from the Central Crater depositing ash and lapilli on the lower flanks, and the eruption began on May 19 from a fissure at around 1400 m asl on the south flank fed by the same dyke that gave rise to the 1883 eruption (Romano and Sturiale, 1982; Azzaro and Barbano, 1996). Felt seismicity occurred before, during and after the eruption (Anon, 1886a). The average effusion rate of this eruption was 29.8 m^3s^{-1} (Romano and Sturiale, 1982), but is likely to have been much higher during the first 10 days and velocities of around 3 km h^{-1} were reported for the early lavas stages of eruption (Anon, 1886i). The flow field reached its maximum length of 6.5 km by the end of May and the eruption ended on 7 June (Fig. 4).

2.2.10 The 1892 eruption The eruption was preceded by strong earthquakes which continued as the eruption started on July 9 and people were frightened to enter Nicolosi cathedral (Anon, 1892a, 1892b, 1892c). A fissure developed on the south flank at a height of *ca.* 2000 to 1800 m, and strombolian activity formed what are now called the Silvestri Cones (Fig. 4). This was a long-lived *Type B* eruption of 193 days and had an average effusion rate of 8.6 m^3s^{-1} (Romano and Sturiale, 1975). The lava output must have been much higher in the early few days with the flow field reaching its near maximum extent of 7km at this stage. By early August it was clear that Nicolosi was no longer threatened (Anon, 1892d). During the remaining four months the flow field thickened and widened in the medial and proximal areas.

2.2.11 The 1910 eruption Associated with strong seismic activity, in the early morning of March 23 a fissure opened up on the south flank stretching from 2850 m down to 1950 m asl with eruptive vents below 2300 m (Branca and Del Carlo, 2004). There was associated explosive activity with a high plume, ash fell on Catania and towns on the eastern flank of the volcano (Anon, 2010b). Fluid lavas were erupted from the fissure and travelled 5 km in the first 10 hours (Chester et al., 1985). Thereafter the rate of advance was reduced, lava crossed the Nicolosi to Ragalna road (Figs. 1 and 4) and by April 6 the lava front had stopped just 250 m from the Nicolosi to Borrello road (Anon, 1910a). Subsequently there was no further extension of the flow field and the eruption ended on 18 April.

2.2.12 The 1911 eruption Following earthquakes on September 9 the eruption started early in the morning of September 10. Explosive activity from the Central Crater produced an eruptive column 2 km high and ash fell on the lower southern flank of the volcano and on Catania (Anon, 1911d). Fissures opened progressively down the North-East Rift with eruptive vents forming between a height of 2550 m and 1650 m (Chester et al., 1985; Branca and Del Carlo, 2004). The average effusion rate of this *Type A* eruption was high at 57.6 m^3s^{-1} (Romano and Sturiale (1982), but would have been much higher in the early stage. The lava flowed quickly downslope and by September 14 had cut the Linguaglossa – Randazzo road and the Circumetnea railway (Anon, 1911a - Figs. 1 and 2). By September 15 activity was diminishing and by September 23 the eruption had ended. Almost a month after the eruption there was a large earthquake in the Timpe Fault system near Fondo di Macchia and the village which had been devastated by the earthquake in 1865 was destroyed once again (Carveni et al., 2011a, 2011b). It is interesting to compare the 1865 earthquakes (section 2.2.6) with those of 1911. In the case of the former, the eruption occurred on the North East flank leading to subsequent seismic activity in the Timpe fault system, whereas the 1911 events were on the North East rift thought to be connected to the Pernicana fault (Azzaro, 2004), which marks the boundary of the un-buttressed gravitationally unstable eastern flank of Etna. As in earlier eruptions the earthquake may have been caused by tectonic movements triggered through injection of magma.

2.2.13 The 1923 eruption On June 16 the eruption started early on June 17 with fissures opening between 2500 m and 1800 m asl on the North East Rift (Chester et al., 1985; Branca and De Carlo, 2004). This flow was erupted from Monte Ponte di Ferro at *ca.* 1800 m asl, had a high velocity - travelling 7 km in 10 hours - and by the evening of June 17 was within a kilometre of the Circumetnea railway (Ponte, 1923). The advance of lava then slowed and the railway station at Castiglione was not overwhelmed by lava until late on June 19. The flow advanced for a further 1.4 km before coming to halt on June 29. The eruption continued until July 18, with further small branches developing further up the flow field (Ponte, 1923). This was a *Type A* flow field. Woodland, cropland and some isolated houses were destroyed in the Piano di Pallamelata and Picciolo areas, major damage occurred in the villages of Cerro and Catena - a suburb of Linguglossa - was evacuated with some houses also being destroyed (Fig. 1 and 2 - Anon, 1923a, 1923b; De Fiore, 1926; Ponte, 1923; Cavallaro, 1987). Seismic activity was weak and frequent before and during the eruption and strong after it. During the eruption roads were blocked by ash and some roofs failed (Anon, 1923g).

2.3 The impact of lava flows

As section 2.2 shows, during the course of the *long nineteenth century* and although villages were threatened on several occasions, destruction was confined to isolated rural dwellings and the small villages of Cerro and Catena (near Liguaglossa) which were partially destroyed in 1923. In spite of this good fortune the rural economy was badly affected many times because lava approached so close to villages that measures had to be taken to minimise risk (see sections 4.1 and 4.2), with widespread destruction of valuable agricultural land occurring on numerous occasions. In *pre-industrial* times the fringes of settlements comprised a *corona*, an approximately circular rim of particularly intensive agriculture that could be easily worked by short distance commuting from agro-towns. Large-scale loss of land occurred during the *long nineteenth century* to the *coronas* (Fig. 1, 2, 3 and 4) of: Zafferana, 1792/3; Rovittello, 1809; Milo, 1810; Bronte, 1832 and 1843; Zafferana, 1852/3; Passopisciaro 1879; Nicolosi, 1883, 1886, 1892 and 1910; Nicolosi and Borrello; Rovittello, 1911; and 1923, Rovittello and Linguaglossa (Rodwell, 1878; Hyde, 1916; Chester et al., 2010). It may be estimated that between 1500 and 1900[5], some 8% of the land area of Etna below 2000 m was effectively sterilized by lava, a figure that falls to 3.5% for flow erupted between 1792/3 and 1923.

3. Etna and the Etna region at the start of the *long nineteenth century*

When the 1792/3 eruption began there was already a long history of people coping with volcano-related emergencies and since prehistoric times Etna had evolved into one of most distinctive, densely settled and productive agricultural regions in southern Europe. How this occurred and why, during the course of the *long nineteenth*

[5] The dates of certain historic flows erupted between 1500 and 1972/3 are disputed (see Tanguy et al. 2007). Figures are calculated using the estimates of area given by Romano and Sturiale (1982).

century Etna reached its apotheosis as a *pre-industrial* region in terms of the population[6] it could support by traditional agriculture, are important questions their answers providing the context into which the coping strategies adopted during eruptions may be placed.

Despite the ever present threat of volcanic activity and earthquakes, since prehistoric times the Etna region has acted as a magnet for human settlement (Leighton, 1999). Catania (Fig. 1), a city whose population swelled from 70,608 in 1861 to over 250,000 in 1921, was: destroyed by earthquakes on two occasions (i.e. 1169 and 1693), severely affected on four further instances (i.e. 1542, 1716, 1818 and 1848) and slightly damaged an additional eight times (Azzaro et al., 1999). To this must be added partial destruction by lava flows in 1669 and probably in 1371 (or 1381) as well (Chester et al., 2010); and by tsunamis in 1693, and possibly in 365 AD (Tonini et al., 2011). This apparent contradiction between hazard exposure on the one hand and the region's attractiveness on the other may be explained by a number of environmental and human causes that operate at two scales and which are summarized below. For a more detailed discussion reference should be made to Chester et al. (2010).

[6] Administratively most of Etna is contained within the Province of Catania. In 1806 the population of Sicily was estimated at 1.6 million with 14% residing in Catania Province, and by 1861 this had risen to 2.4 million and 15%, respectively. The latter figure rose to 17% by 1901, continuing to rise until the 1923 eruption (1921 census 19%) and reached 20% by 1971 (Pecora, 1968; Chester at al., 1985; Ligresti, 2002). The ability of the region to support a large population is even more remarkable when it is considered that today the Plain of Catania (Fig. 1) to the south of the city is one of the most agriculturally productive sub-regions of Etna, yet was hardly settled at all until the 1940s because of its malarial character. Also in the late nineteenth century Sicily lost population by emigration mostly to the USA, a flow which peaked at 148,000 in 1913, yet the population of the Etna region continued to rise.

At a Sicilian scale Italian geographers have drawn a distinction between the dry poverty-stricken interior of the island and the intensively-cropped, often irrigated coastal lands, terming it an "ugly picture in a frame of gold" (Milone, 1960; King, 1973, pp. 112). The "ugly picture" is explained in the main by poor land-use decisions made by Roman (264 BC - 827 AD), 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 Romans, Arab and later settlers cleared land for settlement, used and exported timber and grazed extensive tracts of land, while later rulers added intensive peasant cereal cultivation carried out on large estates (*latifundia*), with a largely absentee aristocratic ownership and agents (*gabelloti*) keen to maximize yields against a background of severe population pressure and large-scale erosion of soils totally unsuited to this form and intensity of agriculture. In addition *gabelloti* were strongly associated with the mafia, and banditry and crime became accepted as part of the culture across much of interior Sicily and the fertile northern coastlands (King, 1974; Dickie, 2011). Irrigation was first introduced by the Romans and became widespread from the time of the Arabs, diffusion being dependent on the availability of ground water. The northern coastal strip 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, which include not only features of climate, vegetation and soils, but also particularities produced by economics, history and culture. The region is favoured by: a strong increase in precipitation with height to over 1200 mm near to the summit; a steep environmental lapse rate of temperature, with heavy snowfall occurring in winter; temperature contrasts between the warmer northern, north-western and western and other sectors of the volcano; and high irrigation potential. Lavas are permeable being recharged by winter rainfall and snow melt. At first sight the link between climate and land-use appears deterministic with much more intensive cultivation occurring under irrigation in the eastern, south-eastern, southern and south-western sectors within what is termed the *regione piedmontese* (mountain foot region), that stretches from sea level to 1000 m (Cullotta and Barbera, 2011 - Fig. 5). The relationship is more complex than this and land use intensity also reflects distance from Catania, the principal export port of the region, with intensity declining rapidly with increasing distance. Yields were maintained - indeed increased - over time without any fall in productivity or widespread erosion through a combination of factors.

a. The creation and continual maintenance of lava-block agricultural terraces on steep slopes. These were well established by the 13th century and acted both to increase the amount of flat land and reduce erosion.

b. The inter-cropping of cereals and vegetables beneath tree crops in order to increase yield per unit area and reduce the amount of bare ground.

c. The use of mulching to reduce evaporation and increase soil organic matter.

d. The careful selection and grafting of cultivars which were particularly suited to Etnean conditions.

e. The close integration of animals into the system of cropping, not just producing usable products, but also large qualities of manure (Benjamin, 2006; Dazzi, 2007; Chester et al., 2010).

f. The application of large drafts of family labour which, in contrast to the lands of the interior, represented not just additional mouths to feed but the essential personnel required for such tasks as the maintenance of terraces, the management of livestock and the harvesting of produce from small plots which have subsequently proved almost impossible to mechanise. Indeed a lack of labour is one reason why some terraces in more marginal area of the volcano have been abandoned during the past fifty years (Chester et al., 2010)

Unlike much of interior Sicily many farmers either owned their land or had secure tenancies and in the nineteenth century mafia influence was less marked (Rochefort, 1961; Dickie, 2011), but in common with other areas of Sicily farmers did not normally live on the land they worked but resided with their families in large *agro-towns* or peasant cities commuting to work every day. Within *agro-towns* a distinctive *pre-industrial* 'Sicilian way of life' was practiced (King, 1973, pp. 51-65). This was greatly to influence responses to eruptions in the *long-nineteenth century* (section 4.1) and in the Etna region included: strong bonds within families and extended families which usually extended to other villages through marriage and God parenthood, with different generations living in the same house; a mistrust of outsiders; a segregation of tasks by gender with women being confined to the home, though on Etna this was less marked than in other parts of Sicily and all family members were usually engaged in some agricultural work; and an adherence to a particular form of 'popular Catholicism'. Catholicism in southern Italy and Sicily emphasized the power of the Madonna, St. Joseph and local saints - together with their relics and votive objects - to eliminate or at least reduce the impact of all manner of individual and collective disasters (see section 4.1.1 - Carroll, 1992, 1996; Chester et al. 2008).

4. Pre-industrial coping strategies during the *long-nineteenth century*

The ways in which people coped with eruptions between 1792/3 and 1923 may be classified under two headings: responding to emergencies and recovering from losses in the short and longer terms. In both cases people adopted responses which were typical of *pre-industrial* societies (Table 1)

4.1 Responding to emergencies

People responded to eruptions at three levels: as members of family and extended family units; through mutual support as part of a village or larger settlement; and as citizens of a Nation State, the Kingdom of Sicily until 1816, the Naples-based Bourbon Kingdom of the Two Sicilies until 1860 and united Italy thereafter.

4.1.1 Family coping strategies Contrary to popular expectation, experience from many disasters around the world shows that panic, which may be defined as "irrational, groundless, or hysterical flight that is carried out in with complete disregard for others" (der Heide, 2004, pp. 342), is largely a myth. Panic rarely features in responses to disasters, 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*. Apprehension and even fear 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 being possible exceptions (Anon, 1911a) - and fear never prevents families coping in a positive manner and with a strong sense of solidarity (Chester et al., 2010). There were two instances when there was major loss of life. In 1843, 36 people were killed instantly, a further 23 died later in Bronte (Figs. 1 and 3) and 10 were injured (Gemmellaro, 1843) when a phreatic explosion occurred as lava passed passed over waterlogged soil (Gemmellaro, 1858, pp. 145-149; Tanguy and Patanè, 1996)[7]; and in 1865, 61 people were killed and 45 wounded (many mortally) by the earthquakes induced by dyke injection (see section 2.2.6) that destroyed Fondo di Macchia and other east flank villages (Fig. 1). As mentioned in sections 2.2.6 and 2.2.12 there were also injuries and possibly some deaths in the 1911 earthquake on the eastern flank of the volcano. In both 1843 and 1865, contemporary reports (Anon, 1843b; 1865b; Radice, 1928; 1932) portray situations that would be described today as exemplifying the 'disaster syndrome', where members of affected families were so overwhelmed by grief that they were psychologically incapable of being able care for themselves and others (de Heide, 2004, pp. 342). There is no evidence, however, that such depths of grief and despair affected more than the immediate families of those who were killed.

Lava incursions have affected agricultural land and villages on many occasions and by the nineteenth century families were well aware of the risks they faced and the

[7] It is sometimes stated that this phreatic activity occurred when lava ruptured a water tank, but in examining the contemporary sources, Tanguy and Patanè (1996, pp. 157), conclude it was: *due à la progression de la coulée sur un sol gorgé d' eau* (i.e. caused by the progression of the flow over soil soaked with water - our translation).

action they should take in order to deal with them. Often people 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 1923 when refugees fled as far afield as Catania and Messina (Anon, 1923c), a response that was greatly assisted by the ready availability of rail transport.[8]

Other people were not prepared to leave their home village or farm and many accounts are suggestive of considerable suffering amongst the rural population. To quote just a few of many instances, 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 Borrello (Figs.1 and 4) are depicted as sleeping in the fields (Anon, 1883e) and in 1892 widespread suffering is noted in Nicolosi, Borrello and Belpasso (Anon, 1892d). These and other reports of the marginalized poor may be misleading and, although distress in villages and rural areas undoubtedly occurred, suffering was mitigated by family-based coping stratagems (Table 1). Much of the rural housing that was destroyed belonged to aristocratic families who coped with

[8] The mainline railway from Catania to Messina opened in 1866. The narrow gauge *Circumetnea*, which links Catania, Paternò, Adrano, Bronte, Randazzo, Linguaglossa and Giarre -Riposto (Fig.1), opened in 1895. The railway was cut near Rovittello in 1911, was back in action only to be covered by lava again in 1923, this time nearer to Linguaglossa. Following this a new loop was constructed round the flow front taking the line via Castiglione and adding 7 km to its length. The old route was re-established in 1952 (King, 1973, pp. 81-83; Anon, 2011e).

notable *sang froid*, through the cushion of disposable wealth and often adopting an accepting - even fatalistic – attitude to their losses (e.g. Anon, 1809a; 1843a; 1865c). With regards to poorer families, many 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. This land use pattern was long established on Etna and has been an important coping mechanism in many twentieth century eruptions (Clapperton, 1972). Whether it was a deliberate adjustment to risk, or merely good fortune and a consequence of the application of inheritance laws is unknown, but security was also enhanced because many farmers did not rely solely on raising crops for their livelihoods, but also engaged in hiring their labour to others and in grazing high altitudes pastures (Cumin, 1938). 'Sleeping' or 'living' in the fields may be an outsider's perception of apparent distress because many farming families, although living in agro-towns, owned permanent shelters on cultivation plots which were usually used for siestas during hot summer months and/or for storage, but could be quickly converted into temporary accommodation (Chester et al., 2005). Although several small villages were ruined (see sections 3.2.6, 3.2.12 and 2.3), no major settlement was destroyed by volcanic activity in the *long nineteenth century* and displaced populations soon returned home.

4.1.2. Mutual support Although the family was the vital unit when coping with the effects of eruptions, some responses involved the mobilization of larger numbers of people including neighbours and groups who resided, either in the rural areas where the 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 with water was possible). For instance in 1865 and clearly learning from the disastrous phreatic explosion which occurred in 1843, the authorities ordered troops to pump water out of wells and cisterns (Anon, 1865a). People harmonized with nature (Table 1) by accepting that, although losses might be inevitable, these could be minimized. For example, often much could be salvaged (e.g. the removal of household property, personal effects and even crops) in advance of an area being covered by lava. The ways in which this occurred are listed in Table 2, but mutual support also involved trying to account for losses and propitiating the deity (or deities) supposedly responsible through the practise of religion.

The perception that disasters are products of divine action sent to punish sinful people transcends religious tradition, time and culture (Chester and Duncan, 2009) and in Southern Italy, Sicily and especially on Etna this view has shaped the ways in which people reacted to catastrophes caused by earthquakes and volcanic eruptions (Chester et al., 2008). Three elements of this religious awareness have a long pre-Christian antecedence: supernatural control of eruptions; divine appeasement; and the role of heroic figures. All were later incorporated into the popular Catholicism of the region.

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 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 (Carroll, 1992, 1996; Chester et al., 2008). 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 (Table 2). 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 (Chester et al., 2008). 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 (Leibniz, 1952), 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.

The *long nineteenth century* saw the full panoply of popular religious observance being played out every time there was an eruption, sometimes under the bewildered and at times dismissive gaze of outsiders (e.g. Anon, 1809a; Reclus, 1865; Anon, 1879f), the principal religious responses to eruptions are summarised in Table 2 (see also Fig. 6).

In *pre-industrial* times and specifically in the *long nineteenth century,* there was a marked inconsistency between religious practices and practical actions (Dibben, 1999).[9] 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, not only through the individual and collective measures already discussed, but also in accepting the help of outsiders, government and their agencies (section 4.1.3). This 'parallel practice' holds important lessons for present day civil protection and is more fully discussed in section 5.

4.1.3 The role of the State in responding emergencies Records show that, whereas the volcanological characteristics of 1792/3, 1809, 1811/12 and 1819 eruptions were recorded by both Sicily-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 provincial *intendente* (i.e. prefect) visited Bronte to express solidarity with its people (Radice, 1928, 1936), outside assistance became progressively more significant during each subsequent eruption but local leadership remained dominant

[9] Believing two mutually incompatible explanations, or holding one view yet acting contrary to it, is sometimes termed *cognitive dissonance* in hazard studies. In psychology and religious studies *cognitive dissonance* has a more restrictive definition (Carroll, 1990, pp. 123-4) and for this reason *parallel practice* is used in this paper.

and State influence inchoate, making little impact on the process of long-term recovery (section 4.2). This increasing State involvement was greatly assisted by improvements in communications: the telegraph[10] from 1852; and railways from 1866 (see footnote 7). By the 1860s officials in Catania could use the telegraph to communicate with Rome and the larger towns and villages on the volcano, and American press reports were being published just 48 hours after the events that were being described (Anon, 1865e).

In addition to expressing solidarity with the people at risk, the principal way in which the State viewed its role was in the provision of police officers and soldiers to maintain law and order. This was a misconception because in common with many other areas that have been studied in detail (de Heide, 2004, pp. 362-3), including the eruption of Vesuvius in 1944 (Chester et al., 2007), there were virtually no examples of civil unrest and/or looting. The only exceptions were the 'religious riots' of 1923 (see section 4.1.2 and Table 2) and an isolated instance of looting in 1911 when "marauders" from Catania were allegedly involved (Anon, 1911c). Indeed troops and police more commonly assisted local people in providing personnel to enhance well established 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 and Catania (Fig. 1 - Anon, 1886b, 1886e, 1886f) and in 1923 troops assisted with the digging of lava diversion channels (Anon,1923a).

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[10] Sicily was first linked to the mainland by telegraph in 1852 and during the next 20 years the network in Sicily became extensive, with additional cables linking Sicily to southern Italy, Malta, Sardinia and North Africa (Anon, 2011b; Glover, 2011).

The authorities also sought to ensure that lessons from previous eruptions were learnt. In 1865 troops and firefighters were sent from Catania and Giarre to Fondo di Macchia (Fig. 1) and other villages to clear rubble and rescue people from buildings destroyed by volcano-related 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 telegraph message 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 passed (Anon, 1886g). The 59 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 acutely aware of the dangers 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 (established 1879)[11] - on the course eruptions might take, Professor Orazio Silvestri being involved in 1883 and 1886 eruptions and Professor Gaetano Ponte in 1923 (Anon, 1883f, 1883g; Silvestri, 1886; Anon, 1923a). Towards the close of *long nineteenth century* there are examples of: troops breaking down earthquake-weakened walls and providing tents

[11] 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 Decree 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 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).

(Anon, 1883b); and forcing the evacuation of dwellings in 1911 and 1923 (Anon, 1911b). The 1923 eruption marks the first example of the authorities deliberately using the favourable publicity generated by its response to an emergency in order to boost its prestige. The eruption occurred less than one year after Mussolini and the *fascists* assumed power and the dictator visited the scene of destruction with King Vittorio-Emanuele III. He ensured that the fascist militia was involved and placing an aircraft at the disposal of Professor Ponte so that he could monitor the eruption (Chester et al. 1999). Mindful of powerful role alike of popular Catholicism and heroic figures, one pro-fascist newspaper claimed that the arrival of the *Duce* was of Messianic import being the reason why the eruption ended so abruptly and caused caused so little damage (Anon, 1923h; Mack-Smith 1983, pp. 118). Indeed so successful was this publicity, that Mussolini's role was subsequently commemorated by the *Accademia Gioenia di Catania* who named the principal eruption craters after the King and the *Duce* (Chester et al., 1999). These names do not appear on current maps. Finally one feature with which the authorities had to deal and that became more acute with the advent of railways and the electric telegraph, was 'dark' (or grief) tourism. These are visits made to sites of disasters to view destruction and early excursions by British visitors are recorded in 1809, 1852 and 1879 (Anon, 1809c, 1879a; Rodwell, 1878, pp. 105). In 1865 Sicilian and foreign tourists are described as 'pouring into the region' (Anon, 1865e), but these numbers pale when compared to the numbers who visited in 1910 (Anon 2010b) and 1923. Indeed, if the 1923 eruption had continued, then the presence of so many visitors could have severely inhibited the responses of both the local people and the authorities (Anon, 1923j).

4.2 Recovering from losses over the short and long term

Although damage was caused to many villages by volcanic earthquakes, most notably in 1865 when Fondo di Macchia (Fig. 1) was destroyed and 1883 and 1886 when buildings collapsed in Nicolosi and other settlements on the south flank of Etna (Table 3), during the *long nineteenth century* only the small villages of Cerro and Catena (near Linguaglossa) were destroyed by lava, no major settlement was affected and losses were largely confined to inundations of agricultural land by lava flows. Quantifying the value of losses in agricultural output is difficult for two reasons. First until the late nineteenth century virtually no data were collected and, secondly, it is very difficult accurately to estimate the value of agricultural losses in *pre-industrial* societies because much of the output is untraded. Estimates made in 1886, 1910 and 1923 show very high monetary losses of 765,000 ~~lira,~~ over 4 million lira and 8 million lira, respectively (Gentile-Cusa, 1886; Anon, 1910b; Anon 1923k). In contrast the value of official aid in most eruptions was modest: 2000 lira from the *prefect* in 1865 (Anon, 1865b); 500,000 lira from central government in 1879 to cover both the eruption and flooding in northern Italy (Anon, 1879g); 100,000 lira from the State budget, plus a gift of 20,000 lira from the King in 1886 (Anon, 1886c; Gentile-Cusa, 1886); 10,000 lira from the Ministry of the Interior in 1892 (Anon, 1892f) and 75,000 lira from the monarch and the Pope in 1923 (Anon, 1923c, 1923i).[12] During the *long-nineteenth century*, no comprehensive state-based

[12] There was little change in the purchasing value of the Lira between 1865 and 1914. Italy was part of the *Latin Monetary Union*, sharing its currency with France, Switzerland and other countries. Its exchange value with the US dollar was *ca*.1$ = 5.2 lira (sterling *ca*.£1 = 25 lira). In 1923 the value had fallen to $1 = 23 lira (Fratianni and Spinelli, 1997). Converting figures into present day values using the consumer price index as an inflation measure may be accomplished by means of the *Measuring Wealth* converter

system of financial relief was in place, although in 1886 claims against the 100,000 lira 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, 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, 1923l); 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). These were modest though welcome contributions. For instance in 1886 total damage to farm land alone was estimated at 765,000 lira which is very high when compared to the 100,000 lira provided from the State budget (Gentile-Cusa, 1886, pp. 196).

Recovery both in the immediately aftermath of the eruption and in the longer-term was focused on methods that were characteristic of *pre-industrial* societies (Table 1). Some of these have already been alluded to (section 4.1) and include harmonizing with the well- known threat of lava incursion by holding land in parcels in different parts of a *comune* or even in more than one *comune*, by having alternative sources of income through pastoralism and/or working as paid labour and sharing losses within extended kinship groups (Chester et al., 2005, 2010). Contemporary accounts do not record whether these responses were successful or, indeed, how long it took for recovery to be achieved. Arguments from silence are never strong and all that can be concluded is that where eruptions on the same flank occurred with little time elapsing, for instance on the

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(Anon, 2011c). For instance, 500,000 lira in 1879 equates to *ca*. $2.2 million in 2011 and 8 million lira in 1923 equates to *ca*. $1.2 million in 2011.

western flank in 1832 and 1843, on the southern flank in 1883, 1886, 1892 and 1910 and on the north eastern flank in 1911 and 1923, there is no evidence that people were still suffering either economically or emotionally from the effects of previous events. Indeed the *Circumetnea* railway was cut in 1911 near to Rovittello (Fig. 1) only to be destroyed again in 1923 (see footnote 9 check).

There is plenty of evidence that farming families took a much longer-term perspective when harmonizing with nature. Long-term harmonization (Table 1) involved farmers, with little capital but much accumulated experience, adopting an outlook that stretched hundreds of years into the future. This was achieved by assisting processes of succession through the deliberately planting of two species that are capable of breaking up lava flows by their root development so making then more suitable substrates for vegetation development (Fig. 7). One example was the deliberate introduction from the seventeeth century of the prickly pear cactus (*opuntia ficus-indica*) from South America (King, 1973), but Sir Charles Lyell (1858, pp. 726) also notes in connection with 1852/3 eruption that "proprietors have already planted certain tracts of …. (the lava) with broom, which is growing most freely". Certini et al. (2001) have pointed out that broom wood was a traditional charcoal crop on Etna and so yields an economic return many centuries before farming could be re-established. Processed prickly pears were edible by both human beings and animals**.** *Pre-industrial* farmers also knew that pyroclastic materials weathered more quickly than lava to produce potentially high yielding cropland. For example near to the village of Nicolosi (Fig. 1 and 4), vines have been grown on volcanic ash soils (i.e. *andisols*) from the 1669 eruption since at least the mid -nineteenth century, whereas even today adjacent lavas can only support low intensity grazing (Chester, et al., 2010). The creation of agricultural land by the construction of terraces is evident on the 1809 flow and the introduction of soil to create 'made ground' suitable for cropping occurs on the 1843 flow at *ca.* 540 m and the 1911 flow *ca.* 680 m. In both cases this was to allow olive groves to be established.

In addition to agriculture, flows erupted from 1792 to 1923 shows a variety of post-eruption land uses. Where required roads were quickly built over flows in order to restore communications, on many flows quarrying took place and, because land which is sterile for agriculture can still be used for building, there are instances where the urban fabric of villages has expanded over adjacent lava flows. For instance northern Zafferana is located on the 1852/3 flow and Passopisciaro has spread over the 1879 flow.

5. Conclusion: The lessons of pre-industrial loss bearing for hazards response today

Since 1923 major flank eruptions affecting housing and/or agricultural activity have occurred in 1928, 1971,1974, 1981, 1983, 1991-3, 2001 (Guest et al., 2003) and 2002-3. In each successive eruption and especially after 1971, the State has become more involved and responses have become *industrial* in character (Table 1). Today emergencies are closely managed by central government, through the Ministry of Civil Protection (*Dipartimento della Protezione Civile* - founded in 1992), who can call on the expertise of local authorities (*comuni*) and scientific bodies, especially the National Institute of Geophysics and Vulcanology 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).

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 throughout Sicily has been greatly 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). Over the past forty years investment has been concentrated in more environmentally favoured and larger more easily mechanised and accessible holdings both within the *regione piedmontese* and on the Plain of Catania. Some abandonment from cultivation of marginal land often at higher altitudes and/or more inaccessible locations has taken place, and the numbers employed in agriculture have fallen, those in service occupations have increased and many *comuni* - particularly those within easy driving distance of Catania - are now principally commuter settlements, providing homes for inhabitants who are less conscious of risks they face than were their forebears during the *long-nineteenth century* (Dibben, 2008).

Vulnerability is defined as the propensity of a society to suffer damage from volcanic activity, whereas resilience is its capacity to resist and recover (Gaillard, 2007, pp. 522-3; Manyena et al., 2011)**,** and in all cultures disasters exemplify the balance between these two factors. Hence in a *pre-industrial* societies such as Etna Region during the *long-nineteenth* century resilience was expressed at local level in measures discussed in the present paper. Today and in common with other *economically more developed* countries, when disasters strike Italy the State is responsible for disaster relief, overall vulnerability (e.g. as 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 diversion and land-use planning based on hazard mapping), rather than being tailored to the particular needs of a given community.

On Etna, although intervention by the State has boosted overall resilience, the traditional deep-seated disaster resilience of *pre-industrial* times has been reduced. Today the Etna region is a major tourist destination, has proved a magnet for second home owners and, particularly in settlements near Catania and adjacent to the coast, much of the traditional Sicilian way of life and the distinctive character of the agro-town with their concomitant features of *pre-industrial* resilience have largely disappeared, though some features of are still extant in more isolated settlements located on the Northern and North-Western and Western sectors of the volcano (Dibben, 2008; Chester et al. 2010).

Elements of *pre-industrial* loss bearing on Etna (Table2) have nonetheless survived and still feature in contemporary hazard responses. Salvaging all that may be easily removed from a building and/or agricultural holding remains important on Etna and may reflect a continuation of nineteenth century precedents for such actions. Such actions 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 *Dipartimento della Protezione Civile* (Department of Civil Protection) was in discussion with the *Associazione 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. This envisages compulsory policies underwritten by the State (Garonna, 2011).

Educating local people about how to react when 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. In November 2008, for example, the *comune* of Mascali commemorated the eightieth anniversary of the 1928 eruption with 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. In a population whose memories of traditional modes of coping are fading, 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 - our translation) aimed at school children. Not only are volcanological risks considered, but the whole gamut of human factors which may either increase or decrease resilience are also considered (Edurisk, 2011).

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. In July 2001, for example, the Sicilian-born Archbishop Luigi Bommarito of Catania, celebrated mass in the village of Belpasso, in order to ask God to arrest the progress of the lava flow which was thought to have been threatening the village. At the time it was estimated that between 7000 to 10,000 people were in the congregation who represented a wide cross-section of village's population, including many professional and well-educated people (Kennedy, 2001). Interviews carried out in the village of Trecastagni by Christopher Dibben found that "for many, religious beliefs play a significant role in their representation of the volcano" (Dibben, 1999 pp. 196). The 'parallel practice' noted in section 4.1.2, 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 a large proportion of the population of the Etna region. In addition to ethical consideration over freedom of expression and worship, from the perspective of civil protection there are no reasons why these expressions of popular devotion to be discouraged.

As mentioned in section 2.2, 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 severely 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 resistent 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).

It is often stated that diversion of lava flows was illegal from 1669 until 1983. Legislation was passed after the 1669 eruption when civil unrest broke out when men from Catania tried to divert a lava flow. This action would have caused Paternò to be threatened and was strongly resisted by its inhabitants (Chester, 1985, pp 323; Behncke, 2011). As Table 3 shows and despite this legislation attempts to control lava are recorded in 1832, 1879 and 1923, in the latter case with some official sanction. When similar action was taken in 1983 using explosives to breach the walls of a lava channel and earthen barriers to prevent lateral spread, it was generally supported by the population. Barriers and other initiatives were again used in 1992, 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. As 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 and 1923, where lava flows quickly approached populated areas (section 2.1). 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.

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Table and Figure Captions

Table 1. 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).

Table 2. Summary of religious responses to eruptions during the *long nineteenth century*.

Table 3. Examples of coping mechanisms involving neighbours, rural communities and the inhabitants of agro-towns.

Figure 1. Etna: General location map.

Figure 2. Lava flows of the Linguaglossa area. Based on information in: Sartorius von Waltershausen (1880); Gemmellaro (1885a, 1885b); Ponte (1923); Romano (**1979** and data collected in the field.

Figure 3. Lava flows of the Bronte area. Based on information in: Sartorius von Waltershausen (1880); Gemmellaro (1885a, 1885b), Romano (1979) and data collected the field.

Figure 4. Lava flows of the Nicolosi area. Based on information in: Sartorius von Waltershausen (1880); Gemmellaro (1885a, 1885b); Silvestri (1883, 1893); Romano (1979) and data collected in the field.

Figure 5. 1870's view of Etna from Catania. The marked contrast between the intensively cropped *regione piedmontese* and the barren upper slopes should be noted (Frontispiece from: G.F. Rodwell (1878).

Figure 6. Plaque commemorating the 1923 eruption at Catena, a suburb of Linguaglossa. The inscription reads *In Recordo del Miracoloso Evento* (in memory of the miraculous event - our translation). Much of Catena was destroyed, but Linguaglossa was saved. This is one of many memorials to the supposed efficacy of intercession through saintly figures, the use of their relicts and/or images in halting lava flows. In this case **of** the staff S. Eglidius was carried in procession to the flow front (see Table 2).

Figure 7. The 1809 lava flow above the village of Rovittello (Fig. 1). Even after nearly 200 years of weathering, the flow is still only capable of supporting low intensity grazing. The trees on the flow include Etna broom, which was in some cases deliberately planted by farmers to speed-up vegetation and soil colonization.

Table 1

Pre-Industrial (Folk) Responses	**Industrial Responses**	**Post-industrial (Comprehensive) Responses**
A wide range of adjustments	A restricted range of adjustment.	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 indigenous methods of coping which are characteristic of a particular society and its history.
Action by individuals 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* (Anon, 2011a).
Losses are perceived as inevitable. The 'mindset' of many inhabitants is strongly influenced by nations 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 USA and Japan come closest to them (Chester, 1993, pp. 237).

Table 2

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 (Fig. 1). A memorial was built and every year a pilgrimage commemorates this event, as does a memorial bronze plaque in the parish church (Anon, 2010a).
1809	Several rural estates were threatened and images of saints were brought from Castiglione (Fig. 1), 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 (Figs. 1 and 3) 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 (Anon, 1865d). People were alarmed and felt that the villages of Linguaglossa, Piedimonte, Mascali and S. Alfio (Fig. 1) were threatened, even though in the event the lava never came 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 (Figs. 1 and 2) much of the population visited the flow front, carrying an image of the Madonna (Anon, 1879f).
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 (Figs. 1 and 4) 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 (Figs. 1 and 4), 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). The Bishop was Giovanni Battista Arista (1863-1920) who was born in Palermo and was bishop from 1907-1920.
1923	People from Piedimonte (Figs. 1 and 2) brought the statue of S. Antonia, their patron saint, and placed it **in** the town square where people prayed day and night accompanied by the tolling of a church bell. People in Linguaglossa (Fig. 1) 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).

Table 3

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). 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 (Anon, 1865a) and 1886 (Anon, 1886c). Worries

about explosive activity were balanced against the needs of agriculture.

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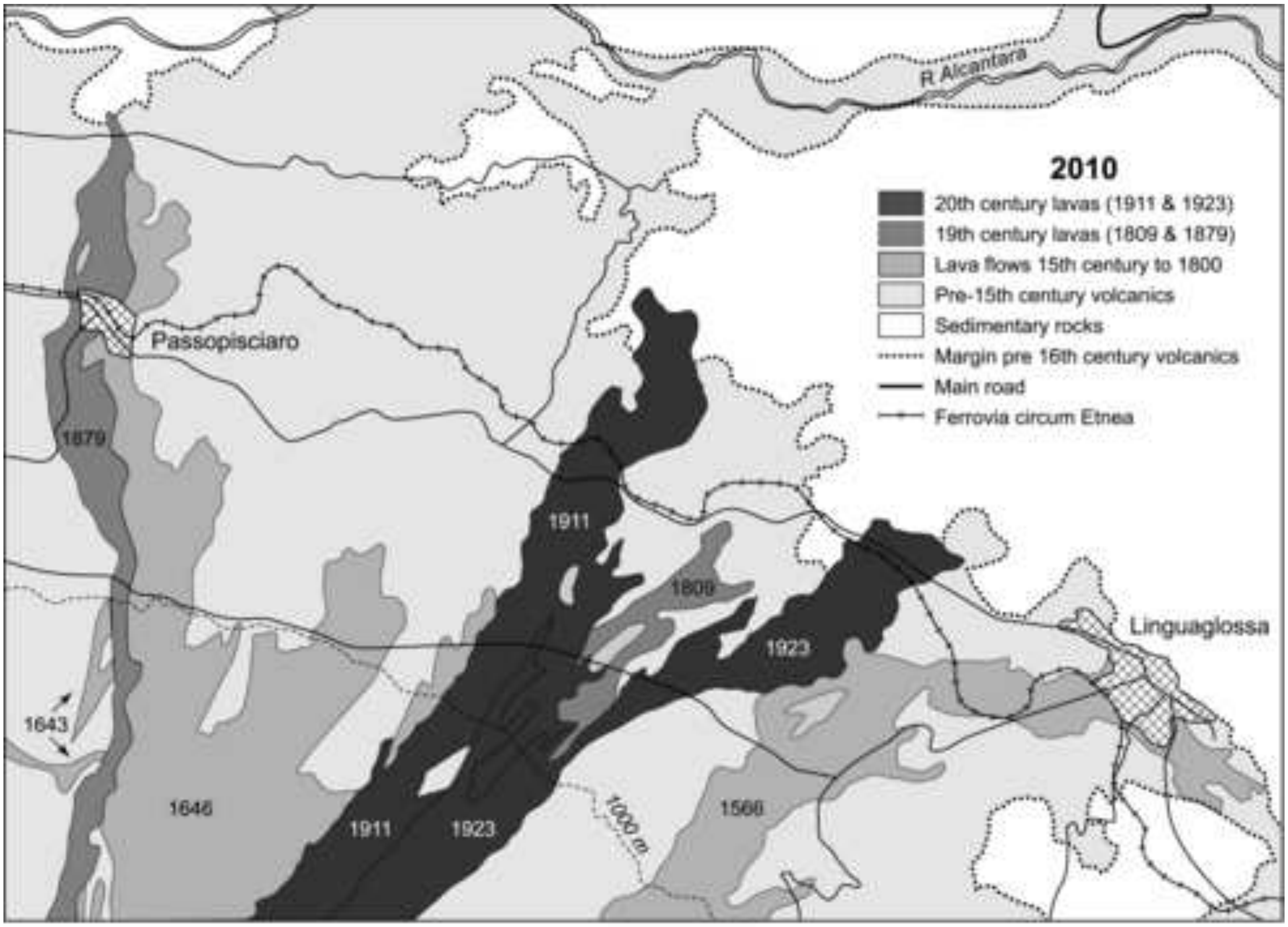

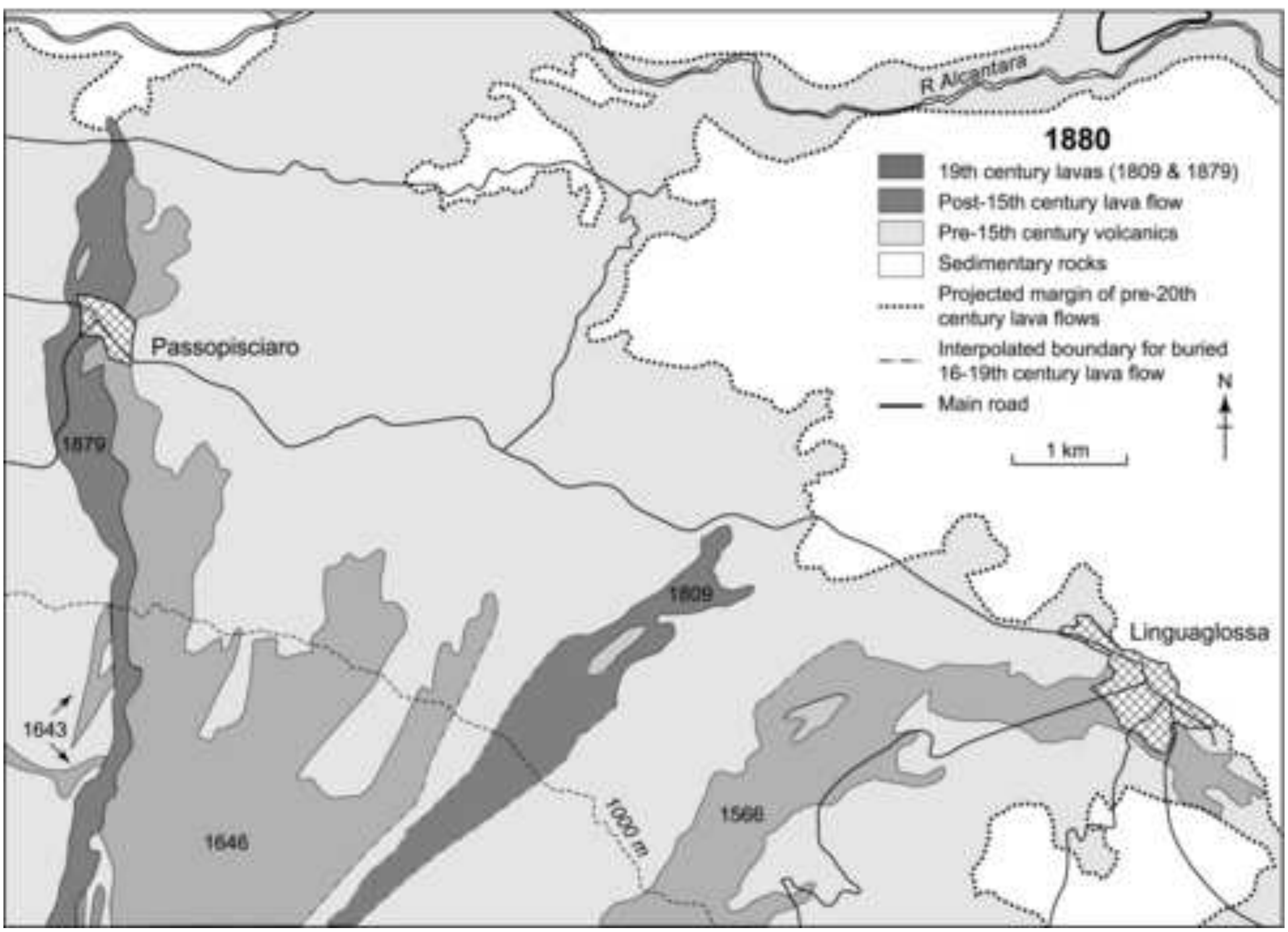

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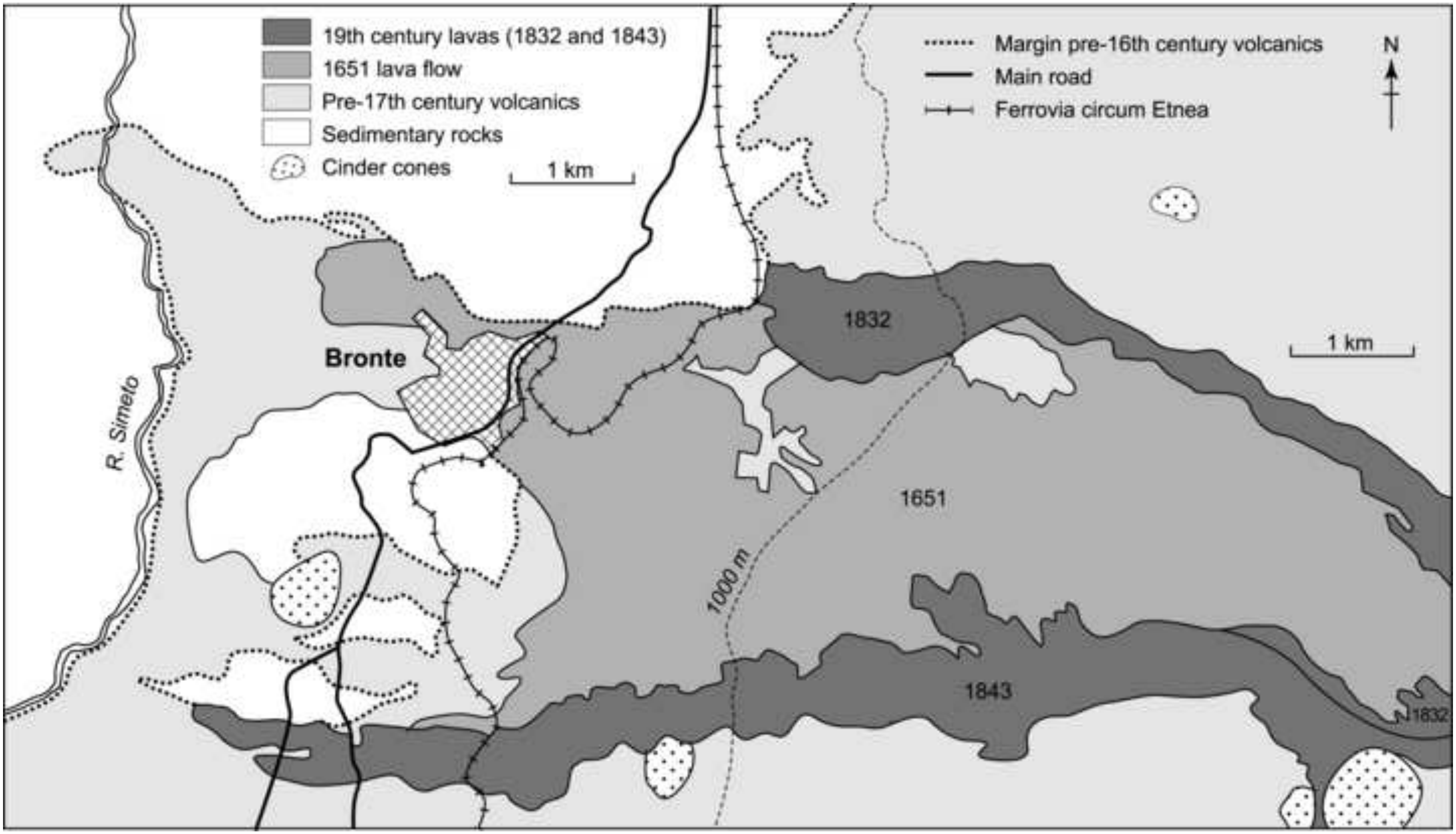

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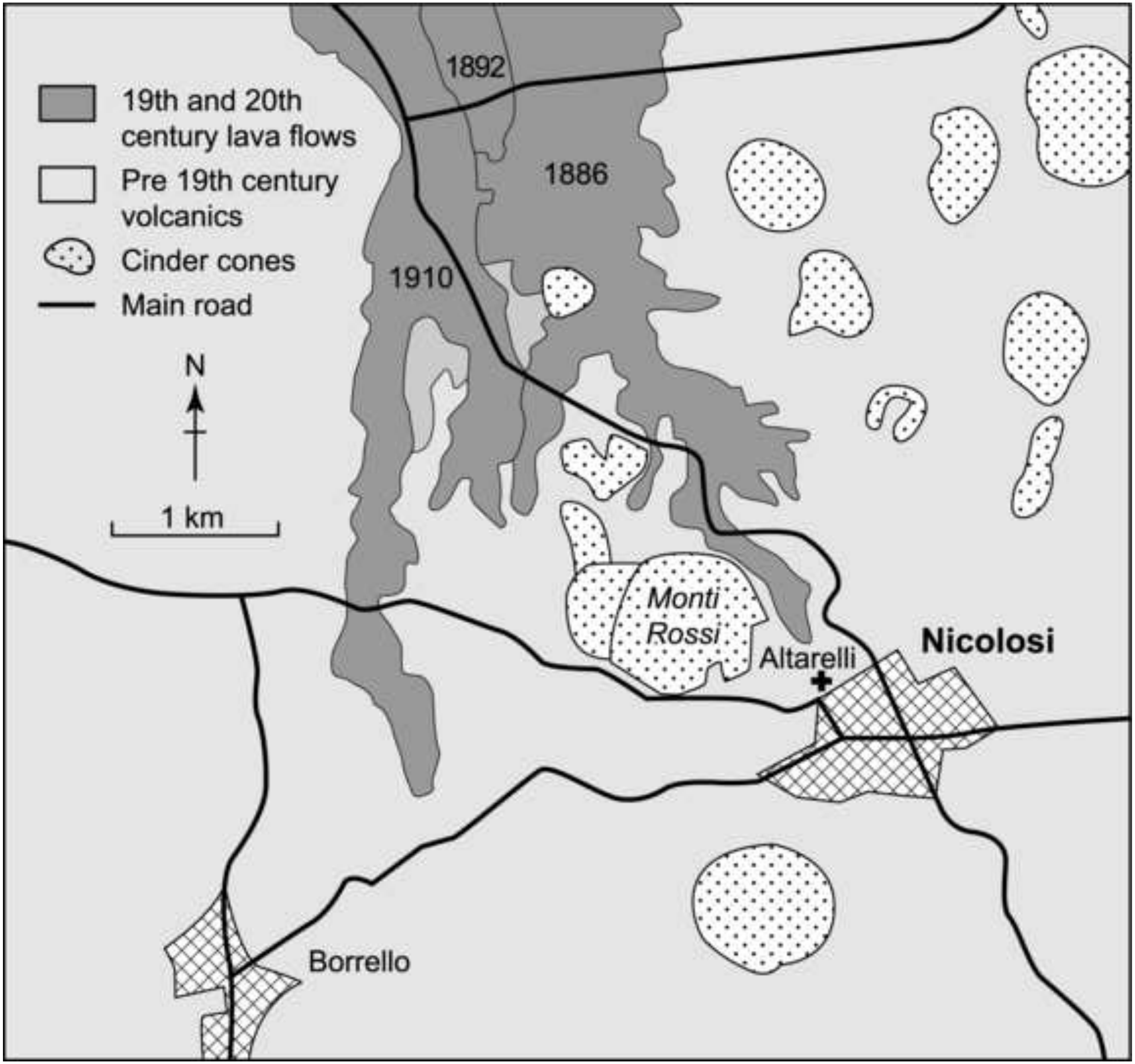

VIEW OF ETNA FROM CATANIA.

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