

MONTSERRAT VOLCANIC ERUPTIONS 1995-1998: CAUSES, HAZARD MANAGEMENT AND HUMAN IMPLICATIONS

'Now she puffs but will she blow?
Trust the Lord and pray it's no!'
Montserrat T-shirt slogan

Before July 18, 1995 the 11,000 islanders of the British colony of Montserrat in the Caribbean had lived in one of the most beautiful places on earth. This small mountainous island – colonised by Irish settlers in 1632 – was known as the Emerald Isle, because of the lush tropical vegetation which covered the mountainous slopes. On that day, however, the Soufriere hills volcano, which had lain dormant for 400 years, awoke violently, emitting billowing clouds of ash and steam in a phreatic eruption. Today, five years later, two-thirds of the island has been abandoned, 8,000 people have left the island and the remainder are rebuilding their lives in the northern safe zone. The Soufriere Hills volcano dominates an island at largest only 12km by 8km; everyone lived near the volcano.

Why is there a volcano here?

The Soufriere Hills volcano is situated above a destructive plate margin, or subduction zone. Oceanic crust from the North American plate is sinking under the Caribbean plate, forming the Antilles volcanic island arc (Figure 1). As the slab of crust descends, sediments, water and the heat of the mantle cause the wedge of mantle above the slab to melt. The molten rock is less dense than the surrounding crust and rises to the surface (Figure 2). The magma formed at a depth of around 6km, with a temperature of 820–885°C, and then partially crystallised before a new injection of deep magma boosted it towards the surface. At the surface, a thick viscous dome of lava appeared in English's Crater in the Soufriere Hills. Most of the gas in the lava had already escaped but some remained in pockets, which caused explosive eruptions. The volcano is a strato volcano, composed mainly of consolidated ash layers from previous eruptions.

Figure 1: Plate setting for Montserrat

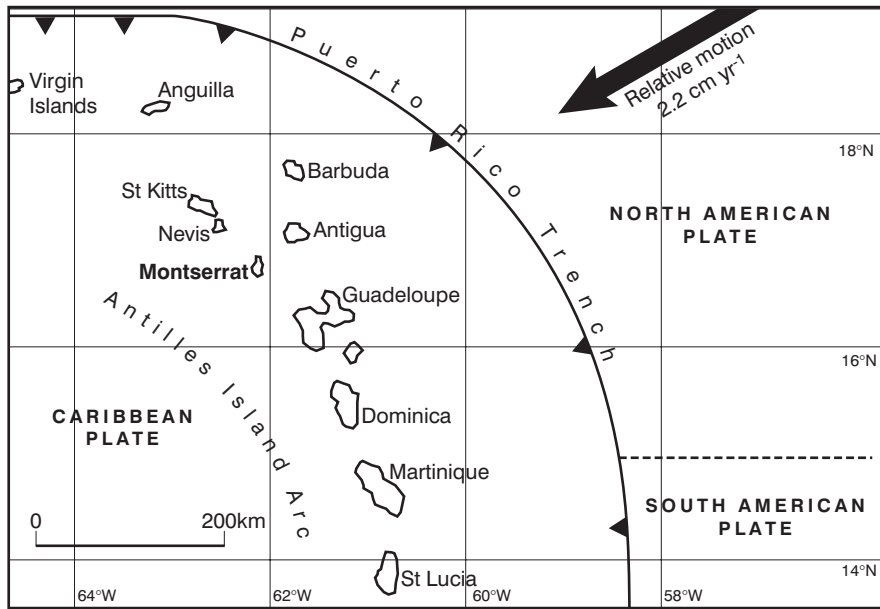
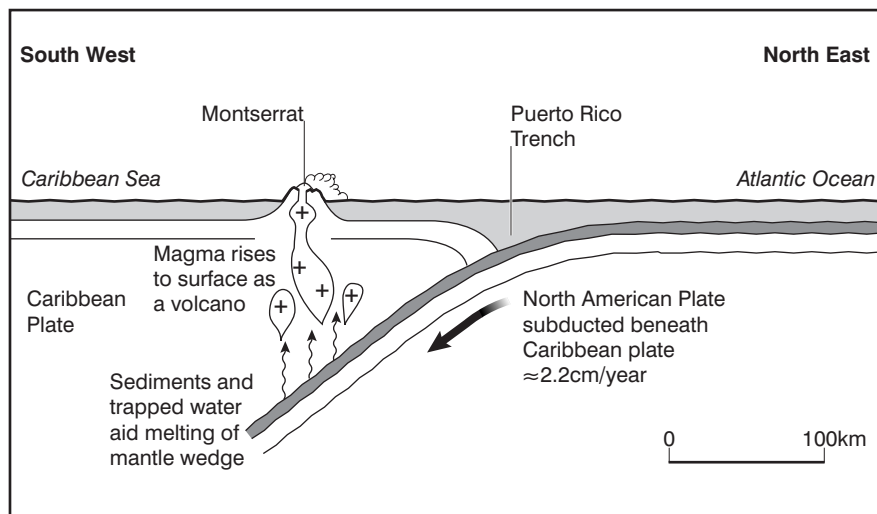


Figure 2: Cross-section through the Antilles Island arc



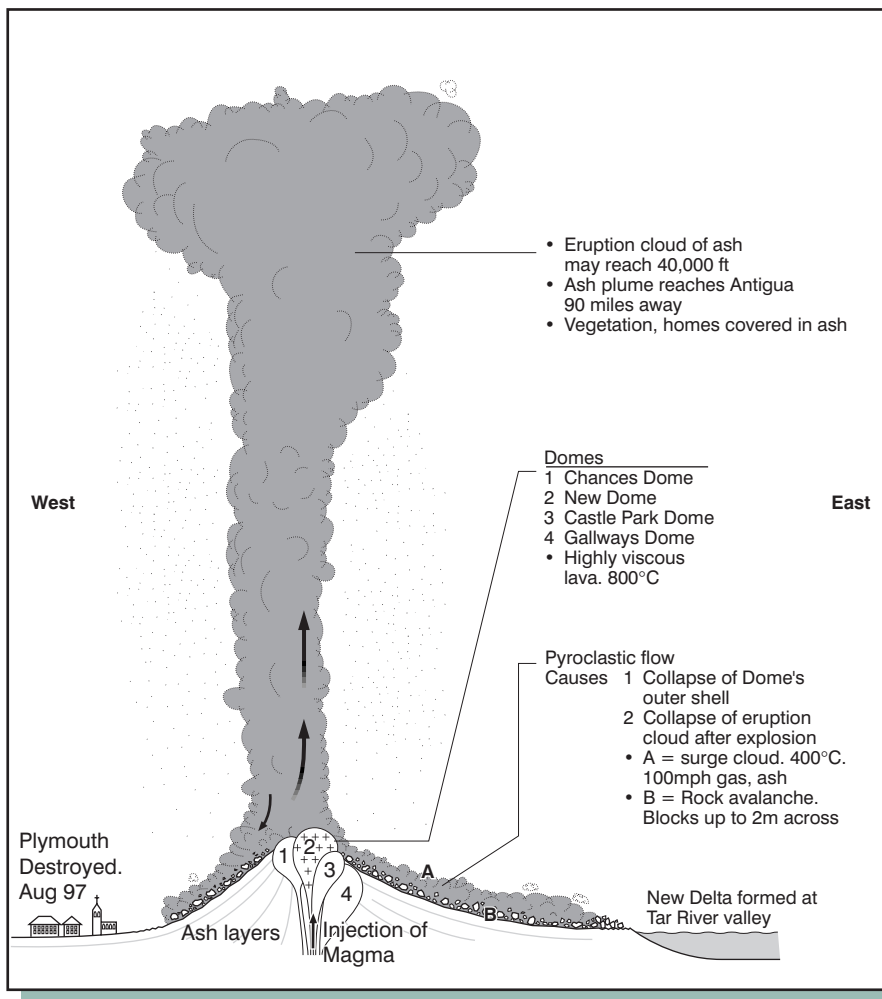
English's Crater is an east-facing amphitheatre formed during an ancient eruptive phase. Before 1995 an old dome called Chance's Peak sat within the crater; this was quickly engulfed by the new dome growth (Figure 3). Initially pyroclastic flows flowed eastwards from the open crater down the Tar River valley, but as the dome grew, eventually flows were able to come down any side of the volcano. The flows particularly followed four main river valleys: Tar River, White River, Mosquito Ghaut and Fort Ghaut. Where the flows

reached the sea they created new deltas of land e.g. Tar River valley delta (Figure 5(d)).

Geological hazards

A natural hazard is an extreme natural event which is a danger or threat to people and their activities. Volcanoes are commonly associated with gushing lava flows; however, on Montserrat there have been no lava flows. The most dramatic and dangerous result of the eruption on Montserrat has been surging grey

Figure 3: Soufriere Hills Volcano, 1995-97



Eruption diary

1992/1994	Earthquake swarms first detected
1995	
July	Phreatic eruption of ash and steam
August	5,000 evacuated as a precaution
December	Plymouth evacuated as new dome grows.
Nov 1995-Jan 1996	New dome grows in English's Crater and rapidly buries old dome.
1996	
January	Residents allowed to return during quiet phase.
March-Sept	First pyroclastic flows down the Tar River valley, creating a new delta in the sea. South of island evacuated. Plymouth abandoned.
April	
1997	
June 25/6	Most devastating flow yet down NE slopes of volcano. 19 people killed who had returned to their homes in the danger zone. 9000m high eruption cloud.
August	Pyroclastic flows destroy Plymouth, Montserrat's capital 3 miles from crater. Permanent relocation of inhabitants away from island is considered by British government. Exclusion zone expanded, residents advised to seek shelter, wear helmets and masks outdoors. Warning of cataclysmic eruption.
September	Montserrat's Volcanic Observatory advises all residents to move as far north as possible immediately. 5,000 now live in shelters. Flows destroy Bramble airport 3.5 miles from crater. People may be moved forcibly from the exclusion zone.
October	Eruptions approximately every 9 hours. Ash and tephra land in safe zone. Dome is 250ft above old crater and growing at 280ft ² /second.
November	Dome collapse remains a threat, causing large eruptions.
December	Boxing Day eruption. Pyroclastic flows down the White River valley. Eruption clouds to 36,000ft.
1998-1999	
July 20, 1999	Large eruption from dome collapse. Eruption cloud to 35,000 ft. Threat of dome collapse is still real. People largely out of danger unless in the exclusion zone. Restructuring of the north continues.
2000	
September	Activity at Soufriere Hills continued at an elevated level. A small explosion occurred which produced pyroclastic flows down the eastern flanks and an ash cloud that rose to about 10,000 feet. Light ash fell in the Salem area.

Figure 4: The main hazards from the Soufriere Hills volcano

Phenomena	Cause	Hazard/Threat/Effect
Pyroclastic flow: rapid avalanche of hot ash, gas and rocks moving at 100 mph with temperatures around 400°C	Collapse of the outer hardened dome exposes the hot lava inside. Explosion occurs either horizontally or in a vertical column of ash which then collapses and flows down the sides of the volcano	Incineration of any organic material, eg vegetation. Loss of life: 19 people died 26/6/97. Demolition of structures and burial in ash. Plymouth (8/97) and Bramble Airport (9/97) destroyed.
Lahar: rapidly moving slurry of ash and water and other debris	Heavy rainfall often from tropical storms or hurricanes mixes with loose ash on volcanic slopes	Burial and destruction of properties, vegetation and crops. Plymouth gradually being buried.
Ash and tephra fall: particles from 1mm to 10cm of shattered rock and hot lava fragments including pumice	Violence of eruption shatters lava and rock into small particles. Eruption clouds can reach 40,000 feet	Day can become night under heavy ash fall. Vegetation is coated in ash. Hot tephra sets fire to plants and roofs. Causes breathing difficulties and lung disease - silicosis caused by fine airborne ash called cristobilite. Ash plume extended 90 miles to Antigua
Earthquakes	Movement of magma inside the volcano	Noticeable but no threat to structures
Volcanic gases: carbon dioxide and sulphur dioxide	Released from magma	Poisons plants and animals

clouds of hot ash, gas and rocks, called pyroclastic flows. Such flows occur when the dome collapses or explodes. Tonnes of hot rock, lava and ash explode from the crater in a fast-moving cloud. The cloud can race straight down the mountainside, or if there is a large vertical explosion, which creates an ash column, come crashing down as the ash column collapses. Such clouds have two parts: on the ground, an avalanche of large boulders and rocks, and above this a cloud of ash and gas with temperatures of 400°C+. The cloud moves at speeds of 100mph, obliterating and incinerating everything in its path.

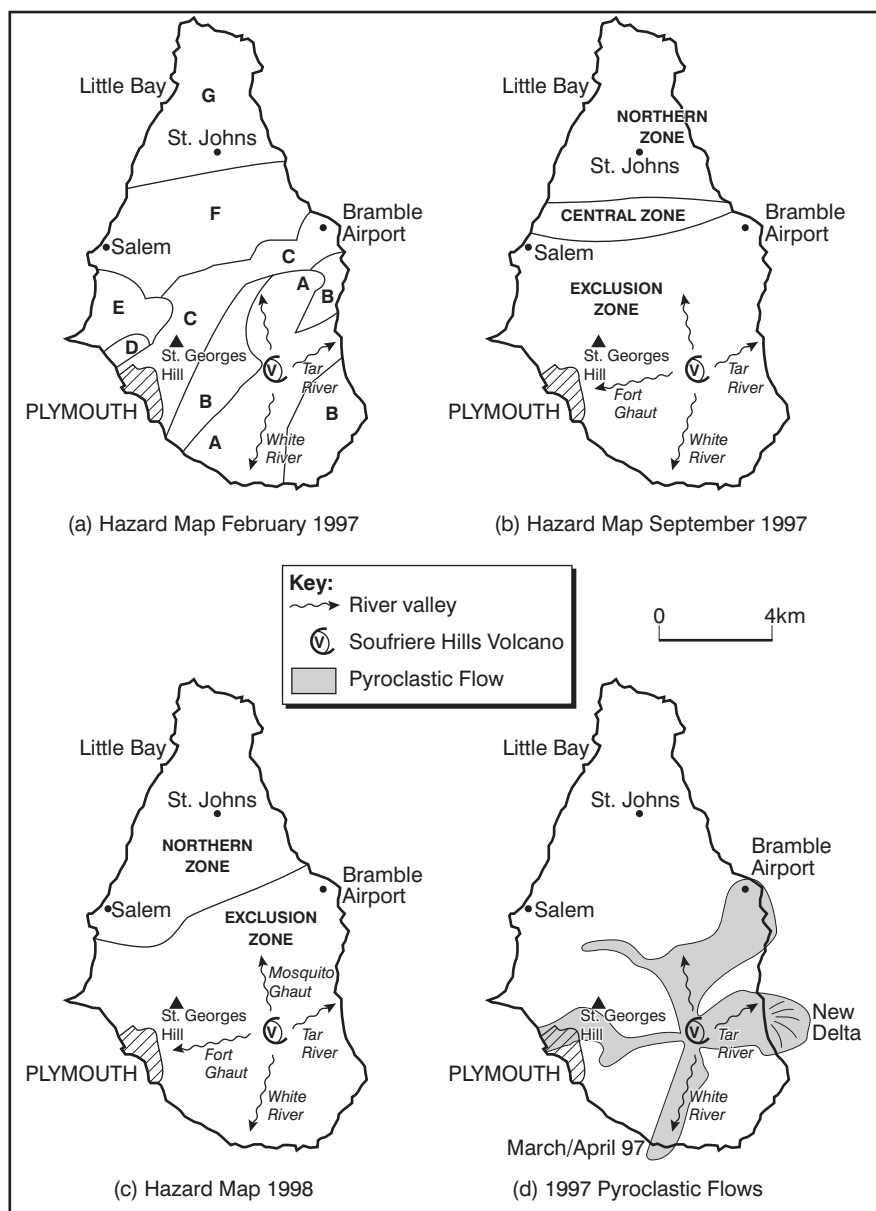
Figure 4 summarises the main hazards connected with the Soufriere Hills volcano. However, it should also be noted that Montserrat is a multi-hazard country, and hurricanes pose a regular threat, most notably Hurricane Hugo in 1989.

Hazard management on Montserrat

The initial earthquake (seismic) activity was detected by the University of the West Indies Seismic research unit. The United States Geological Survey (USGS) responded with their Volcano Disaster Assistance Programme (VDAP), which is always ready to assist with volcanic monitoring in countries which may not have enough resources of their own. Eventually the Montserrat Volcanic Observatory was established to co-ordinate monitoring and research. Universities from the USA and Britain provided staff to monitor the volcano and advise the Governor of Montserrat with practical information on the dangers posed to the population by the volcano.

- An extensive seismograph network was established around the volcano to measure earthquake strength and depth.
- Earth deformation meters and tiltmeters were also put in place to show any signs of the ground swelling or deflating as magma rose within the volcano.
- A satellite location GPS (global positioning system) was also used to check ground movements.
- An instrument called COSPEC was used to measure gas emissions from the volcano, particularly sulphur dioxide

Figure 5: Hazard maps of the island (a–c); pyroclastic flows (d)



- which is a good indicator of magma type and movement.
- The pH of rainwater was monitored as it gives an indication of the magmatic gas content.
 - Geologists regularly flew into the most dangerous areas to sample new flow deposits, measure cracks caused by the volcano swelling and check the growth of the dome.

Hazard maps

The theoretical risk that a volcano poses can be expressed as

$$\text{risk} = \text{people, property} \times \text{hazard} \times \text{vulnerability.}$$

There is currently a 1 in 10 chance of a fatality from a pyroclastic flow, but this could be reduced to virtually zero if the exclusion zone were enforced more strictly.

From this and the data gathered, hazard maps could be created which split the island into zones. As the eruption developed, the zones would have to be modified. On the February 1997 map (Figure 5(a)) the most dangerous zones (A) follows the main river valleys on the volcano. On this map, Plymouth is categorised as level C, or mid-risk. After the large eruption of June 25, 1997 the map was redrawn more simply. By now, only 40km² of the island's 100km² were considered safe to live in (Figure 5(b)). In August of 1997 this map proved its worth when Plymouth was destroyed by Pyroclastic flows. As the pattern and extent of flows became more well known, Salem which was previously in the exclusion zone was declared safe enough for people to return to (Figure 5(c)). The preservation of human life is always top priority and

the exclusion zone in theory only allows scientists in, to monitor the volcano. The system is effective unless people decide to return to their homes when the volcano appears to calm down and an eruption occurs, as happened on June 25, 1997.

Effects on the population

The effects on the population have been devastating. At one point 5,000 people were living in temporary shelters in the north, in some cases for over two years. The north of the island had few settlements of any size and found it difficult to cope with the influx from the south. Salem is now being repopulated and is being developed together with St Johns as new population centres. The following are some of the problems :

- Plymouth contained all the main services – hospitals, banks, schools, government and many private businesses.
- collapse of the tourist and rice-processing industries
- unemployment has risen from 7% to 50%.
- agriculture is at a standstill.
- respiratory problems caused by ash.
- psychological problems and discontent with relocation package
- traffic congestion
- shortage of available building land
- 70% rise in rent for accommodation
- skills shortage as people left.

Recovery

In 1997 the British government offered £2,400 to each adult to help with relocation from Montserrat. This announcement was met with rioting and despair by people who had lost homes and businesses and had been living in appalling conditions for over two years. Claire Short, the British minister for international development at the time, caused a political storm when she was reported as saying, 'They'll be wanting Golden elephants next', in reply to an appeal for £20,000 for each adult by Montserrat's Chief Minister, David Brandt. Eventually the situation improved, and funding for redevelopment of the island has now increased from £10 million to

Figure 6: Update, October 27, 2000

Montserrat Volcano's dome growth continues

The dome of the Soufriere Hills volcano continues to grow and although a collapse is likely, the lives of persons in the north of the island are not threatened. Due to dome growth, the volcano is now about 1,000m above sea-level. Growth over the last few months has been about 4 cubic metres per second and a broad estimate of the volume of material has been put at 50 million cubic metres. "The dome is high, it's peak size, and we are anticipating a collapse," Montserrat Volcano Observatory (MVO).

£75 million over three years as the main funding for Montserrat's Country Policy Plan (CPP). Redevelopment will take in the following:

- development of Little Bay Port to replace Plymouth's facilities
- conversion of St Johns hospital to main island hospital
- provision of water supplies in the north
- improving air access
- housing (1998 \$17 million dollars).

The British government has now introduced a scheme to give financial help to people returning to Montserrat, if they have somewhere to stay.

2001 Update

The island of Montserrat is slowly recovering from the disastrous eruption of 1995–97. The volcano, however, is steadily building a new dome, and pyroclastic flows and ash fall are still a threat. It is hoped that the northern part of the island will eventually be able to sustain a population of 10,000. The tourist industry is gradually recovering (tourist revenue in 1998 was \$13 million), with people coming to see the volcano that still threatens to destroy the lives of those on Montserrat. Scientists, politicians, the world's media and the people of Montserrat continue to watch the smoking volcano (Figure 6).

Bibliography

The Geological Society (1996) 'The Soufriere Hills Eruption Montserrat', report. *Geography Review* (March 1998) 'Death and Destruction on Montserrat'

Montserrat Volcanic Observatory: www.geo.mtu.edu/volcanoes/west.indies/soufriere/govt/
The Caribbean Disaster emergency Response Agency: www.cdera.org/

Key search engine words: Montserrat, Volcanic eruption, redevelopment, pyroclastic flows, maps.

FOCUS QUESTIONS

1. Why is there a volcano on Montserrat?
2. What combination of physical, geographical and human factors have made this eruption so devastating?
3. Use a large outline map of Montserrat to design a conference poster on the eruption. This should include information on a) cause and hazards, b) environmental impact c) human impact d) hazard management.
4. Research the internet to find out more on a) the political row over recovery
b) the ongoing threat.
5. Montserrat is a multi-hazard environment. Research the other threats to Caribbean islands such as Montserrat.