British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Seismic Data from the Montserrat Eruption at BGS

Earth Hazards Programme
Open Report OR/09/57

BRITISH GEOLOGICAL SURVEY

EARTH HAZARDS PROGRAMME
OPEN REPORT OR/09/57

Seismic Data from the Montserrat Eruption at BGS

R Luckett

Keywords

Volcanoes, seismology, archive.

Bibliographical reference

LUCKETT, R. 2009. Seismic Data from the Montserrat Eruption at BGS. *British Geological Survey Open Report*, OR/09/57. 16pp.

Keyworth, Nottingham British Geological Survey 2005

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available from the BGS Sales Desks at Nottingham, Edinburgh and London; see contact details below or shop online at www.geologyshop.com
The London Information Office also maintains a reference collection of BGS publications including maps for consultation.
The Survey publishes an annual catalogue of its maps and other publications; this catalogue is available from any of the BGS Sales Desks.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Department for International Development and other agencies.

The British Geological Survey is a component body of the Natural Environment Research Council.

British Geological Survey offices

Keyworth, Nottingham NG12 5GG

☎ 0115-936 3100 Fax 0115-936 3200
e-mail: sales@bgs.ac.uk
www.bgs.ac.uk
Shop online at: www.geologyshop.com

Murchison House, West Mains Road, Edinburgh EH9 3LA

☎ 0131-667 1000 Fax 0131-668 2683
e-mail: scotsales@bgs.ac.uk

Natural History Museum, Cromwell Road, London SW7 5BD

☎ 020-7589 4090 Fax 020-7584 8270
☎ 020-7942 5344/45 email: bgslondon@bgs.ac.uk

Forde House, Park Five Business Centre, Harrier Way, Sowton, Exeter, Devon EX2 7HU

☎ 01392-445271 Fax 01392-445371

Geological Survey of Northern Ireland, Colby House, Stranmillis Court, Belfast BT9 5BF

☎ 028-9038 8462 Fax 028-9038 8461

Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB

☎ 01491-838800 Fax 01491-692345

Columbus House, Greenmeadow Springs, Tongwynlais, Cardiff, CF15 7NE

☎ 029–2052 1962 Fax 029–2052 1963

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU

☎ 01793-411500 Fax 01793-411501
www.nerc.ac.uk

Foreword

This report is the published product of a study by the British Geological Survey (BGS). It describes the seismic data held by the BGS which was recorded during the eruption of the Soufriere Hills Volcano on Montserrat.

Acknowledgements

The data described in this report is the result of much hard, sometimes hazardous, work by the staff of the Montserrat Volcano Observatory. Many people from various institutions have been involved, particularly staff from the Seismic Research Unit at the University of the West Indies in Trinidad and from the BGS. However, only a few have been constantly responsible for maintenance and data archiving, these are Venus Bass, Tappy Syers, Dave Williams and Pyiko Williams. The author would like to thank Brian Baptie and Sue Loughlin for reviewing this document.

Contents

FIGURES

TABLES

Summary

The Soufriere Hills Volcano on Montserrat in the West Indies began to erupt in July 1995. By the end of the year staff from the British Geological Survey (BGS) were involved in monitoring the eruption and the BGS either jointly or singly managed the Montserrat Volcano Observatory between September 1996 and April 2008. In this time a wealth of seismic data was collected by the observatory corresponding to many types of volcanic activity. This data has been archived at the BGS and this report aims to explain how to access it and to put the data in the context of the various seismic monitoring networks that recorded it.

1 Introduction

In the first two years of the eruption of the Soufriere Hills Volcano the capital city of Montserrat had been destroyed and a vast majority of the island's population displaced. The eruption has continued, with periods of quiescence, up to the current day (October 2009) and represents one of the longest running dome-building eruptions in modern times. The eruption has displayed a variety of volcanic phenomena including andesitic dome growth, pyroclastic flows, Vulcanian and sub-plinian explosions and lahars (Sparks and Young, 2002). All of these types of activity have distinctive associated seismic signals and studying these signals can give great insight into the internal dynamics of the volcano and better understanding of its behaviour. The seismic data

collected from over 12 years of monitoring such an active volcano is an invaluable resource for volcanology. Over 2 Tbytes of continuous data is held on disk and is easily read using freeware software, allowing inspection of waveforms for any time interval without any further data processing. In addition, a database of events that triggered the observatory acquisition system is available, allowing events to be selected by event type, location, or other relevant criteria and instantly displayed.

Seismic data from the MVO is stored at Murchison House on UNIX disks. The files are stored in a SEISAN database (basically a directory structure, Havskov and Ottemoller 2005). In principal, this comprises of waveform files in SEISAN binary format each with a linked ASCII reading, or index, file containing metadata such as arrival time picks or earthquake location. The root directory for the database structure is /data/montserrat1/seisan and there are three databases present, “irig”, “MVOE” and “DSNC”, as explained here. Before 1996, only event data was kept and the corresponding files are stored in the “irig” database (named after the time signal recorded in every file). At this time, arrival time picks were written down on paper but some locations were recorded in text files. These locations have been added to readings files for events in the irig database. From 1996 onwards, event data continued to be generated and this is in the “MVOE” (MVO event) database. In this case, the readings files contain picks and locations as expected, as well as other automatically calculated information such as maximum amplitude at each channel. In addition, from this time continuous data was stored in 20 minute waveform files. These are archived in the “DSNC” (digital seismic network continuous) database. There are no reading files for these files as there is no appropriate metadata.

The tables of data completeness show when stations started and stopped recording and when they were out of operation for months for logistical reasons. What is not shown is the data not present in the database because of problems reading the DAT tapes on which data was archived. Duplicate tapes were written throughout the period discussed here, with one copy kept at the observatory and the other stored at the BGS in Edinburgh. Unfortunately, in some cases both copies of a tape proved partially unreadable and efforts to have tapes recovered commercially have failed.

2 Network 1995 to 1996

Prior to 1995, two stations were operated on Montserrat by the University of the West Indies as part of their regional network (MGHZ and MLGT). Immediately after the eruption began, these were supplemented by a seismic network installed by the USGS Volcano Disaster Assistance Program (Aspinall et al., 1998). The resulting network is shown in Figure 1, although not all of these stations operated concurrently. These were all 1 Hz instruments telemetered to a PC-SEIS acquisition system (Murray et al. 1996). Because of the narrow bandwidth of the analogue telemetry used only a very limited range of amplitudes could be recorded by these stations, with most events saturating the system and being recorded 'clipped'. An attempt to rectify this was the installation at Long Ground of two radio links - one for high gain data (MLGT) and one for low gain data (MLGL). Between July 1995 and October 1996, between six and nine of the stations shown in Figure 1 were in use. After that time, the network continued to be run in parallel with the new 'broadband network' and was referred to as the 'short period network'. The number of

stations in this, now secondary, network decreased over the years and now only the two University of the West Indies stations remain in use.

Only triggered data were recorded by this network and in general only the waveforms for the events are retained – some locations have been used to generate readings files but we do not have the corresponding picks. The events are stored in SEISAN format in the 'irig' database as described above. As parts of this network continued to work for the next ten years, these stations were sometimes used to improve event locations done principally using data from later networks. Thus events in the MVOE database sometimes contain traces recorded at stations of the 'short period' analogue telemetered network.

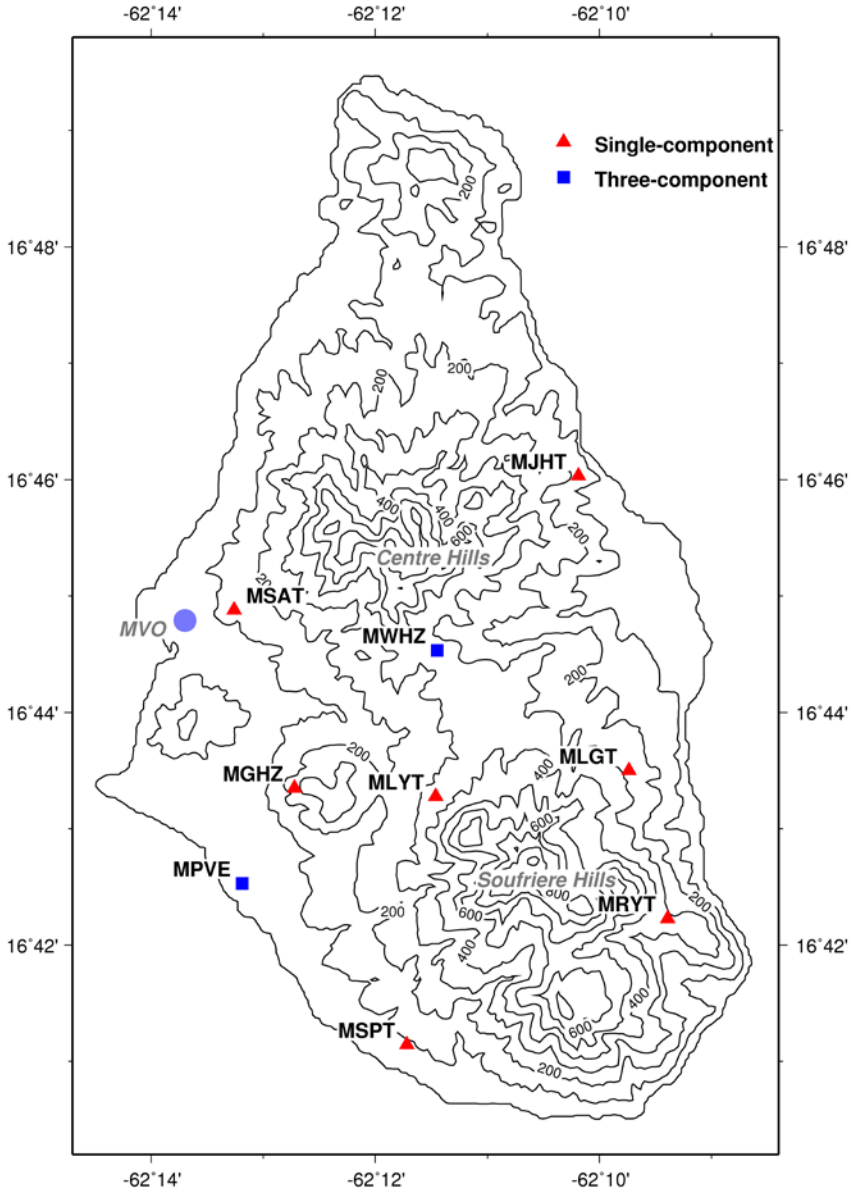

Figure 1: The 'short-period' network as it was between 1995 and 1997. Prior to the position shown the MVO was situated in other places for short periods and the network was not stable, with not all of the stations existing at the same time.

3 Network 1996 to 1998

In October 1996, a new array of seismometers, complete with its own acquisition system, was installed by the BGS (Neuberg et al. 1998). It was known as the 'broadband network' to differentiate it from the existing 'short-period network'. The intention was that the new network (Figure 2) should replace the old one and many of the stations were sited in the same place as existing stations. In practice, however, the two networks ran in parallel for several years. The new network consisted of five 3-component broadband seismometers (Guralp CMG-40T with a 30 second corner frequency) and three vertical only Integra LA100/F 1 Hz instruments. Data was 24 bit digitised at the site and telemetered back to the observatory using UHF radio links. On the east side of the island, where radio contact to the observatory was difficult, data were transmitted to Bethel telephone exchange and carried from there by dedicated telephone line.

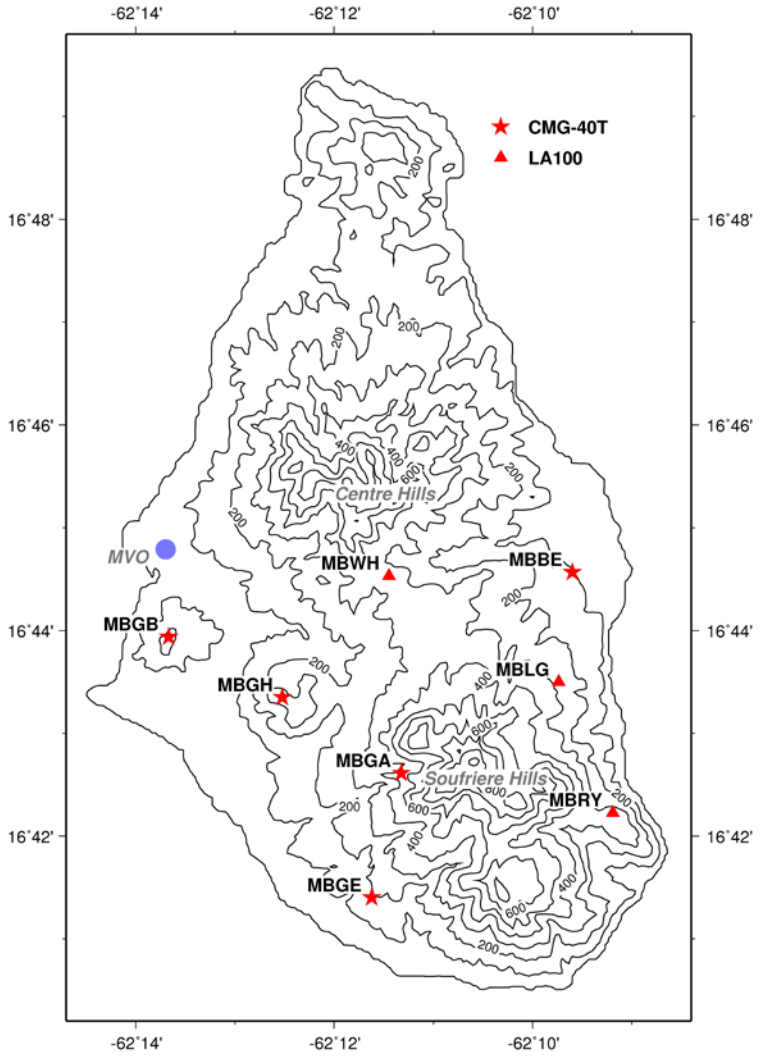

Figure 2: The first 'broadband' network. The stations shown existed for at least part of the time interval October 1996 to March 1998.

At the observatory, data was input to an Interpolating Line Interface supplied, like the radios, by Earth Data Ltd. This interpolated between samples from the different stations to produce samples synchronised with a time signal received from a GPS clock at the observatory. Acquisition consisted of a SEISLOG (Utheim and Havskov 1997) system running under OS9 on a VME computer. Data was digitised at 75 Hz.

In June 1997, volcanic activity destroyed the Bethel telephone exchange as well as the station there (MBBE) so communications were lost to MBLG and MBRY. MBGA was also destroyed by pyroclastic flows that month. Then in September, the location of the observatory became unsafe and communications with all digitally telemetered sites except MBWH were lost when a new observatory was set up in the north of the island, out of reach of existing radio links. In December the site at MBGE was destroyed. The dates when stations stopped recording is shown in Table 1.

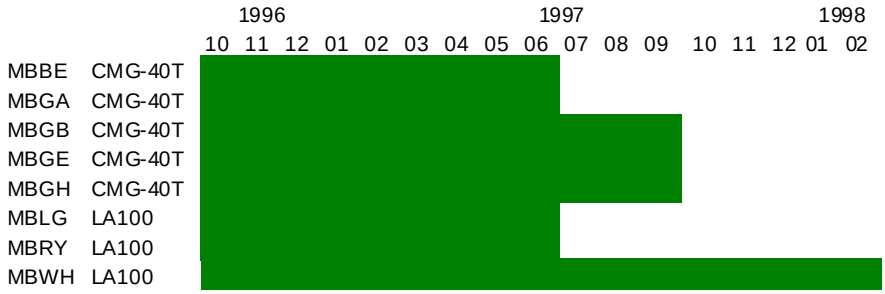

Table 1: Months when each station of the 1996-1998 network was functioning. Any data at all in a given month is enough to shade the cell green so much downtime is not apparent.

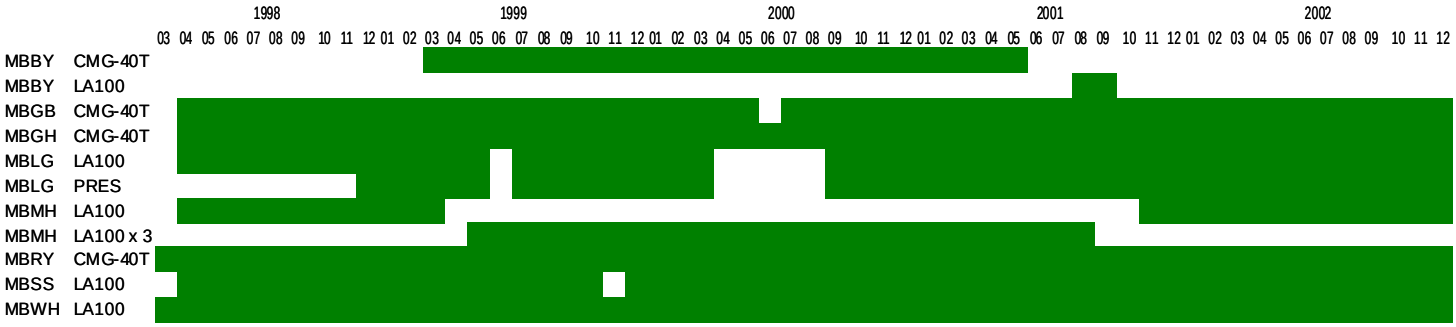

Table 2: Months when each station of the 1998-2202 network was functioning. Any data at all in a given month is enough to shade the cell green so much downtime is not apparent.

4 Network 1998 to 2002

In April 1988, the network was rebuilt based on the remnants of the old one (Figure 3, Table 2). Telemetry problems were solved by installing repeater sites on the Centre Hills and the Silver Hills. A dedicated telephone line was used between the old observatory - now empty for safety reasons - and the new one to transmit data still only available at the old site. Two new single-component 1 Hz stations were installed, MBSS, to the south of the volcano, and MBMH at the

new observatory in the north. MBRY was upgraded from a 1 Hz instrument to a broadband. In December 1998, a pressure sensor was installed at MBLG to record air-waves caused by gas emissions from the dome. The signal from this sensor was digitised at 75 Hz on the second channel of the seismometer digitiser and appears as MBLG APS in the data. In March 1999, a broadband station was added at MBBY to improve the azimuthal coverage of the network. Acquisition continued to be performed by SEISLOG software until 2001 when it was replaced by a combination of SA24 and Earthworm (Johnson *et al.* 1995).

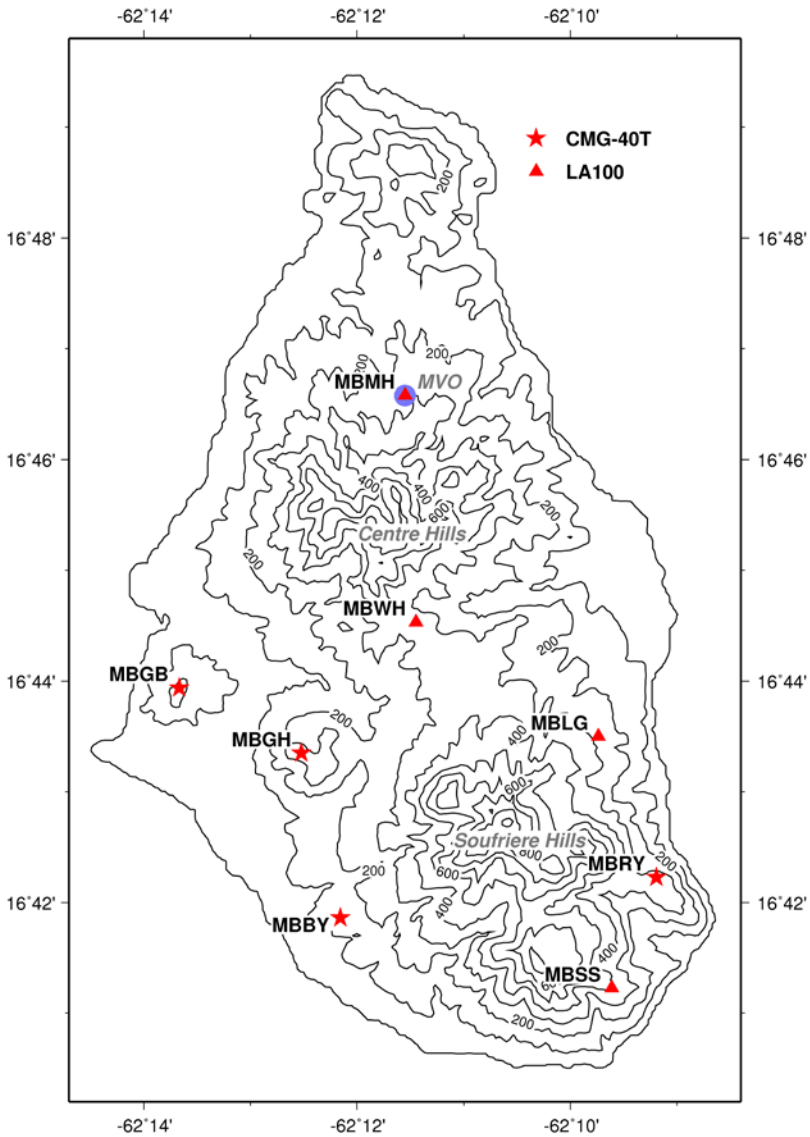

Figure 3: The network as it existed between March 1998 and January 2003.

5 Network 2003 to 2005

In January 2003, the observatory moved back down south to the purpose built premises that it still occupies. This initiated a slight reorganisation of the network (Figure 4, Table 3). At this

time the station at MBMH was lost, as it was in the grounds of the house being used as the temporary observatory. This station was replaced in April 2003 by another site in the north of the island, MBRV. The slightly amended 2003 network is shown in Figure 3. Also shown are two stations installed by outside agencies in this period. These are MBLY, installed by the MULTIMO (Multi-Disciplinary Monitoring, Modelling and Forecasting of Volcanic Hazard) consortium (Green and Neuberg, 2005) and MBHA, installed by Pennsylvania State University. Data from these stations was integrated with the main MVO network from the months indicated in table 3. For most of this time interval MBBY did not function as volcanic conditions made it difficult to visit the site. When the site was rebuilt and reintroduced to the network in September 2004, it was effectively the first station of the 2005 network upgrade - i.e. it had a DM24 and fed into Guralp's SCREAM! software (www.guralp.com), see section 6.

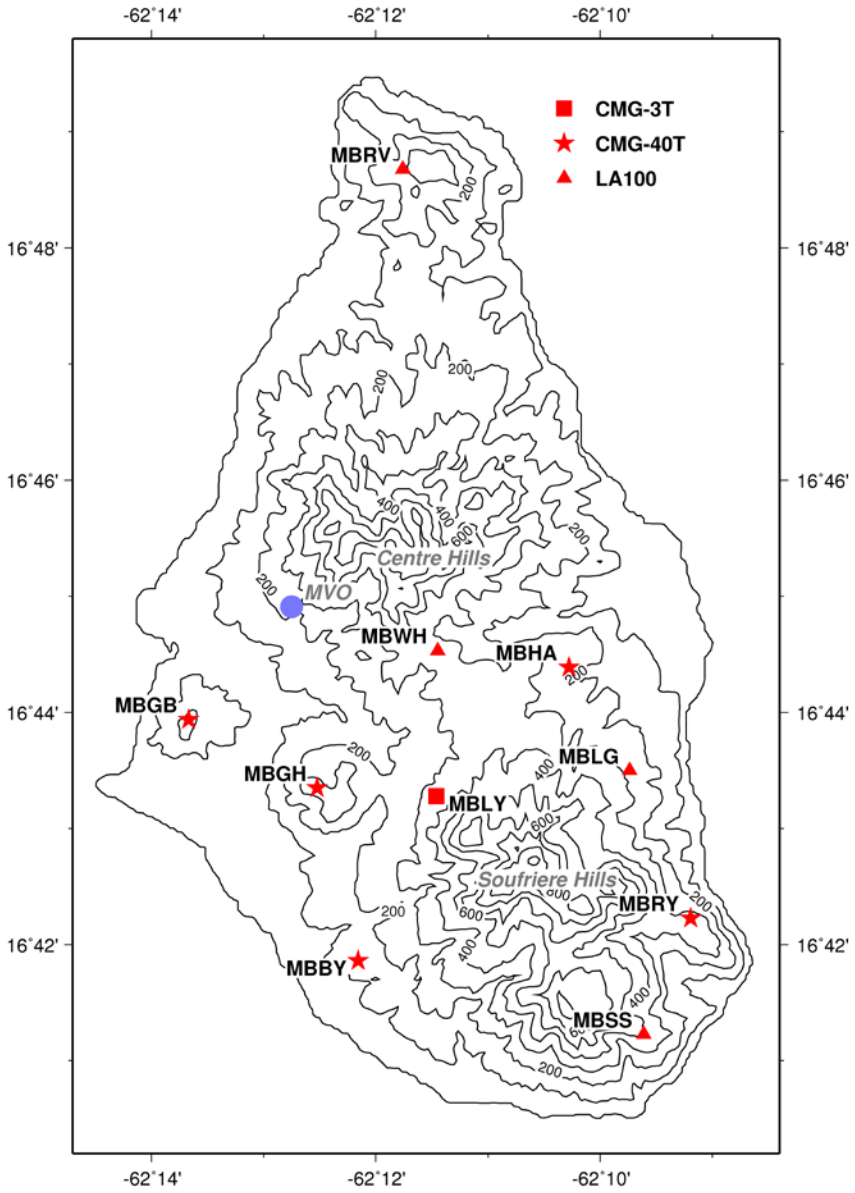

Figure 4: The network as it existed between January 2003 and March 2005.

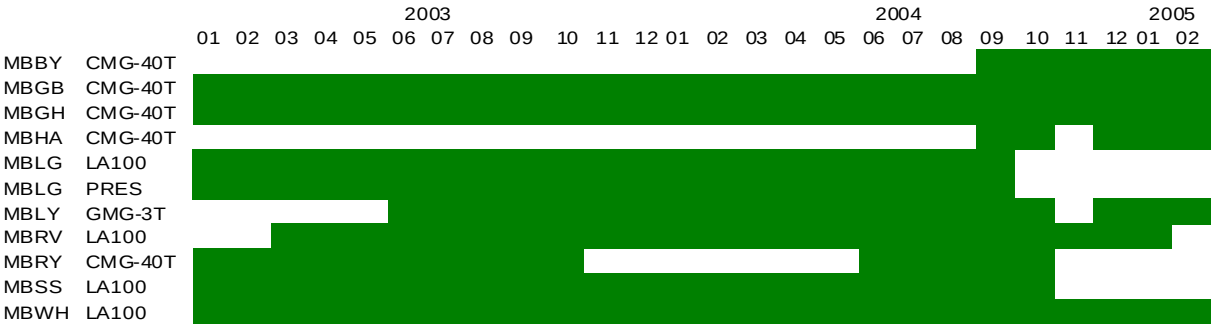

Table 3: Months when each station of the 2003-2005 network was functioning. Any data at all in a given month is enough to shade the cell green so much downtime is not apparent.

6 Network 2005 to 2007

In March 2005, an upgrade to the network was started (Luckett et al. 2007). The Earth-Data digitisers were replaced by Guralp DM24 digitisers, meaning that there is now a GPS clock at each site and that data is time stamped independently at each station. Spread-spectrum radio modems (Freewaves) are used for communication, solving recently escalating interference problems between the UHF radios and marine band signals. The acquisition was modernised with the introduction of Guralp's SCREAM! software that allows two way communication with the digitisers in the field. The sampling rate was changed to 100 Hz and the 1 Hz instruments used are Mark products L4s rather than Integras. In the course of this upgrade the single component instruments at MBLG and MBWH were replaced with 3-component broadband instruments and new stations were installed at MBFR in the South and MBFL at the observatory. The upgraded network is shown in Figure 5 and the uptime for each station in Table 4. After 2005 channels from the weather station at Georges Hill (near MBGH) are sometimes included in the continuous data files. These have station name GHWS. In June 2006, two pressure sensors were installed at MBGH 100 metres apart facing the volcano. These were digitised in the same manner as the seismometer and have the channel codes MBGH PR1 and MBGH PR2.

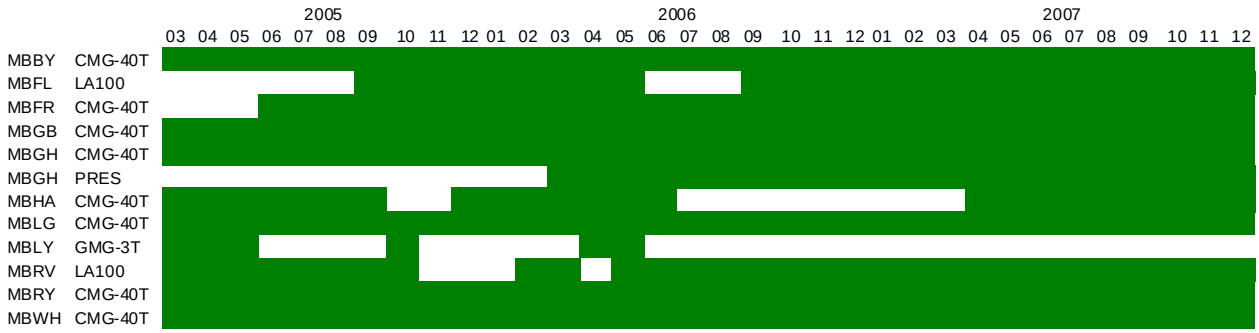

Table 4: Months when each station of the 2005-2007 network was functioning. Any data at all in a given month is enough to shade the cell green so much downtime is not apparent

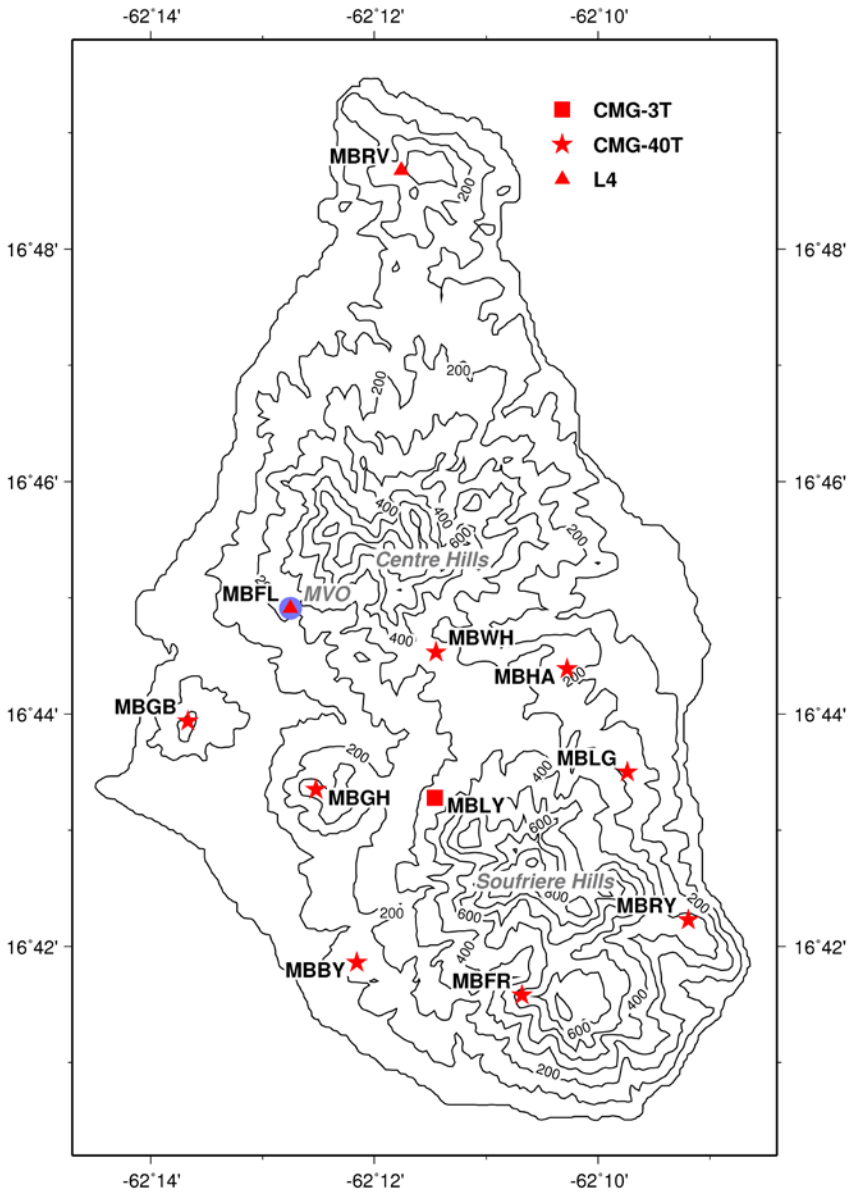

Figure 5: The network as it existed between March 2005 and December 2007.

Appendix I – station locations

MBBE	16°	44.61'	N	62°	9.61'	W	102
MBBY	16°	41.86'	N	62°	12.15'	W	161
MBFL	16°	44.91'	N	62°	12.76'	W	243
MBFR	16°	41.58'	N	62°	10.68'	W	541
MBGA	16°	42.61'	N	62°	11.31'	W	478
MBGB	16°	43.94'	N	62°	13.66'	W	253
MBGE	16°	41.40'	N	62°	11.62'	W	183
MBGH	16°	43.35'	N	62°	12.51'	W	350
MBHA	16°	44.39'	N	62°	10.28'	W	291
MBLG	16°	43.50'	N	62°	9.73'	W	287
MBLY	16°	43.28'	N	62°	11.46'	W	355
MBMH	16°	46.58'	N	62°	11.55'	W	270
MBRV	16°	48.68'	N	62°	11.76'	W	231
MBRY	16°	42.23'	N	62°	9.19'	W	355
MBSS	16°	41.22'	N	62°	9.62'	W	395
MBWH	16°	44.53'	N	62°	11.46'	W	407
MGAT	16°	42.61'	N	62°	11.32'	W	479
MGHZ	16°	43.30'	N	62°	12.41'	W	351
MJHL	16°	46.03'	N	62°	10.19'	W	149
MJHT	16°	46.03'	N	62°	10.19'	W	149
MLGL	16°	43.50'	N	62°	9.74'	W	287
MLGT	16°	43.50'	N	62°	9.74'	W	287
MLYT	16°	43.28'	N	62°	11.46'	W	355
MPVE	16°	42.53'	N	62°	13.19'	W	20
MRYT	16°	42.23'	N	62°	9.19'	W	355
MSAT	16°	44.88'	N	62°	13.26'	W	195
MSPT	16°	41.01'	N	62°	11.95'	W	127
MWEH	16°	44.53'	N	62°	11.45'	W	407
MWEL	16°	44.53'	N	62°	11.45'	W	407
MWHE	16°	44.53'	N	62°	11.45'	W	407
MWHZ	16°	44.53'	N	62°	11.45'	W	407
MWNH	16°	44.53'	N	62°	11.45'	W	407
MWNL	16°	44.53'	N	62°	11.45'	W	407
MWZH	16°	44.53'	N	62°	11.45'	W	407
MWZL	16°	44.53'	N	62°	11.45'	W	407

Table 5: Locations of the stations discussed in this report. Elevations are in metres above sea level.

References

Aspinall, W. P., A. D. Miller, L. L. Lynch, J. L. Latchman, R. C. Stewart, R. A. White, and J. A. Power (1998). Soufrière Hills eruption, Montserrat, 1995-1997: Volcanic earthquake locations and fault plane solutions. Geophysical Research Letters 25, 3,397-3,400.

Green, D. N., and J. Neuberg (2005). Seismic and infrasonic signals associated with an unusual collapse event at the Soufrière Hills volcano, Montserrat. Geophysical Research Letters 32, 1-4.

Havskov, J., and L. Ottemoller (2005). SEISAN: The Earthquake Analysis Software Version 8.1 User's Manual. Bergen: University of Bergen, Norway.

Johnson, C., A. Bittenbinder, B. Bogaert, L. Dietz, and W. Kohler (1995). Earthworm: A flexible approach to seismic network processing. IRIS Newsletter 14, 1–4.

Luckett R., B. Baptie, L. Ottemoller, and G. Thompson (2007). Seismic Monitoring of the Soufrière Hills Volcano, Montserrat. Seismological Research Letters 78, 192-200.

Murray, T., J. Ewert, A. Lockhart, and R. LaHusan (1996). The integrated mobile volcano-monitoring system used by the Volcano Disaster Assistance Program (VDAP). In Monitoring and Mitigation of Volcano Hazards, ed. R. Scarpa and R. Tilling, 315-362. Berlin: Springer.

Neuberg, J., B. Baptie, R. Luckett, and R. Stewart (1998). Results from the broadband seismic network on Montserrat. Geophysical Research Letters 25, 3,661-3,664.

Sparks, R.S. and Young, S., 2002. The eruption of Soufriere Hills Volcano, Montserrat (1995-1999): overview of scientific results. Geological Society, London, Memoirs, 21: 45-69.

Utheim, T., and J. Havskov (1997). The SEISLOG Data Acquisition System. Bergen: University of Bergen, Norway.