Nevis

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Abstract

The island of Nevis consists of a single volcanic complex made up of a series of volcanic domes or centres. There have been no recent signs of increased activity on Nevis; however, frequent shallow earthquake swarms and hydrothermal activity associated with the Nevis Peak volcanic centre indicate that this centre is potentially active, and an increase in activity could occur at any time. The probable style of a future eruption is a lava dome-forming eruption from the summit area which may generate pyroclastic flows, surges and air fall. Lahars would also be a significant hazard during times of heavy rainfall. A major volcanic eruption would require the evacuation of the entire island. Additionally, the Southern Peninsula of St. Kitts may be significantly affected by ash fall.

Introduction

The information in this contribution has been compiled from all past studies on Nevis as well as from a recent hazard assessment done by the Seismic Research Unit (Simpson and Shepherd 2002). Funding for the hazard assessment was provided by the Organization of American States (OAS) as part of the Post-Georges Disaster Mitigation Project.

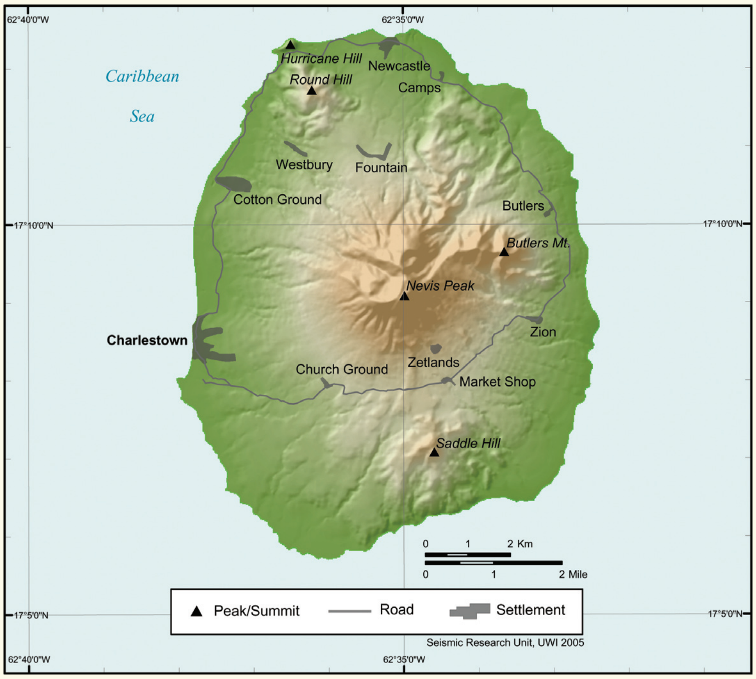
Geographical setting

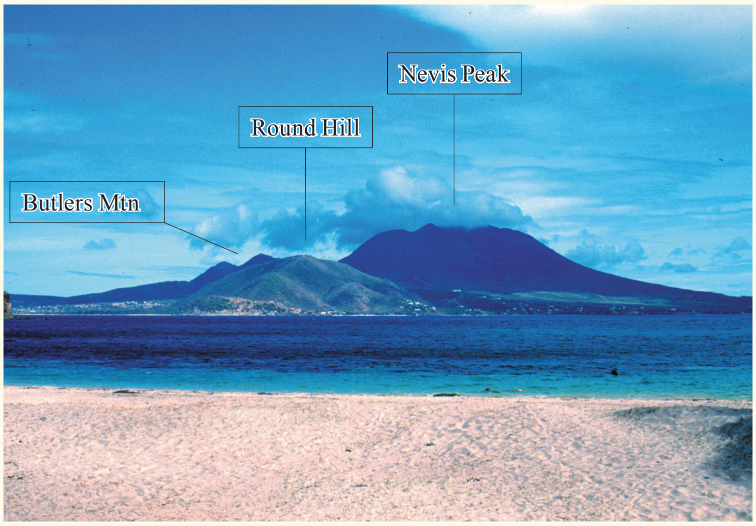
The island of Nevis is situated in the northern region of the Lesser Antilles. Nevis is 93 km^2 in size and has a population of ~9,000. The island is approximately circular with a steep, central, mountainous interior. The foothills gently slope radially from the mountainous interior to the coast. There are no bays, inlets or cays of significance, and most of the island is surrounded by sandy beaches. The highest point on Nevis is Nevis Peak, which rises to 984 m (3232 ft). The higher slopes are covered by rainforest, and the low-lying and coastal areas are covered by dry scrub. The capital, Charlestown, is situated at the base of the volcano in the southwest of the island.

Previous work

Few detailed studies of the geology of Nevis exist, due at least in part to extensive vegetation cover and poor rock exposure. Early studies of the general geology of Nevis were carried out by Sapper (1903), Earle (1925) and Martin-Kaye (1959, 1961). The most extensive study of the geology and petrology of Nevis to date was presented in Hutton (1965) and Hutton and Nockolds (1978). A detailed study of the Saddle Hill eruptive centre was made by Wilson (1992). Geotermica Italiana (1991) conducted a detailed investigation into the hydrogeology and geothermal resources of Nevis, and produced an updated geological map. Simpson and Shepherd (2002) recently prepared the first volcanic hazard assessment for Nevis.

Relief Map of Nevis



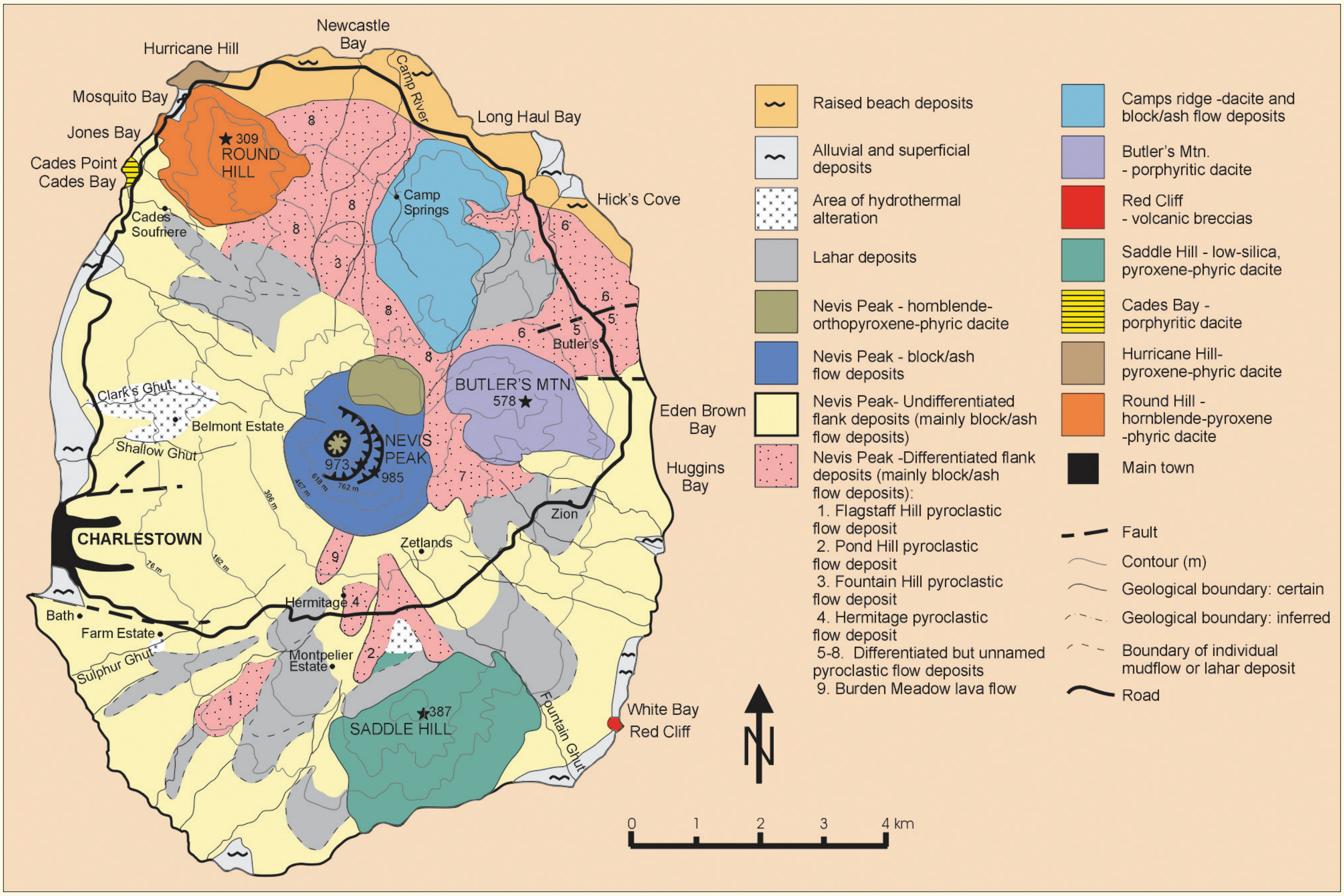


View of Nevis Peak, Round Hill and Butlers Mountain from St. Kitts

Geology

Although the island of Nevis is made up primarily of volcanic material, the oldest outcropping rock on the island is a small conglomerate unit containing blocks of crystallised limestone that contain fossils of mid-Eocene age (Hutton 1965). Seven volcanic centres have been identified on Nevis: Hurricane Hill, Round Hill, Cades Bay, Saddle Hill, Red Cliff, Butlers Mountain and Nevis Peak (Hutton 1965; Hutton and Nockolds 1978). These centres have been interpreted as remnants of lava domes that were generated by effusive eruptions. Ages for Hurricane Hill, Round Hill and Cades Bay range from 3.43 to 2.7 Ma, and these are considered to be the oldest centres. Extrusive activity at the Round Hill and Cades Bay centres seems to have been controlled by a NW-SE trending feeder system, and that of Hurricane Hill by a NE-SW trending system (Geotermica Italiana 1991). Saddle Hill and Butlers Mountain have yielded radiometric ages of 1.80 and 1.10 Ma respectively, and are therefore somewhat younger. The small eruptive centre of Red Cliff is interpreted as a remnant of a volcanic cone whose source was probably situated slightly east of the present shoreline and is now removed by wave action (Geotermica Italiana 1991). No radiometric age is available for Red Hill, but the relative freshness of the lava led Hutton and Nockolds (1978) to suggest an age comparable to that of Nevis Peak (1 Ma). These older volcanic centres discussed above are unlikely to be the sites of future volcanic activity.

Generalised geological map of Nevis (modified from Hutton and Nockolds 1978)



K-Ar age dates for volcanic centres on Nevis

Volcanic Centre	Age (Ma)	Ref.
Round Hill ('*Hurricane Hill*' of Hutton 1965)	3.43 ± 0.17	1
Cades Bay	3.22 ± 0.16	1
Hurricane Hill ('*Windy Hill*' of Hutton, 1965)	2.70 ± 0.50	1
Saddle Hill	1.80 ± 0.30	1
Butlers Mountain	1.10 ± 0.16	1
Nevis Peak: main cone	0.98 ± 0.10	1
Nevis Peak: Mt. Lily welded tuff	0.23 ± 0.16	2
Nevis Peak: intracrateral dome	0.10 ± 0.06	2

1 Hutton and Nockolds (1978);
2 Geotermica Italiana (1991);
Ma Millions of years

The Nevis Peak volcanic centre is inferred to be the youngest on the island, based on its youthful appearance and age determinations of 0.98 - 0.10 Ma (Hutton and Nockolds 1978; Geotermica Italiana 1991). It is the only volcanic centre considered likely to erupt again in the future.

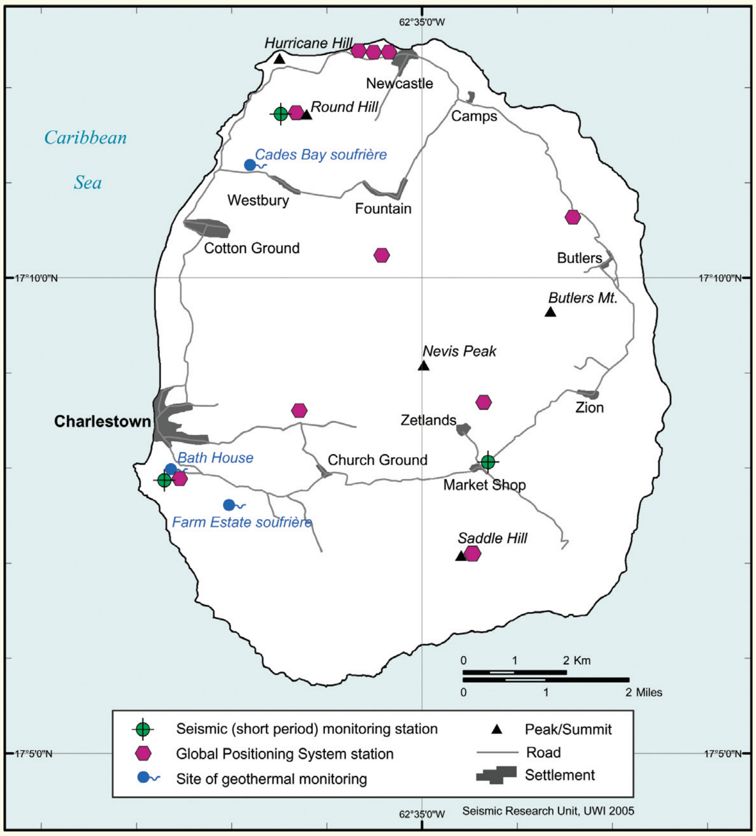
Volcano monitoring

Volcanic and seismic activity in Nevis is monitored by the Seismic Research Unit of the University of the West Indies, St. Augustine, Trinidad. The first permanent seismic station was installed on Nevis in 1980 at Gingerland, about 3 km southeast of Nevis Peak. Recently (2002) two additional stations were installed on Nevis, at Round Hill and Bath House. Prior to 1980, seismic activity in Nevis was monitored solely from a seismic station at Bayford's Farm in St. Kitts, except for 1962-1963, when a temporary network was established on Nevis in response to a volcanic earthquake swarm.

Scientist undertaking GPS measurements at Round Hill

In January 2002 a GPS network was established on Nevis. The network consists of 10 stations, 3 of which are located close to the summit of Nevis Peak. The network is re-measured annually and is used to monitor potential ground deformation associated with the volcano. Geothermal activity is also being monitored periodically for changes in temperature, chemistry, vigour or location.

Volcano monitoring network on Nevis



Potentially active volcanic centres

Nevis Peak volcanic centre

Nevis Peak volcanic centre, which dominates the island, is the only potentially active centre on Nevis. It is a Pelean-type volcano that has produced andesite to dacite (58 - 65 wt% SiO_2; Hutton and Nockolds 1978) lava domes and associated volcaniclastic deposits. The volcanic centre consists of a central or main cone, flank deposits that extend radially to the sea and two younger lava domes. The main cone has a youthful appearance and is almost entirely covered by thick vegetation.

Past eruptive activity

Exposures are largely limited to road cuttings, which predominantly consist of volcaniclastic rocks that are highly weathered and therefore difficult to interpret. The volcaniclastic deposits exposed in the road cuttings are most likely pyroclastic flow, surge and/or lahar deposits. Given the available data, the best interpretation of the Nevis Peak volcanic centre is that it was formed dominantly by effusive eruptions of lava that produced several nested lava domes and voluminous block and ash flow deposits. The largest and oldest of these lava domes forms the bulk of the main cone and has been dated at 0.98 Ma. This lava dome is interpreted to have been built on an older volcanic complex, which is now preserved as a terrace at an elevation of approximately 460 m (Hutton and Nockolds 1978). Periodic collapse of the lava dome generated pyroclastic flows, surges and airfall that blanketed the flanks of the volcano and infilled topography creating the gentle slopes that characterise much of Nevis today.

In an unpublished report, Geotermica Italiana (1991) identified an extensive welded tuff deposit on the northern third of the island. The deposit was dated at 0.23 Ma and interpreted to have been derived from the northern sector of Nevis Peak. Descriptions of this deposit in the Geotermica Italiana (1991) report are limited, and no evidence is presented to support the welded nature of the pyroclastic flow deposit. Work by Simpson and Shepherd (2002), Hutton and Nockolds (1978), Hutton (1965) and Martin-Kaye (1959, 1961) does not support the Geotermica Italiana (1991) interpretation of extensive welded tuff deposits on Nevis. Therefore, the Geotermica Italiana (1991) interpretation is currently unsubstantiated and will not be relied upon here.

The northwest quadrant of the Nevis Peak volcanic centre is cut by a 1000 m-wide, semi-circular depression that is open to the west and northwest (see geology map). This was referred to as a breached crater by previous workers (Martin-Kaye 1959; Hutton and Nockolds 1978). The exact origin of this semi-circular depression is unknown, but it was likely formed by the collapse of the northwest summit of the volcano during a dome-collapse event. Geotermica Italiana (1991) suggested that there is evidence for a strongly hydrothermally altered debris avalanche deposit in the Belmont Estate area to the west of Nevis Peak, which may be related to this collapse. Within this depression there is a small dome, which was referred to by Hutton and Nockolds (1978) as the Intracrateral Dome. This dome appears to have grown after formation of the depression as it partially fills the depression. An age of 0.10 Ma has been obtained for this dome (Geotermica Italiana 1991). A second dome called the Great Dome by Hutton and Nockolds (1978) is located on the northern outer slopes of the Nevis Peak volcanic centre.

Age determinations

There are only three radiometric age dates for the Nevis Peak volcanic centre. A K-Ar date from dacite lava from the summit region of the main cone yielded an age of 0.98±0.10 Ma (Hutton and Nockolds 1978). An age of 0.23±0.16 Ma was obtained for an inferred pyroclastic flow deposit (Geotermica Italiana 1991). The youngest known age on the island, 0.10±0.06 Ma, comes from the intracrateral dome (Geotermica Italiana 1991). The age of the Great Dome is not known, but is interpreted to be younger than 0.98 Ma based on contact relationships. No charcoal has been found in any deposits from Nevis. With the limited number of age dates it is impossible to estimate the eruption frequency of the volcano.

Historical eruptions

There have been no reports of volcanic eruptions on Nevis in historical time.

Geothermal activity

Two localities on Nevis, Cades Bay soufrière and Farm Estate soufrière, are sites of minor fumarolic activity. A number of hot springs are also present; the hottest are those at the Bath Estate and at Cades Bay beach. In addition there are large areas of pervasively hydrothermally altered rock present throughout the island (e.g. Clarks Ghut) that are interpreted as areas of past/extinct fumarolic activity. Current geothermal activity is largely concentrated on the western half of the island.

Cades Bay soufrière

The Cades Bay soufrière is an area of warm, hydrothermally altered ground ~ 30 x 30 m in size. Local residents and Robson and Willmore (1955) report that the Cades Bay soufrière began to form in 1953 with the burning of vegetation, deposition of sulphur in the soil, and development of small boiling pools and vigorously steaming vents. Soil temperatures of up to 100° C were reported for these early stages (Robson and Willmore 1955). In more recent years activity has decreased considerably, with steaming vents only visible during and after heavy rainfall. In 2001 ground temperatures of 100° C were measured. It is likely that the Cades Bay soufrière formed in response to local readjustments in the groundwater system brought about by the severe earthquake swarm in Nevis between 1950 and 1951.

Main areas of geothermal activity in Nevis (Lindsay 2001)

Area of activity	Description	Temp. (2001)
Cades Bay soufrière	Area of warm altered ground that became active in 1953	96 - 100.1 ºC
Farm Estate soufrière	Weakly steaming vents in Sulphur Ghut	53 - 99.3 ºC
Cades Bay Beach	'Champagne' springs in shallow water	51.7 ºC
Bath Estate	Springs in small stream below bath house	48.4 ºC
Camp Springs	Springs used for Nevis water supply	31.6 - 38.6 ºC

Farm Estate soufrière

The Farm Estate soufrière is an area of warm, hydrothermally altered ground occupying part of the Sulphur Ghut stream valley and from which sulphur has been mined in the past for gun powder. A few weakly steaming vents are present, with more energetic steaming vents appearing after heavy rainfall. The activity at Farm Estate appears to have been at this low level for at least the last 60 years. Robson and Willmore (1955) report that the Farm Estate soufrière 'was found to be nearly extinct' when they visited it in 1953, although they obtained temperatures from within small crevices of up to 100 °C. More recently (2001) temperatures of up to 99.3 °C were obtained from weakly steaming vents.

Hydrothermally altered ground at Farm Estate soufrière

Seismicity

Nevis experienced significant volcanic earthquake swarms in 1926, 1947-48, 1950-51, and 1961-63. These earthquakes were relatively shallow and originated at depths between 1-11 km. No earthquakes other than regional tectonic earthquakes have been reported felt in Nevis since May 1963. The permanent seismograph station at Gingerland has been in continuous operation since 1980 and detects local volcanic earthquakes once or twice per year.

1926 and 1947-1948 swarms

Between February 18 and March 2, 1926 at least 24 earthquakes were reported felt on Nevis (Port-of-Spain Gazette 3.3.1926) and later interpreted as a volcanic earthquake swarm (Robson 1964). Six earthquakes were reported felt on Nevis between December 1947 and October 1948 (Robson 1964); these may in fact represent the early stages of the 1950-51 swarm.

1950-51 swarm

The 1950-51 earthquake swarm began on December 29 (Willmore 1952), when an earthquake of magnitude 5.1 occurred at shallow depth directly below southeastern Nevis. This earthquake was felt very strongly and caused significant damage. About 150 more earthquakes were felt during January 1951, and there were renewals of activity in both March and May, 1951. A network of shock recorders was set up in February 1951 enabling some of the March and May events to be located more accurately than the first shock. The earthquakes occurred beneath Nevis at depths of less than 10 km in a region roughly northwest and southeast of Nevis Peak.

1961-63 swarm

The sequence of events in 1961-63 (Robson et al. 1962) was similar to that of 1950-51. An initial shock, again of magnitude 5.1, occurred to the west of Nevis on November 2, 1961. Over 100 aftershocks were recorded by the permanent seismograph station in St. Kitts over the following two weeks, and many of these were felt in both Nevis and St. Kitts. By the end of November the sequence appeared to have died away. These earthquakes were interpreted as a normal tectonic earthquake sequence in which a mainshock of relatively high magnitude was followed by a series of smaller shocks of progressively diminishing size.

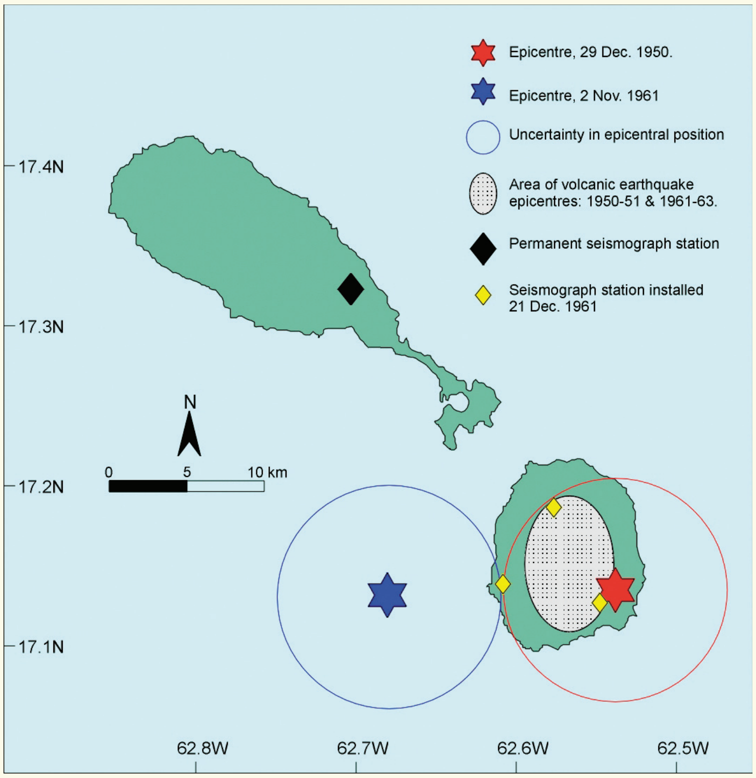
On December 14, 1962 activity was renewed at a rate of 5-10 earthquakes per day. This time the earthquakes were felt only in Nevis, and only a few of them were recorded by the seismograph station in St. Kitts. In response to this activity a seismograph network was established in Nevis, allowing the locations of subsequent earthquakes to be determined with much greater precision than had previously been possible.

The seismograms showed clearly that the earthquakes which occurred after December 14 were quite different in character from the aftershocks of the earthquake of November 2. The later earthquakes were in fact volcanic earthquakes originating at depths of 1-11 km below and to the southeast of Nevis Peak. They continued at a fairly constant rate until mid-1962, after which numbers declined. By early 1963 the rate had fallen to less than one per week. The seismograph network was withdrawn on May 8, 1963. In total, 611 earthquakes were recorded between December 21, 1961 and May 8, 1963, of which about 100 were reported felt.

Future eruptions from Nevis Peak

Past activity on Nevis indicates that the most likely style of a future eruption is an effusive dome-forming eruption, similar to the ongoing eruption of the Soufrière Hills Volcano in Montserrat. Less likely is an explosive magmatic eruption.

Volcanic seismicity of Nevis in 1950-51 and 1961-63



The most recent eruptions from the Nevis Peak volcanic centre have come from the summit area of the main cone, and this is regarded as the most likely vent area for a future eruption.

Volcanic hazards

Volcanic hazards associated with a dome-forming eruption on Nevis include dome-collapse pyroclastic flows and associated surges, airfall and lahars. Pyroclastic flows and surges would travel down the flanks of the volcano, initially being confined to valleys and then spreading out onto the gentle slopes towards the sea. If the pyroclastic flows and surges are large enough they may enter the sea and create new land. Given the present topography it is likely that in the early stages of an eruption dome-collapse events would be initially directed on one side of the volcano. The most vulnerable areas would be the north and northwest part of the island due to the topography of the breached crater which would confine the lava dome on the south and southeast sides. However, as a lava dome continued to grow the dome-collapse events could affect a wider area. There are a few areas that, due to the topography, will be somewhat shielded from pyroclastic flows and surges (e.g. Saddle Hill, Hurricane Hill).

Particularly vigorous flows and surges may be energetic enough to cross topographic barriers, and will have a more widespread effect. Such flows and surges could occur as a result of an energetic volcanic blast triggered by a large dome collapse. The debris avalanche and lateral blast that result from such an event could devastate a large area in the direction of the blast, largely irrespective of the topography.

Ash would be the most widespread hazard and could affect the entire island as well as the southwest peninsula of the neighbouring island of St. Kitts. Ash would be dispersed widely around the volcano especially westward, in the direction of the dominant easterly winds. The pattern of ash fall exhibited by the ongoing eruption of the Soufrière Hills Volcano in Montserrat (Norton et al. 2001) has been used to define a probable ash fall pattern for Nevis Peak. If a volcanic eruption occurred during times of heavy rainfall, lahars may be generated contemporaneous with pyroclastic flows, surges and airfall. They also may occur during times of heavy rain after an eruption has ended. Lahars will be confined to valleys and thus their flow paths will be the main rivers/streams and their tributaries. Ballistic projectiles could also be generated during simultaneous explosive eruptions and are likely to affect areas within 3 km of the eruptive vent. Projectiles are not typically expected to reach further than 5 km from the vent.

Pyroclastic flows generated by explosive eruptions could occur on Nevis. However, given the current understanding of the Nevis Peak volcanic centre, dome collapse events have been more common in the past than column collapse generated pyroclastic flows.

Volcanic earthquakes are likely to accompany a volcanic eruption on Nevis, and in themselves may be severe enough to cause damage.

Significance of the local earthquakes

The frequency of occurrence of local earthquake swarms in Nevis during the first 60 years of the 20th century was higher than in any other volcanic island in the Lesser Antilles except Guadeloupe. The average rate of about one in every fifteen years was about twice as high as in the adjacent island of Montserrat, and the earthquakes were generally bigger than those recorded in Montserrat.

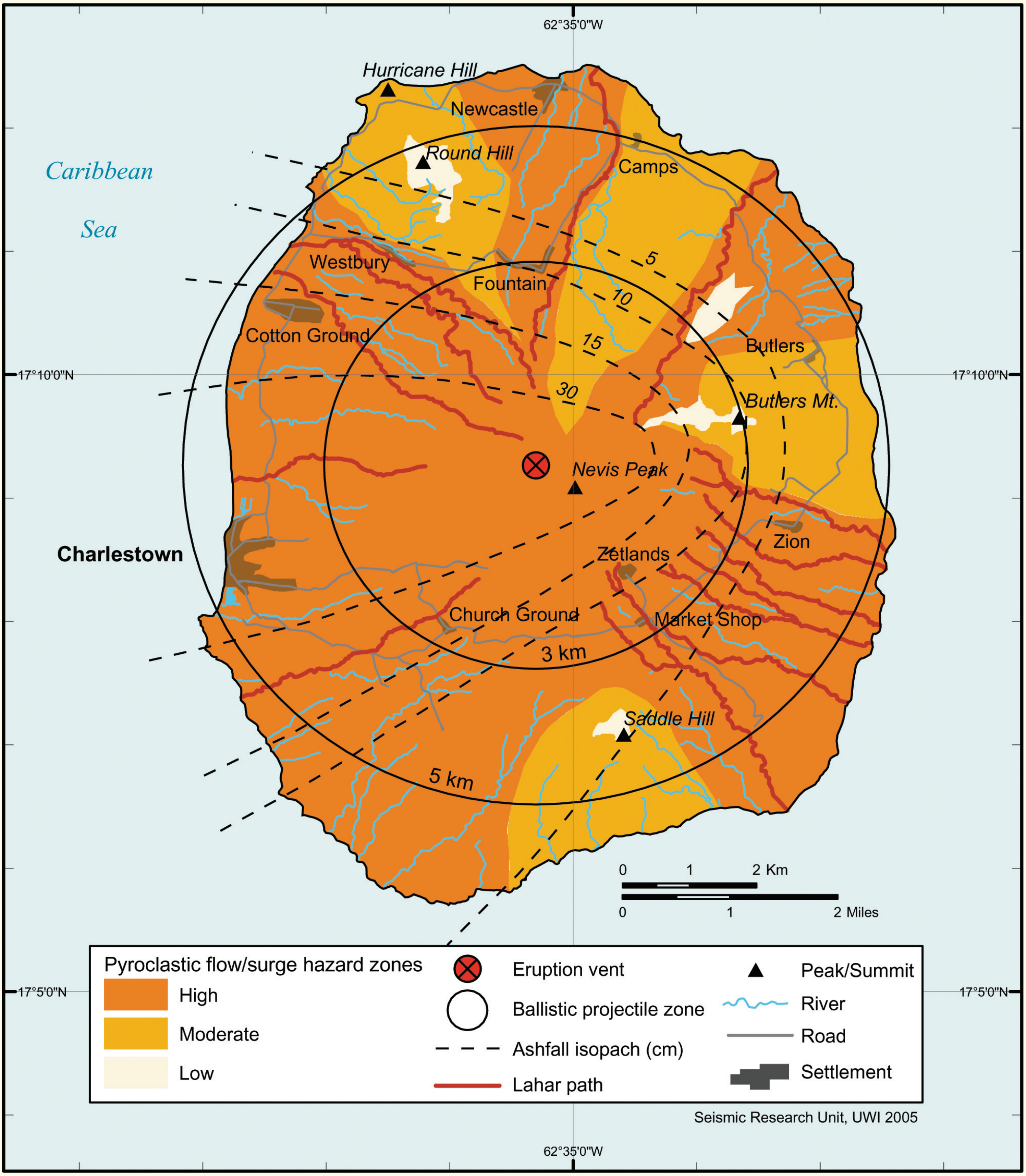
The only earthquake swarm for which the data were of sufficiently high quality to permit a detailed interpretation was that of 1961-63. Robson et al. (1962) suggested that the mainshocks which began each sequence triggered off disturbances in a body of magma which is emplaced beneath and to the southeast of Nevis Peak. Earthquake swarms are commonly associated with potentially active volcanoes in the Lesser Antilles and may represent abortive attempts by magma to reach the surface. Despite the intensity of past swarms in Nevis, no eruption has occurred. However, the possibility exists that future swarms may precede eruptive activity.

Integrated Volcanic Hazard Zones

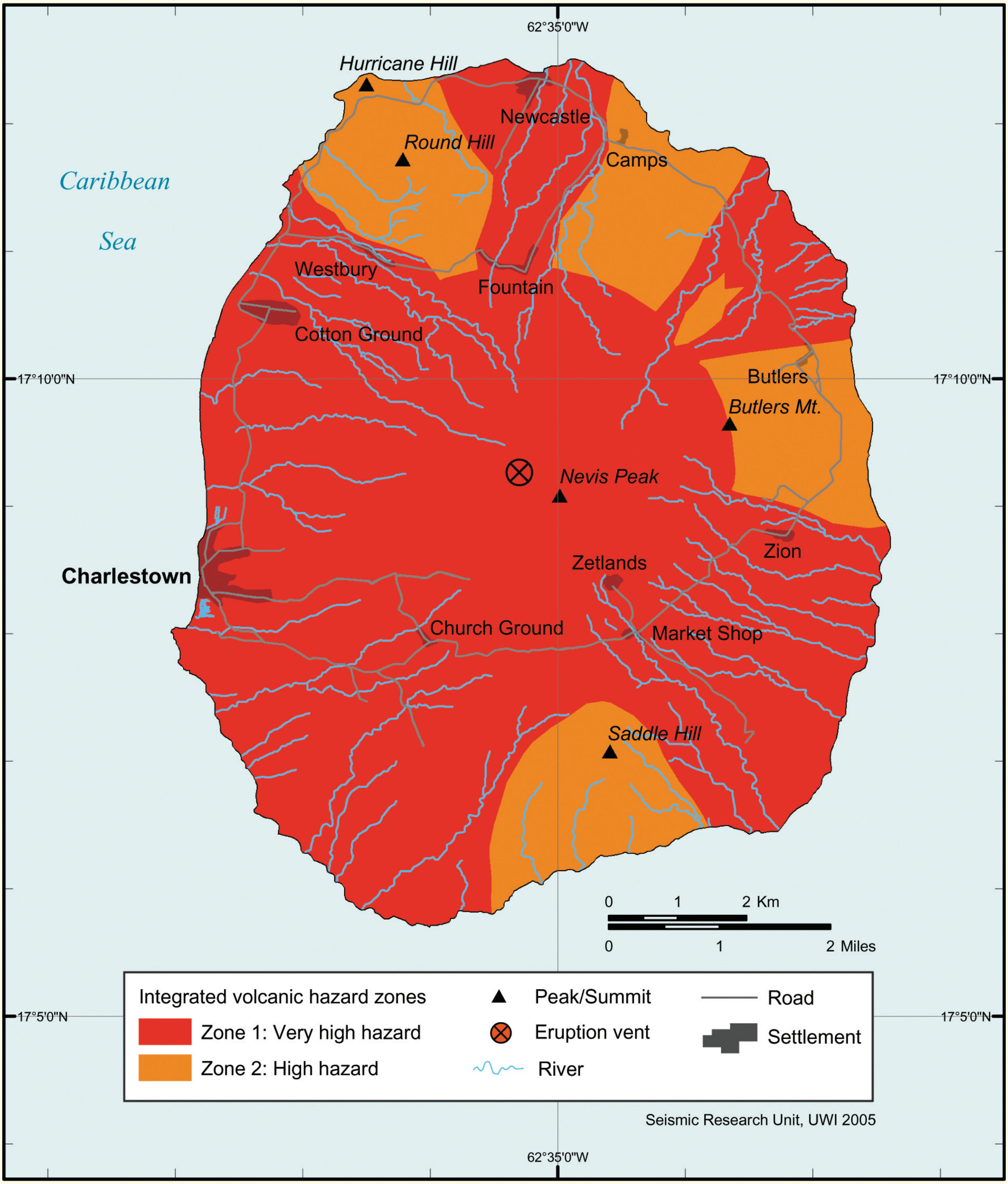
The hazard map has been used to create integrated volcanic hazard zones for the island of Nevis. These zones give an indication of overall hazard in different parts of the island. Zone 1 includes all the areas of high pyroclastic flow and surge hazard, all lahar paths, the area within the 3 km ballistic projectile zone and the area likely to receive >30 cm of ash. Zone 2 includes all the areas of moderate pyroclastic flow and surge hazard, the area within the 5 km ballistic projectile zone and the area likely to receive 10-30 cm of ash.

In the event of a volcanic eruption the entire island of Nevis would be in either zone 1 (area of very high hazard) or zone 2 (area of high hazard). All buildings and infrastructure on the island are likely to be severely impacted and potentially destroyed. The entire population of Nevis would probably be required to evacuate before an eruption began in order to avoid loss of life. The Southern Peninsula of St. Kitts may also be affected by ash fall from an eruption from Nevis Peak.

Volcanic hazard map for an effusive dome building eruption from Nevis Peak



Integrated volcanic hazard zones for an effusive dome building eruption from Nevis Peak



Nevis Peak with Charlestown in foreground

Conclusion

The Nevis Peak volcanic centre is likely to erupt again in the future. This chapter does not attempt to provide a comprehensive review of all possible future eruption scenarios, rather a summary of the most likely scenario is presented. The most likely type of activity expected is a lava dome-forming eruption, with associated pyroclastic flows, airfall and lahars. The approach to hazard assessment used for Nevis has been empirical and is based on a thorough review of past activity, on the distribution and type of existing deposits and on the structure and composition of the volcano. The ongoing eruption of the Soufrière Hills Volcano on Montserrat is a good analogue for the type of activity that could occur at the Nevis Peak volcanic centre. Future hazards are expected to include volcanic earthquakes, pyroclastic flows, pyroclastic surges, airfall and lahars. Evidence for past explosive eruptions has not been documented; however this style of eruption cannot be ruled out. The continuous operation of a volcano monitoring network is an essential component in predicting and mitigating the effects of future eruptive activity.

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