NEVIS GEOLOGICAL PROFILE

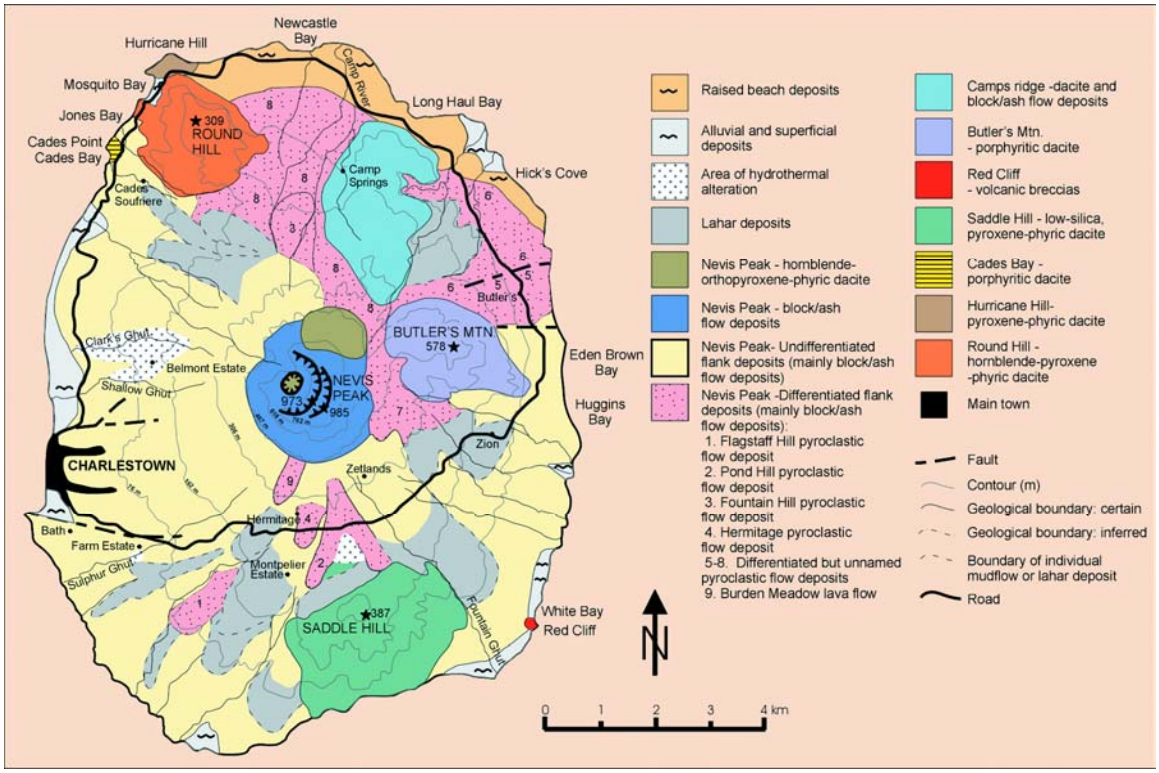
SUMMARY
The island of Nevis consists of a single volcanic complex made up of a series of volcanic domes or centres. There have been no recent signs of increased activity on Nevis; however, frequent shallow earthquake swarms and hydrothermal activity associated with the Nevis Peak volcanic centre indicate that this centre is potentially active, and an increase in activity could occur at any time.

Caption: View looking southeast at the main edifice of Nevis Peak and the older dome of Butlers Mountain (to the left). Note the communities living on the northern flank of Nevis Peak, this area is a pyroclastic fan developed in a prehistoric eruption of Nevis Peak. View is taken from near the gps benchmark on Round Hill.

GEOLOGY

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 people. The highest point on Nevis is Nevis Peak, rising to 984 m (3232 ft) and this mountain represents a typical andesitic lava dome characteristic of the Lesser Antilles. Although the island of Nevis is made up primarily of

volcanic material, the oldest rock outcropping on the island is a small conglomerate unit containing blocks of crystalline limestone that contain fossils of mid-Eocene age.



Caption: Generalised geological map (modified from Hutton & Nockolds, 1978)

Seven volcanic centres have been identified on Nevis: Hurricane Hill, Round Hill, Cades Bay, Saddle Hill, Red Cliff, Butlers Mountain and Nevis Peak. These centres have been interpreted as remnants of lava domes that were generated by effusive volcanic activity. 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 Hurricane Hill along a NE-SW trending system. Saddle Hill and Butlers Mountain have yielded radiometric ages of 1.80 and 1.10 Ma respectively, and thus 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. No radiometric age is available for Red Cliff, but the relative freshness of the lava leads interpretation to an age similar to Nevis Peak (~1 Ma). All of these older volcanic centres are unlikely to be the sites of future volcanic activity. Nevis Peak is the youngest edifice (dated at 0.98 – 1 Ma) and is the only volcanic centre likely to erupt in the future.

GEOTHERMAL ACTIVITY

Two localities on Nevis, Cades Bay soufrière and Farm Estate soufrière, are sites of very 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 Ghaut) that are interpreted as areas of extinct fumarolic activity. Current geothermal activity is mainly concentrated on the western half of the island.

The Cades Bay soufrière is an area of warm, hydrothermally altered ground ~ 30 x 30 m in size. Local residents 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 ºC were reported for these early stages. In more recent years activity has decreased considerably, with steaming vents only visible during and after heavy rainfall. In 2001 ground temperatures of 100ºC 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.

The Farm Estate soufrière is an area of warm, hydrothermally altered ground occupying part of the Sulphur Ghaut stream valley and from which sulphur has been mined in the past for gunpowder. 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) reported 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 100ºC. Notably, in 2001 temperatures of up to 99.3ºC were obtained from weakly steaming vents.

VOLCANISM

Nevis Peak volcanic centre, which dominates the island, is the only potentially active centre on Nevis. It is a Pelèan-type volcano that has produced andesite to dacite (58 - 65 wt% SiO_2) lava domes and associated volcaniclastic deposits. The volcanic edifice 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.

Exposures are largely limited to road cuttings, which predominantly consist of volcaniclastic rocks that are highly weathered and thus difficult to interpret. The volcaniclastic deposits exposed in the road cuttings are block-and-ash flows, associated surges and/or lahar deposits. The Nevis Peak volcanic centre is interpreted to have formed predominantly by effusive eruptions of lava that produced several nested lava domes and voluminous block and ash flow deposits during their evolution (in the style exhibited by the Soufrière Hills Volcano). The largest and oldest of these lava domes forms the bulk of the main cone and has been dated at 0.98 Ma. This dome is believed to have developed on an older volcanic complex, which is now preserved as a terrace at an

elevation approx. 460 m high. 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 characterize much of Nevis today.

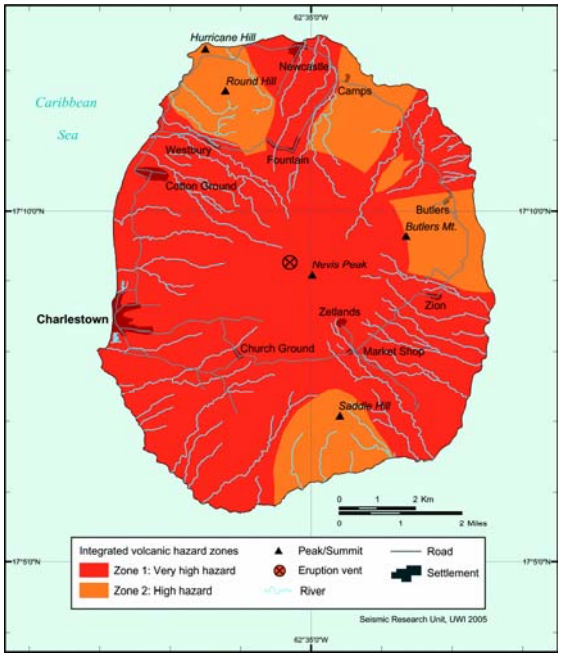
The northwest quadrant of the Nevis Peak volcanic centre is cut by a 1000 m-wide, semi-circular depression that is open to the west and northwest. This was referred to as a breached crater by previous workers but the exact origin of this semi-circular depression is unknown - it was likely formed by the collapse of the northwest summit of the volcano during a dome-collapse event. An extensively hydrothermally altered debris avalanche deposit can be seen at 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, the Intracrateral Dome, which appears to have grown after formation of the large depression as it partially infills it. An age of 0.10 Ma has been obtained for this dome. A second dome, known as the Great Dome is located on the northern outer slopes of the Nevis Peak volcanic centre. There have been no reports of volcanic eruptions in historical time at Nevis Peak.

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 Nevis include dome-collapse pyroclastic flows and 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 spill down valleys and their flow paths will follow 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.



Caption: Integrated volcanic hazard map for an effusive dome building eruption from Nevis Peak.

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 detecting local volcanic earthquakes once/twice per year.

1926 and 1947-1948 swarms

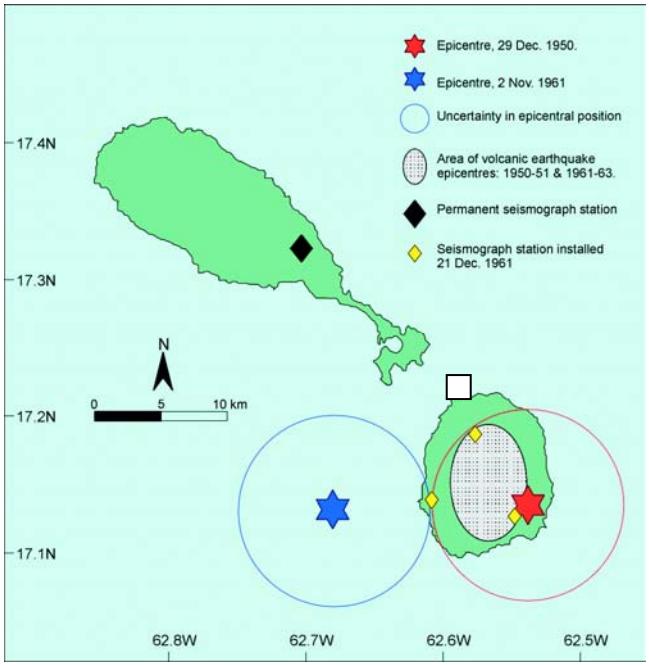
Between February 18 and March 2, 1926 at least 24 earthquakes were reported felt on Nevis and later interpreted as a volcanic earthquake swarm. Six earthquakes were reported felt on Nevis between December 1947 and October 1948; these may in fact represent the early stages of the 1950-51 swarm.

1950-51 swarm

The 1950-51 earthquake swarm began on December 29, 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 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 main-shock 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 occurring 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 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 ~100 were felt.

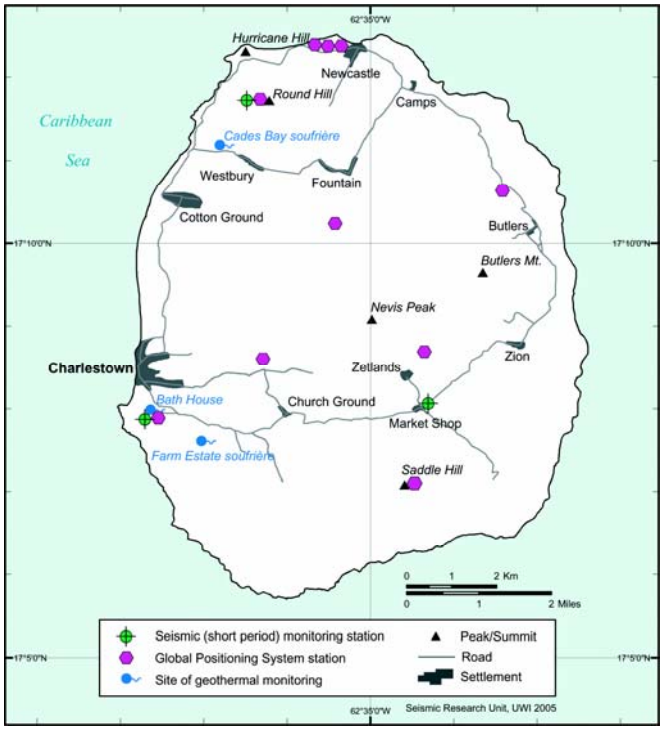


Caption: Volcanic seismicity of Nevis in 1950-51 and 1961-63.

MONITORING

Volcanic and seismic activity in Nevis is monitored by the Seismic Research Centre 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 and is used to monitor potential earthquake activity associated with the volcano. In 2002, two additional seismic 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.

In January 2002 a GPS network was established on Nevis. The network consists of 7 stations, including a permanent GPS (cGPS) site at Bath House Hotel, three of the other sites are located close to the summit of Nevis Peak. The network is re-measured biannually 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.



Map showing the volcano monitoring network on Nevis

Caption: Setting up a gps antenna and receiver above a benchmark located at the summit of Saddle Hill on the southern end of Nevis. Satellite measurements are collected ~ 2 hours simultaneously with other gps kits deployed around the volcano to compute an accurate location for each site.

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