

Nevis

Geology

The island of Nevis consists of a single volcanic complex made up of a series of volcanic domes or centres. Although Nevis is made up primarily of volcanic material, the oldest outcropping rock on the island is a conglomerate 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, Butler's 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 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 (Geothermica Italiana 1991). Saddle Hill and Butler's 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 (Geothermica 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.

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; Geothermica Italiana 1991). It is the only volcanic centre considered likely to erupt again in the future.

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.

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 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.

Volcanism

Nevis Peak volcanic centre

Nevis Peak volcanic centre, which dominates the island, is the only potentially active centre on Nevis. It is a Peléen-type volcano that has produced andesite to dacite (58 - 65 wt% SiO₂; Hutton and Nockolds 1978) lava domes and associated volcanoclastic 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 volcanoclastic rocks that are highly weathered and therefore difficult to interpret. The volcanoclastic 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, Geothermica 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 Geothermica 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 Geothermica Italiana (1991) interpretation of extensive welded tuff deposits on Nevis. Therefore, the Geothermica 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. Geothermica 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 Intracrater 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 (Geothermica 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.

Historical eruptions

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

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. 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.

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 18th and March 2nd 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 29th (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 2nd 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 14th 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 14th were quite different in character from the aftershocks of the earthquake of November 2nd. 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 8th 1963. In total, 611 earthquakes were recorded between December 21st 1961 and May 8th 1963, of which about 100 were reported felt.

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. 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.

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 volcanic activity. Geothermal activity is also being monitored periodically for changes in temperature, chemistry, vigour or location.

Bibliography

Andrew EM, Masson-Smith D Robson GR (1970) Gravity anomalies in the Lesser Antilles. Geophysical Paper No. 5, Institute of Geological Sciences, London: HMSO.

Barrange-Bigot P (1986) Hydrogeological and Resistivity Survey in Nevis. Informal report, United Nations Water in Small Islands of the Caribbean Project - RLA/82/023. Barbados: UN-DTCD.

Earle KW (1925) Reports on the geology of St. Kitts-Nevis, B.W.I. and of Anguilla, B.W.I. Crown Agents for Colonies: 50 pp.

Fink LK (1970) Field guide to Nevis, Lesser Antilles. Contribution No. 22 of the Ira C. Darling Center for Research, Teaching and Service, University of Maine: 9 pp.

Geotermica Italiana (1991) Exploration for geothermal resources in the Eastern Caribbean. Section D: The Island of Nevis. United Nations Department of Technical Cooperation for Development TCD CON 15/90 - RLA/87/037.

Hutton CO (1965) The mineralogy and petrology of Nevis, Leeward Islands, British West Indies. Fourth Caribbean Geological Conference, Trinidad: 383-388.

Hutton CO, Nockolds SR (1978) The petrology of Nevis, Leeward Islands, West Indies. *Overseas Geology and Mineral Resources* 52: 1-31.

Huttrer G. (1977a) A report describing the results of a literature search for geothermally relevant information concerning Saba and Statia, N.A., and St. Kitts and Nevis, W.I. Report for Lockheed Martin Idaho Technologies Company, K97-178019.

Huttrer G (1998) Final report regarding prefeasibility studies of the potential for geothermal development, Nevis, W.I. Report for Lockheed Martin Idaho Technologies Company, K97-178019.

Kennedy TB (1985) Comments on Nevis drilling programme. Informal Report: 4 pp.

Kennedy TB, Robins NS (1988) Contributions to the UNESCO Hydrogeological Atlas of the Caribbean Islands, Vol. 4, St. Christopher & Nevis. BGS Technical Report, WD/88/30.

Lindsay JM (2001) Geothermal features of St. Kitts and Nevis. Seismic Research Unit Internal Report, August 2001.

Martin-Kaye PHA (1959) Reports on the geology of the Leeward and British Virgin Islands: Castries, St. Lucia. Voice Publication Company Limited: 117 pp.

Martin-Kaye PHA (1961) Comments on the geology of Nevis. Progress report No. 12, Geological Survey, Windward Islands: 19-20.

Martin-Kaye PHA (1969) A summary of the geology of the Lesser Antilles. *Overseas Geology & Mineral Resources*, 10(3): 172-206.

Norton G, Harford C, Young S (2001) Volcanic Geology of Montserrat, West Indies. Field Guide.

Pedroni A, Hammerschmidt K, Friedrichsen H (1999) He, Ne, Ar and C isotope systematics of geothermal emanations in the Lesser Antilles Island Arc. *Geochimica et Cosmochimica Acta*, 63(3/4): 515-532.

Robson GR (1964) An earthquake catalogue for the Eastern Caribbean: 1530-1960. *Bulletin of the Seismological Society of America* 54(2):785-832.

Robson GR, Barr KG, Smith GW (1962) Earthquake series in St. Kitts-Nevis 1961-1962. *Nature* 195(4845): 972-974.

Robson GR, Tomblin JF (1966) Catalogue of the active volcanoes and solfatara fields of the West Indies. *International Association of Volcanology*: 10-14.

Robson GR, Willmore PL (1955) Some heat measurements in West Indian soufrières. *Bull. Volc*: 13-39.

Sapper K (1903) Zur Kenntnis der Inseln St. Lucia, Montserrat, Nevis und St. Kitts im West Indien. *Zentralblatt fuer Mineralogie, Geologie und Paleontologie*.

Simpson K, Shepherd J (2002) Volcanic Hazard Assessment for St. Kitts and Nevis. Unpublished OAS report.

Smith W (1745) *Natural History of Nevis and the rest of the Charibbean Islands*. Cambridge.

Tomblin J (1986) Nevis: Volcanic Eruption Scenarios. UNDR0: 5 pp.

van Soest MC, Hilton DR, Kreulen R (1998) Tracing crustal and slab contributions to arc magmatism in the Lesser Antilles Island Arc using Helium and Carbon relationships in the geothermal fluids. *Geochimica et Cosmochimica Acta*, 62(19/20): 3323-3335.

Willmore PL (1952) The earthquake series in Saint Kitts-Nevis, 1950-51; with notes on soufrière activity in the Lesser Antilles (West Indies). *Nature* 169(4306):770-772.

Wilson B (1992) The Saddle Hill eruptive centre, Nevis, West Indies. *Geology Today* 8:28-29.