VOLCANOLOGY OF SABA AND ST. EUSTATIUS, NORTHERN LESSER ANTILLES

Volcanology of Saba and St. Eustatius, Northern Lesser Antilles

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KONINKLIJKE NEDERLANDSE AKADEMIE
VAN WETENSCHAPPEN
2004

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ISBN 90-6984-384-6

The paper in this publication meets the requirements of ♾ iso-norm 9706 (1994) for permanence

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Abstract

The two small islands of Saba and St. Eustatius (Netherlands Antilles) lie on the northernmost subaerial end of the active arc of the Lesser Antilles. They are separated by the 28 km wide St. Eustatius Passage, and 20 km further along the arc the submarine Lumeyes Bank represents the northernmost volcanic center of the arc. Saba with an area of 13 sq. km rises to the single peak of Mt. Scenery at 877 m above sea level. The island is essentially a complex of andesitic Pelean domes with surrounding aprons of pyroclastic material. Rocks of basaltic andesite composition are sparse, as are the products of St. Vincent-type activity. Also present in small amounts are the semi-vesicular products of Asama-style activity, and the pumiceous products of Plinian-style activity. Areas of hydrothermal alteration including sulfur mineralization, which has been commercially mined in the past, are extensive. The island appears to overlie a northeast-southwest fault zone as indicated by recent seismic activity; the distribution of hot springs including submarine springs off the northeast and southwest shores, and a major sector collapse structure which is directed towards the southwest. The oldest dated rocks on the island are around 400,000 years. Stratigraphic studies have shown that the youngest pyroclastic deposit is a thin ash surge with accretionary lapilli (dated at 280 years B.P.) which overlies Amerindian remains but underlies those of European settlers which arrived on the island in 1640. European settlers may have been particularly attracted to the island because of the presence of meadows of grassland instead of tropical rainforest caused by an eruption shortly before European settlement. Between 1995 and 1997 an increase in the number of local earthquakes was associated with

a 7-12°C increase in the temperature of the hot springs. This recent earthquake activity is thought to represent a mild volcano-seismic crisis, with the increased heat flow resulting from either deeper circulation of groundwater or possibly renewed magma movement.

In contrast, the island of St. Eustatius lies at the north end of a continuous submarine bank that also contains the islands of St. Kitts and Nevis. The island has an area of 21 sq. km and is morphologically dominated by two volcanic centers. At the northern end the extinct Northern Centers rise 289 m a.s.l. and were once a separate island surrounded by sea cliffs. Two and a half kilometers to the southeast the morphologically youthful Quill volcano, with an 800 m diameter open crater, rises to 600 m a.s.l. A third volcanic succession is exposed in the White Wall-Sugar Loaf tilted limestone succession, which forms the southern shoreline of the Quill. The Northern Centers comprise five morphologically distinct coalesced volcanoes, the most youthful of which is the Pisgah Hill-Little Mountain-Bergje Dome complex with a crater 880 m in diameter which contains the youthful Bergje dome. The Northern Centers comprises intercalated pyroclastic deposits (derived from Pelean activity) and lava flows. The Quill is almost entirely composed of pyroclastic deposits mainly representing Pelean-, St. Vincent-, and pumiceous Plinian-style activity including both fall and ignimbrite deposits. The White Wall-Sugar Loaf succession is exposed by the uptilting of marine bank sediments to angles of 40° and contains intercalated with the limestones abundant pumiceous subaqueous pyroclastic deposits. Six recently drilled water wells in the flanks of the Quill have revealed heated groundwater suggesting that the Quill is dormant. The last eruption of the Quill was prehistoric and occurred before settlement of the island by Salidoid Indians probably between 1550 and 1205 years B.P. Our interpretation of the radiocarbon ages suggests that the last erupted bedset probably formed between 1755 and 1635 years B.P. This is considerably younger than the published age for the last activity of the Quill of around 8000 years. The products of the last eruption are a very well preserved and exposed bedset of five Marker units named from oldest, K, to youngest, O. Their preservation has permitted one of the most detailed studies of a prehistoric pyroclastic eruption in the Lesser Antilles. The deposits are essentially pyroclastic flows and show a systematic change in chemistry from andesite at 58% silica up

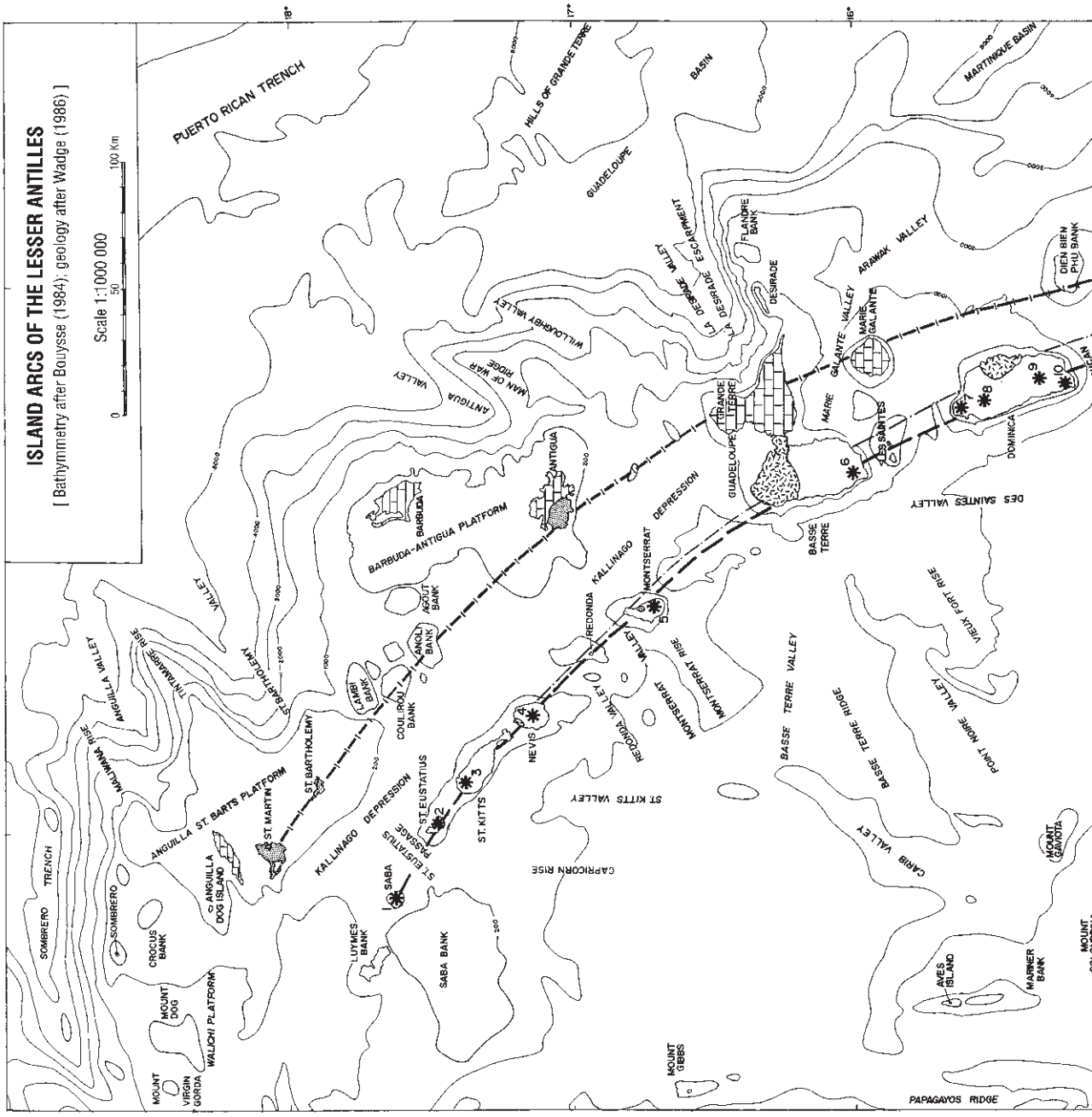
the stratigraphy to basalt at 51% silica. Early formed mixed-magma deposits (basaltic andesite and andesite in single clast) suggest that the eruption was triggered by the introduction of basalt into an andesite chamber followed by mixing and hybridization and the subsequent emptying of the chamber. The Northern Centers are believed to be the oldest centers on St. Eustatius and although not precisely dated are thought to be less than 1 million years. U/Th dating of limestones in the younger Sugar Loaf succession reveals a range in ages from 68,000 to 320,000 years B.P. The Quill, which overlies the White Wall-Sugar Loaf succession and which is chemically distinct from it, is believed to have started forming around 50,000 years B.P.

Saba and the Quill, St. Eustatius although only 35 km apart have, at least for the past 50,000 years, simultaneously produced two chemically distinct magma series: Saba, medium-K calc-alkaline, and the Quill, low-K calc-alkaline. Such differences may be explained by the primary Saba magmas being produced by lower amounts of partial melting of the mantle wedge than those of St. Eustatius. Saba magmas also appear to have been affected by the assimilation of upper crustal sedimentary material. Variations within the two suites suggest that processes of crystal fractionation and magma mixing/co-mingling relate lavas for both islands. The volcanic rocks of the Northern Centers-White Wall-Sugar Loaf form a distinct trend that crosses from basaltic andesite and andesite of low-K suite to dacite and rhyolite of the medium-K suite. St. Eustatius is unique in the Lesser Antilles in that rhyolite evolved twice in its history, first in the Sugar Loaf, and then later in the Quill pyroclastic succession. An estimate of the time required to form these rhyolites is around 30,000 years.

Saba and the Quill are thought to represent different types of volcanoes. The rocks of Saba are commonly filled with rounded hypabyssal inclusions and lack cumulate blocks whereas the lavas of the Quill show the reverse in that they contain cumulate blocks but lack hypabyssal inclusions. Saba is believed to be underlain by a complex of composite dikes, intruded into the underlying northeast-southwest fault zone, where the hypabyssal inclusions form. The Quill is believed to be underlain by a lower crustal magma chamber with a simple conduit linking it to the volcanic edifice. The lavas of the Soufriere Hills, Montserrat show similarities to Saba, and Mt. Pelée, Martinique, and Soufriere, St. Vincent appear to be similar to the Quill.

The northeast end of the Lesser Antilles arc is underlain by extensive submarine banks of low grade metamorphic, volcanic, volcaniclastic and sedimentary rocks capped by Cenozoic limestones. The Saba bank measuring 70 km east-west by 50 km north-south and with water depths of between 20 and 40 m has been drilled for oil so that its stratigraphy is known. On the island of Saba pyroclastic deposits contain sparse blocks of granofels, hornfels and unmetamorphosed late Tertiary fossiliferous limestone. The pyroclastic deposits of the Quill contain an abundance of ejected blocks of green metavolcanic and meta-volcaniclastic rock as well as fossilferous limestone blocks and those of igneous cumulate material.

It is concluded that Saba and the Quill, St. Eustatius are both active volcanoes and that the island of Saba, like Mt. Pelée, Martinique, is likely to produce Pelean style activity whereas the Quill, like St. Vincent, remains in an open crater stage St. Vincent-style activity. An independent geohazard report on the islands has been completed and published by the Netherlands Geological Survey with recommendations to initiate routine monitoring of both islands because of their small areas and relatively dense populations.


ISLAND ARCS OF THE LESSER ANTILLES
[Bathymmetry after Bouysse (1984); geology after Wadge (1986)]
Scale 1:1 000 000
0
50
100 Km
18°
17°
16°
PUERTO RICAN TRENCH
HILLS OF GRANDE TERRE
BASIN
GUADELOUPE
MARTINIQUE BASIN
LA DESIRADE ESCARPMENT
LA DESIRADE
DESIRADE
FLANDRE BANK
DIEN BIEN PHU BANK
ARAWAK VALLEY
WILLOUGHBY VALLEY
MAN OF WAR RIDGE
ANTIGUA VALLEY
GALANTE VALLEY
MARIE GALANTE
MARIE GALANTE
GRANDE TERRE
GUADELOUPE
LES SAINTES
DOMINICA
DES SAINTES VALLEY
ANTIGUA
BARBUDA
BARBUDA-ANTIGUA PLATFORM
AGOUT BANK
ANGUILLA VALLEY
TINTAMARRE RISE
ST BARTHOLEMY
ANGUILLA ST. BARTS PLATFORM
ST MARTIN
ST BARTHOLEMY
KALLINAGO DEPRESSION
ANGUILLA
DOG ISLAND
SOMBRERO TRENCH
SOMBRERO
CROCUS BANK
MOUNT DOG
MOUNT VIRGIN GORDA
WALICHI PLATFORM
ANGUILLA BANK
COULIBRI BANK
ST EUSTATIUS PASSAGE
ST EUSTATIUS
SABA
LUYMES BANK
SABA BANK
ST KITTS
NEVIS
REDONDA
KALLINAGO
MONTSERRAT DEPRESSION
REDONDA VALLEY
MONTSERRAT RISE
MONTSERRAT
ST KITTS VALLEY
CAPRICORN RISE
BASSE TERRE
BASSE TERRE VALLEY
BASSE TERRE RIDGE
VIEUX FORT RISE
PONT NOIRE VALLEY
CARIB VALLEY
MOUNT GAYOTA
AVES ISLAND
MARINER BANK
MOUNT GIBBS
PAPAGAYOS RIDGE
1
2
3
4
5
6
7
8
9
10

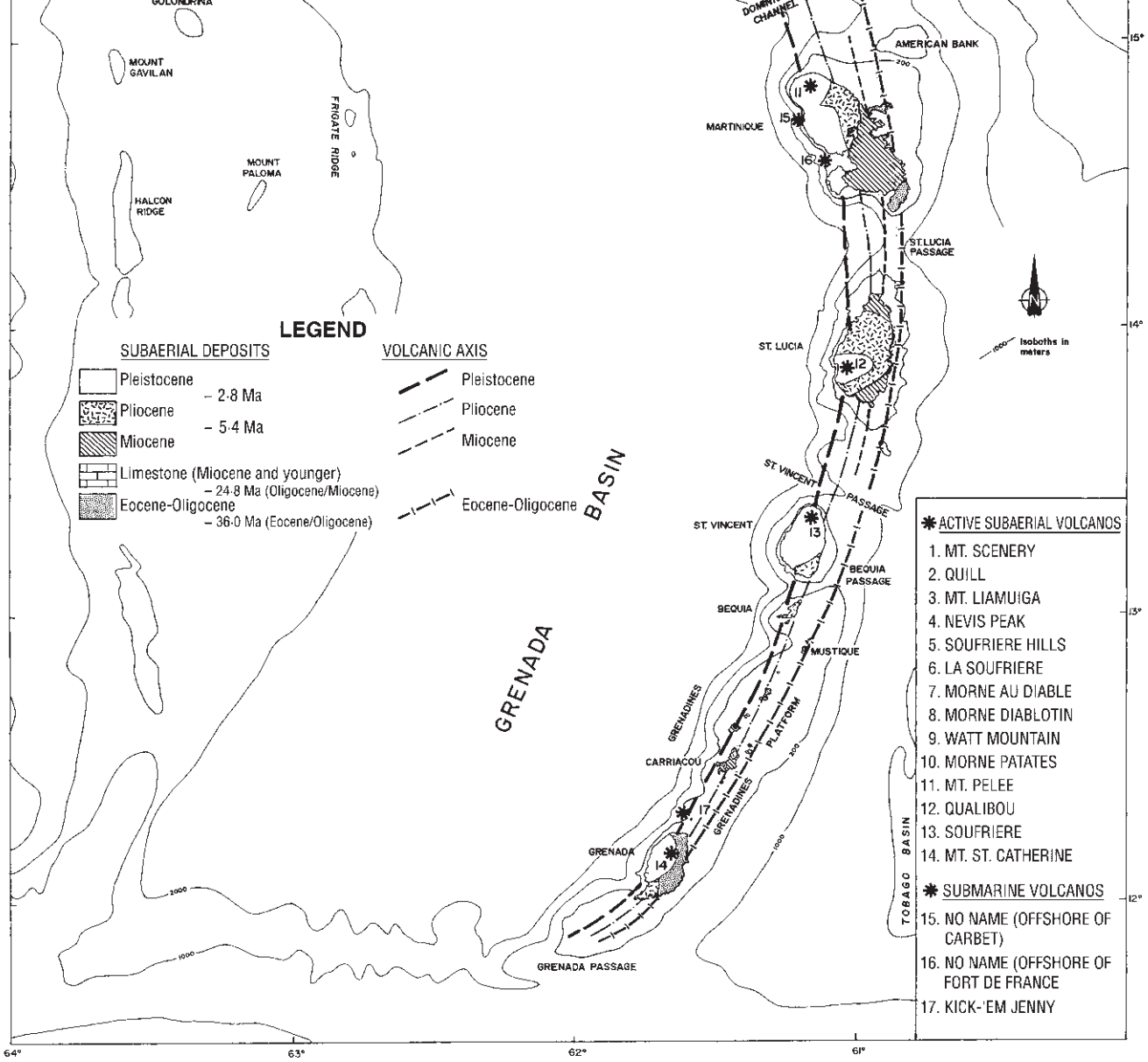


FIGURE 1. Bathymmetry of the Eastern Caribbean showing the ages of the exposed rocks of the Lesser Antilles and axes of component arcs.

Acknowledgments

Work on Saba and St. Eustatius has extended over a period of 25 years during which many individuals and organizations helped us. Our interest in both Saba and St. Eustatius began in 1975 when we sailed to the islands in the company of B. Gunn aboard his fifty-foot ketch Pelorus Jack as part of his sabbatical leave voyage from Canada. His help included the setting up of the X-ray analytical laboratory at the University of Puerto Rico, and the first modern chemical analyses from Saba and St. Eustatius. It was administrator G. Sleeswick of Saba who brought to our attention the lack of monitoring and awareness of volcanic hazard on these islands. J. Tomblin and E.M. Fournier d'Albe of UNESCO supported our letters to G.C. Brouwer of the Rijks Geologische Dienst (RGD), that modern volcanological work should be conducted on these islands. Research presented here was supported by NSF Grants EAR 73-00194, EAR 77-17064, RII 88-02961, HRD 93-53549, and GEO 0119934, NASA-TCESS (Tropical Center for Earth and Space Sciences) grant, and funding from the University of Puerto Rico, and California State University San Bernardino. Production of the 1981 geohazard report was funded by a grant from RGD, administered by G.C. Brouwer and A. van Adrichem Boogaert. We would also like to thank the following for participation in the fieldwork, P. Jansma, J. Joyce, G. Mattioli, K. Rowley, J.H. Schellekens, and J. Tomblin. Mr. George Seaman of Windwardside, Saba collected and brought to Puerto Rico one of the only four charcoal samples dated from that island. We should also like to thank W. Rose Jr. (Michigan Tech.), F. Frey (MIT), J. Stipp (U. Miami), and D. Blatter (UC Berkeley) for undertaking geochemical analyses,

radiocarbon dating and microprobe analyses. Microprobe work by ALS was undertaken at the University of Manchester, and the University of Puerto Rico. UPRM undergraduate students L. Molina, L.A. Muriel, and G. Smith, and graduate students L. Jaramillo, D. Merle, E. Quiñones, A. Matias, and A. Rodriguez, and CSUSB undergraduate student S. Fitzgerald helped with preparing samples for analyses, entering data tables, drawing diagrams, and undertaking field and laboratory research projects on samples from the islands. S. Sherman, J. Davidson, and P. d'Arco are thanked for giving us access to their unpublished data. Special thanks go to J.V. Wright for participation in fieldwork on St. Eustatius, and permission to salvage parts of some early incomplete joint manuscripts, which we considered to be too valuable to be lost. On Saba island we would like to thank ex-Lt. Governor S. Sorton, Senator W. Johnson, Commissioner S. Hassel, T. van't Hof, K. Buchan, P. Ten Holt, and B. Johnson for their help and cooperation. On St. Eustatius L. Bauer is thanked for continuing the temperature measurements on a regular basis of the water wells, and W. and L. Pwinski for their logistical support. Unpublished seismic data and reports were freely provided by W. Ambeh and L. Lynch of SRU, and by C. von Hillebrandt of the Seismic Network of the Department of Geology, UPRM. A.H. Versteeg and K. Schinkel reviewed part of the manuscript and provided important archeological information. The computer expertise of G. Mattioli and P. Jansma in modernizing the facilities of the Department of Geology, UPR proved invaluable. Production of this work was also considerably helped by the logistical work of J.H. Schellekens, R. Ripperdan, and especially D. Martinez of the Department of Geology, UPRM, Joan Fryxell of CSUSB, and P. Jansma of U Arkansas. J. Devine provided a very helpful review of an earlier version of this manuscript. A Special thanks is due to Professor Jan van Hinte, who was a member, presented the manuscript to the Royal Netherlands Academy of Arts and Sciences, and supported its publication.