Saba and St. Eustatius (Statia)

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Jennifer L. Rahn

Abstract

Saba and St. Eustatius/Sint Eustatius (Statia) represent geologically young (less than a million years) Pleistocene island arc volcanoes that rise at the northernmost part of the Lesser Antilles. Both are small islands less than 21 km^2 in size with populations around 2000, and both have stratovolcanic features and many Pelean domes with adjacent pyroclastic flows. As a single volcano, Saba's steep slopes drop off precipitously into the sea, while St. Eustatius lies at the northern end of a shallow submarine bank that links to St. Kitts and Nevis to the southeast. Similar in geologic history and perhaps co-eruptive (though Statia is slightly older and has more erosional features and some uplift), the islands also have similar climates, winds, waves, and ocean current regimes, but lack often-found-in-the-Caribbean geomorphic features such as dunes, perennial streams, wetlands, karst, aquifers, and inland water bodies. Saba and Statia both have heritage sites, including a few (small) Amerindian archaeological sites, but most historical research centers on post-European history including maritime figures, agriculture, and slavery. Owing to their small sizes, neither has been developed very heavily, though Saba is famous for its scuba diving and Statia is known for its oil terminal. Both islands face similar environmental hazards that include hurricanes, earthquakes and volcanism, and drought.

Keywords

Pelean dome • Coral reef • Scuba • Volcano • Landform

6.1 Introduction

Saba and St. Eustatius/Sint Eustatius (Statia) (Figs. 6.1 and 6.2) are both located near the 17° north latitude and 63° west longitude lines. The smaller of the two, Saba (*say-bah*), hosts about 2000 full-time residents on it 12 km^2, while around 3500 people make the 21 km^2 St. Eustatius—*Statia* (*stay-shuh*) as locals call it—home. Separated by 27 km, Saba and Statia sit 45 km southwest (12 min by plane) and 61 km south (20 min by plane) of St. Martin/St. Maarten, respectively. Both islands are special municipalities of the Kingdom of the Netherlands, and the top of Saba's volcano, Mount Scenery, represents the highest point in the Dutch Kingdom (877 m). Saba has four villages, Zion's Hill or Hells Gate, Windwardside, St. Johns, and The Bottom, which serves the island's administrative capital. Statia does not have towns in the classic sense, only a settlement, Oranjestad, the capital. While most people from Saba call themselves Sabans, in the village of Hells Gate, they use Sabians. On Statia, locals refer to themselves as Statians. As of October 10, 2010 (10/10/10, colloquially know as ten-ten-ten), Saba, St. Eustatius, and Bonaire became special municipalities of the Netherlands and are also referred to as the "BES islands" or "Caribisch Nederland." Day-to-day local affairs are managed by an elected Island Council, presided over by a Lieutenant-Governor. The Dutch have jurisdiction, environmental say (both islands are regarded by the European Union as an overseas territory and subject to

J.L. Rahn (✉)
Department of Geography, Samford University, Alabama, USA
e-mail: jlrahn@gmail.com

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Fig. 6.1 General physiographic map of Saba and surrounding features, such as Diamond Rock and the Saba National Marine Park run by the Saba Conservation Foundation. The small mountainous island is only 13 km^2 (5 mi^2) but rises from sea level to 877 m at the peak of Mt. Scenery. Cartography by K.M. Groom

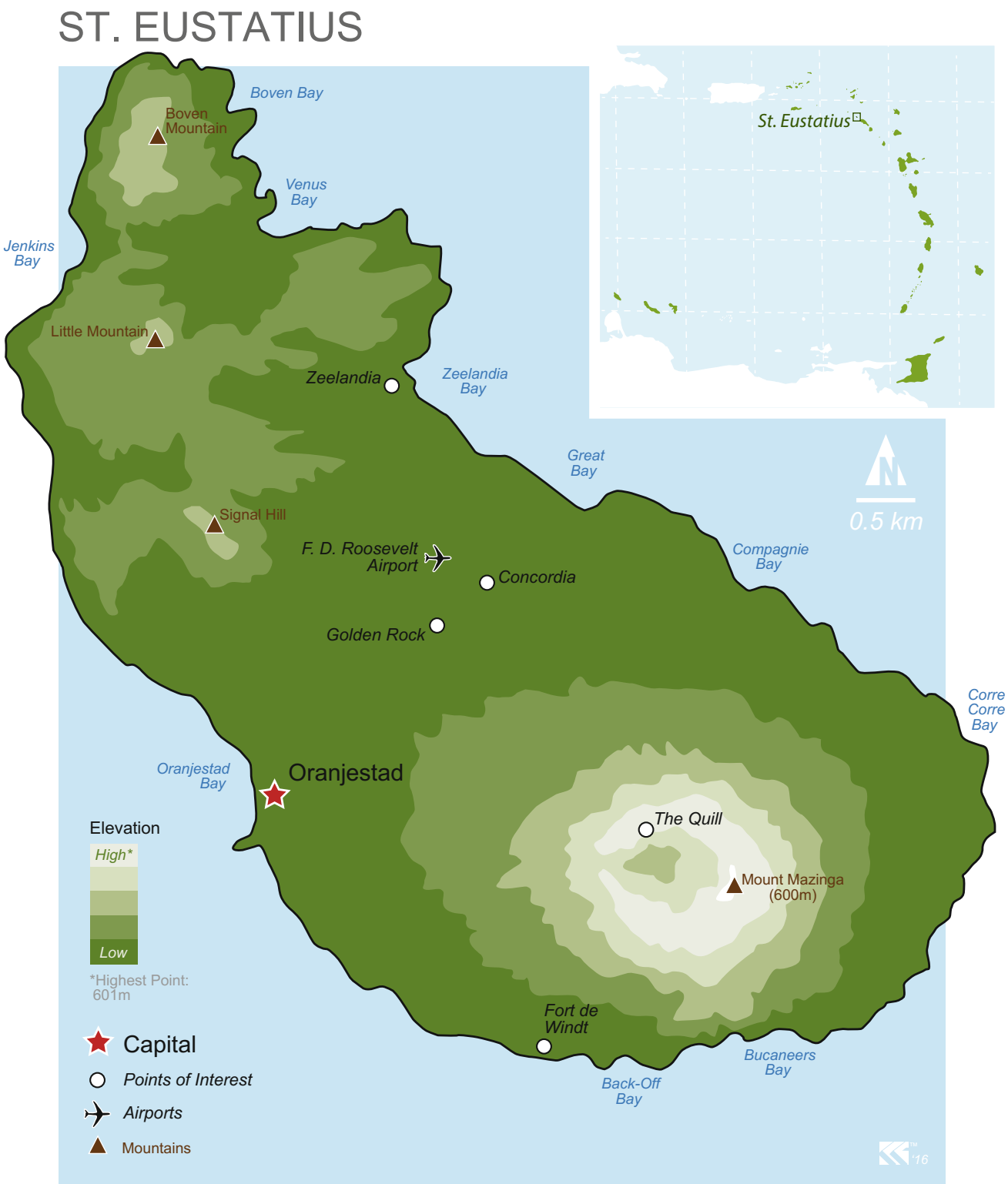

Fig. 6.2 General physiographic map of St. Eustatius. Slightly larger than its neighboring Saba, St. Eustatius is dominated by the large volcanic crater called "The Quill" to the south and a few smaller mountains in the north. Most of the island's population resides within the central lowlands. Cartography by K.M. Groom

EU regulations) and sponsor and subsidize the major projects on the island that affect its landscape and landforms. These islands should not to be confused with the island of Eustatia (30 acres in size) and Saba Rock (approximately an acre and a half in size) in the British Virgin Islands.

6.2 Setting

Saba and Statia represent the northernmost part of the active island arc of the Lesser Antilles. The volcanoes that created Saba and Statia formed from the subduction of the North American plate under the eastern-most section of the Caribbean Plate (see Fig. 2.1). Although the formation of the Lesser Antilles volcanic arc is geologically young (5.3–2.6 Ma), Saba and Statia are the youngest islands of the arc (less than a million years), with the islands' initial underwater activity likely to have happened in the mid-Pleistocene. Statia's subaerial presence occurred about 1 million years ago, while Saba first appeared above sea level around 500,000 BCE.

Roobol and Smith (2004) summarized Saba and Statia's structural evolution and detailed geology, petrology, and petrogenesis specifically, by drawing on previous works of Saba by Molengraff (1886), LaCroix (1890, 1893), Hovey (1905a, b), Sapper (1904), and Perret (1942), and of Statia by Westermann and Kiel (1961), Maclure (1817), Cleve (1871), Molengraff (1886, 1931), Sapper (1903, 1904), and Hardy and Rodrigues (1947). The Quaternary sea-level curve for the Caribbean region shows that sea level fluctuated from +6 to −24 m relative to present sea level, thus affecting the size, shape, and geomorphology of the islands through time (Emiliani 1978; Aubrey et al. 1988). The subsequent volcanic geomorphology was created by both constructive and destructive processes, now visible as landforms on both islands.

Saba is believed to be underlain by a system of parallel dikes emplaced into a fault zone. In contrast, The Quill volcano (Statia) is underlain by a magma chamber in which crystal fractionation occurs to produce a wide range of lava compositions. It has been successfully demonstrated that other volcanoes have similarly contrasted crustal plumbing systems to those of Saba and the Statia (Roobol and Smith 2004). For example, the Soufriere Hills volcano on Montserrat is similar to Saba, whereas Mt. Pelee, Martinique that erupted in 1902 and 1929 is similar to The Quill (Caribbean Volcanoes 2015). Geologists have shown that the island of St. Eustatius is gradually subsiding (DCBIODATA 2015) and there are local reports on Saba of uplift (Eddie Hassell personal communications).

6.2.1 Saba and Statia Climate

Saba and Statia's tropical climate is governed by their latitude, the Northeast Trade Winds, and the North Equatorial Current. Saba and Statia average of 12 h of daylight throughout the year (11 in December and 13 in July), and although temperatures extreems vary throughout the year from 19 to 36 C, they usually range from 25 to 28 C. In general, the islands experience sunny weather, with light constant Northeast Trade Winds that bring constant cool breezes and ample moisture (Statia Tourism 2015). The prevailing winds drive the dominant waves to hit the eastern, windward sides of the islands. Multidirectional wind gusts average 16 km/h (10 mph) and on Saba can reach 40 km/h (25 mph), which often causes all flights to be canceled. On both islands, precipitation varies from 980 to 1110 mm. Both temperatures and precipitation vary on the islands depending on the geographic location (higher precipitation on the windward sides, for example) and local elevation (e.g., cooler temperatures at higher elevations and orographic effect). Several events cause the islands to be relatively cool: The tops of the mountains have frequent cloud cover, winds blow up through the ravines bringing a cool breeze to the higher elevations, and the number of hours of direct sunshine is reduced by the shadow of surrounding mountains. In the case of The Bottom on Saba, this results in only about six hours of direct sunlight each day (DCBIODATA 2015).

While some precipitation falls on Saba and Statia during the hurricane season (June to October) associated with tropical storms, approximately 80% of the annual rainfall is concentrated in the rainy season beginning in October and lasting through December (DCNA 2015). Still, rainfall is inconsistent from year to year, and very dry ones can follow very wet years. Notable droughts happened in 1952/1953, 1982/1983, and 2015 where agricultural production dropped to a minimum, and drinking water had to be imported occasionally (DCBIODATA 2015). The steep hillsides, thin soil layers, and fractured igneous rock prevent the natural catchment of rainfall. Though a few brackish springs exist near the coast, there are no perennial streams, lakes, or aquifers on either island, meaning rainwater must be stored, usually in cisterns below most buildings.

With only rainwater as a freshwater source, Saba and Statia generally remained uninhabited, though it is suspected the islands were being used for fishing and foraging since around 500 BCE. The islands went mostly unused by European Colonialists until the seventeenth century and, though currently Dutch in nationality, the English language remains in strong use, demonstrating the persistence of early British Colonists. While Saba and Statia were a colony of the

Dutch West Indies by 1828, it was not until a couple of decades later that they would become Dutch dependencies (1845), and more than a century after that before they would become part of the Netherlands Antilles (1954). Throughout the twentieth century, Saba and Statia became and remained quiet islands, with tourism (primarily hiking and scuba diving) and archaeological studies beginning in the 1980s.

6.2.2 Saba Geologic History and Evolution

The deceptively simple stratovolcano-like appearance of Saba is misleading because Mt. Scenery, the highest peak on the island, is just one of about twenty Pelean-like domes. These domes, and their associated aprons of pyroclastic material, represent a combination of newer domes sitting eccentrically on top of older Pelean dome complexes (Roobol and Smith 2004). In terms of volcanology, Saba is a single volcanic complex, the subaerial part of which has dimensions that measure 50% of those defined by the 500 m submarine contour. Submarine morphology slopes uniformly away from the island in all directions (Fig. 6.3).

6.2.3 Statia Geologic History and Evolution

St Eustatius lies at the north end of an 80-km-long shallow submarine bank (the edges of which are 180 m below sea level themselves) on which the islands of St. Kitts and Nevis also lie. The geology of St. Eustatius can be divided into three very different landscapes (Fig. 6.4). The oldest geological unit on the island is the northern hills—the Northern Centers as Roobol and Smith (2004) called them—composed of five morphologically distinct older volcanoes, built of lava flows and Pelean domes, and pyroclastic aprons of block and ash deposits, each having varying degrees of erosion. The three youngest centers, although eroded, retain their original volcanic features, and lava flows and lithified pyroclastic deposits from these centers, well exposed in the steep sea cliffs around the northern part of the island, have been dated to an age of less than 1 million years. The southern slopes of the northernmost hill are orange-colored, marking the site of former fumarolic activity. When first formed, the Northern Centers appeared as an independent volcanic island with surrounding shallow water carbonate banks and patch reefs containing volcanic deposits.

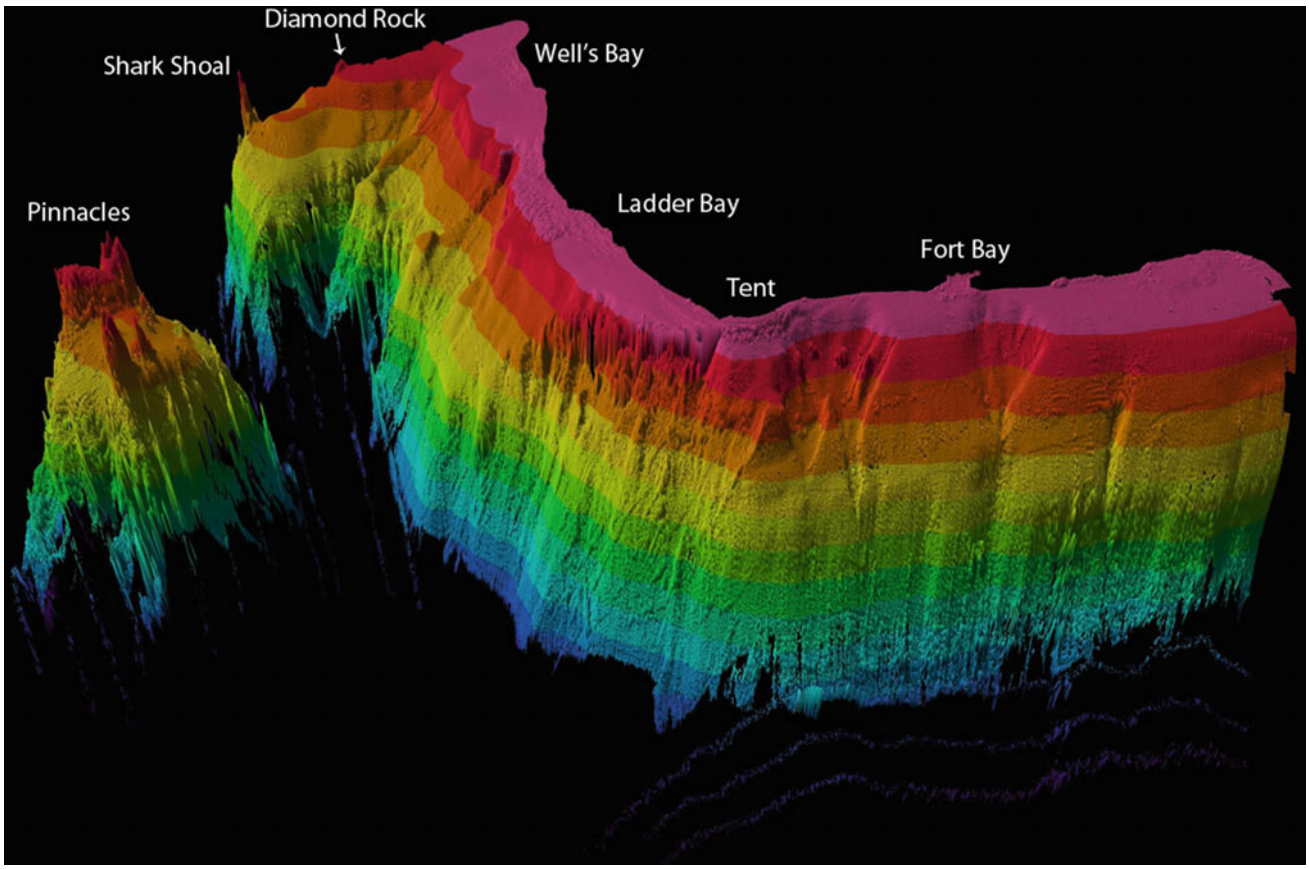

Fig. 6.3 Bathymetric map of Saba. Offshore Saba to the west 1.3 km, a single parasitic submarine Pelean dome (called The Pinnacles) rises from depths of 300 m to only 23 m below sea level. The platform's top, roughly the size of a football field, represents one of the most famous and spectacular dive sites around the island. Image courtesy of http://www.sabapark.org/marine_park/diving/

The Northern Centers may well be broadly contemporaneous (~500 ka) with the older stratigraphic division of Saba including the Diamond Rock–Torrens Point center. At this time, the islands of Saba and Statia were smaller and had different forms to the present-day islands (Roobol and Smith 2004).

Of intermediate age is Sugar Loaf-White Wall formation, a 1.2 km (0.7 mile) uptilted wall and ridge of shallow marine limestone on the extreme south end of the island embedded in the flanks of The Quill. Most likely, it is part of the limestone cap of the submarine platform uptilted by the emplacement of a dome (Roobol and Smith 2004), and a similar structure exists at Brimstone Hill on St. Kitts. Roobol and Smith (2004) characterize this formation as an unusual and interesting documentation of shallow-water phreatomagmatic activity over a period of several hundred thousand years.

The youngest geological unit is the single volcanic cone, The Quill, at the island's south. This morphologically youthful open-crater stratovolcano has flanks sweeping up to angles of 500 at the crater rim. The crater has a diameter of 800 m, and the eastern rim forms the highest point on the island at 600 m asl, though the crater floor rests at 278 m asl. The distal deposits of The Quill have largely been removed by erosion except where they form the nearly flat-lying central part of the island and terminate against the steep hills of the eroded Northern Centers. The Quill, apart from a few lava dome remnants exposed in the inner walls of the crater, is almost entirely a pyroclastic volcano, and the sea cliffs cut into the flank deposits reveal some of the best pyroclastic sections in the Lesser Antilles (Roobol and Smith 2004).

6.3 Landforms

Because they are both young Pleistocene island arc volcanoes, Saba and Statia have similar stratovolcanic features and many Pelean-type domes with adjacent unstable rock debris. Saba is a single volcano whose steep slopes drop off precipitously into the sea, while St. Eustatius is a more complex and older volcano resting at the northern end of an 80-km-long shallow (<180 m deep) submarine bank. Both islands have similar geologic histories and perhaps even co-eruptive, but Statia is older and has more erosional features, sedimentary structures (carbonate depositional sequences), and experienced some uplift. Common Caribbean island geomorphic features that are absent on Saba and Statia are perennial streams, wetlands, karst, aquifers, dunes, and inland water bodies, although there are a few brackish coastal wells. The islands' prime geomorphic agents include precipitation, rock decay, and gravity, each contributing to steeply eroded gullies ("guts") and coastal erosion, but anthropogenic activities, such as free-roaming goats and poor landuse/farming practices (particularly on Statia), also diminish vegetation growth and increase erosion.

6.3.1 Saba Interior Landforms

Saba's largest and most obvious landform, Mt. Scenery, lies approximately in the center of the island, dominating the geomorphic landscape (Fig. 6.5). Because of its classic volcanic shape, it is often assumed this is the main and only volcano of the island. Roobol and Smith (2004) explain, however, that the stratovolcano-like appearance of Saba results from a series of Pelean dome composites and their surrounding pyroclastic aprons that sit atop even older Pelean dome complexes. Because of its archetypal volcanic silhouette and steep coastal cliffs, the producers of the original 1933 King Kong movie used it as the backdrop of Skull Island (National Geographic Society 2007).

Another youthful volcanic feature, the only visible basaltic andesitic lava flow at the northeast corner of Saba, runs across the landscape, cradling the zigzag road (with 18 hairpin curves) up from the airport to Hell's Gate (aka Zion's Hill). The lava's high viscosity resulted in well-preserved lava levees that can clearly be seen as small, narrow, long hills on either side of the main flow (Roobol and Smith 2004). The airport lies at the terminal end of this flow, and the flat area of the airport is the flow covering a pre-existing wave cut platform. This is the largest area of flat elevation on the island, and the Juancho E. Yrausquin Airport (built in 1963) located here claims to have the shortest commercial runway in the world—a mere 400 m. It has also earned the superlative of being on the list of "scariest landings," as the approach is initially into a cliff face, coupled with a sharp bank-left to align with the runway.

6.3.2 Statia Interior Landforms

Statia's main geomorphic features are divided into three distinct landscapes composed of two volcanic areas (in the northwest and southeast) separated by a central, northward sloping plain (Fig. 6.6). In the northwest, The Quill, a symmetrical stratovolcano, also represents the second highest mountain in the Netherlands (600 m, see Fig. 6.7). Formed contemporaneously with Saba around 50 ka, The Quill contains a 2-km-wide crater. Its tropical rainforest vegetation-covered walls drop steeply, 322 m to the crater floor (at 273 m asl). The southeast, dominated by Mt. Mazinga, supports a small cloud forest on part of its crater rim, and the southern flank drops steeply to the sea where a wall and ridge of shallow marine limestone, known as the Sugar Loaf-White Wall (Fig. 6.8), runs east to west for

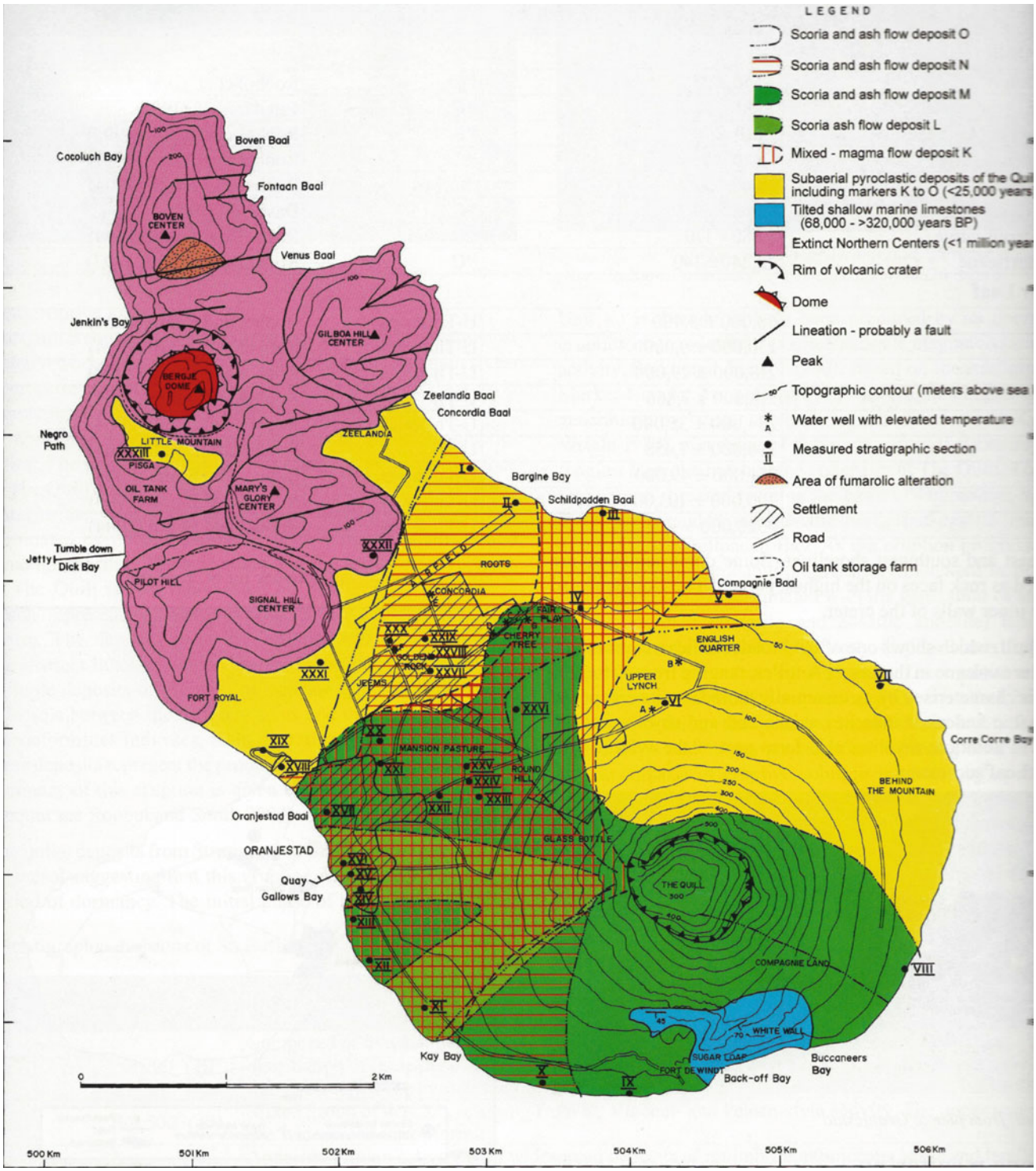

Fig. 6.4 Geologic map of Statia. The southeast end of the island is dominated by a 600 m high dormant volcano, The Quill. In the north end of the island, lower elevation hills have formed from an eroded, extinct volcanic complex (DCNA 2015). Between these two formations, in the central part of the island, is a low sloping 6 km^2 plain at 30–80 m above sea level composed of relatively fertile volcanic soils (DCBIODATA 2015). Map courtesy of http://caribbeanvolcanoes.com/st-eustatius-map/

about 1 km (Roobol and Smith 2004). Perhaps formed as part of the limestone cap of the submarine platform that was uptilted by dome growth, these marine sediments mixed with ash and pumice over time, eventually lithifying into strata visible from the "Around the Mountain" trail and Fort de Windt (Roobol and Smith 2004). On the western side of the

Fig. 6.5 Aerial photograph of Saba' south side with Mt. Scenery dome in the middle of the island. *Center left* in the *shade* is The Bottom. Surrounding The Bottom is the *horseshoe-shaped*, collapse scar of a volcanic lateral blast. Below The Bottom on the coast is Fort Bay, where the piers at the harbor are the only place boats can land on Saba. Photograph by L. Avery

crater, a pyroclastic flow fans out to the coast, and hosts the island's capital, Oranjestad (Roobol and Smith 2004). The northern slope of The Quill gradually drops down to the flat central plain, the Kultuurvlakte ("Culture Plain"), a 6 km^2 fertile plain containing volcanic soil, and where most of the roads, houses, and agriculture occur.

Statia's northern landscape—called the Boven Hills by locals and the Northern Centers by Roobol and Smith (2004)—consists of an extinct Quaternary (500 ka) volcanic complex of unevenly eroded hills. These hills initially comprised the entire island, and outcrops of the lava flows and pyroclastic deposits can be seen in adjacent sea cliffs. In the northern part, the Boven mountain's southern slopes are orange-colored, marking the site of former fumarolic activity (Roobol and Smith 2004). In 1979, on the westernmost hill of the Northern Centers, the Pisgah hilltop was flattened, and excavation began for the construction of an 11.3-million-barrel oil storage and transshipment facility/port. The rest of the Northern Center area is an uninhabited wilderness area with a drier weather pattern than The Quill producing savannah-like vegetation and fauna (DCNA 2015).

6.3.3 Coastal Processes and Landforms

Coastal features on both islands include a few black/brown volcanic sand beaches, more common cobble beaches, and coastlines made up of large rock, coral rubble, and cliffs. The length of coastline of Saba and Statia are 15 and 21 km, respectively. Water temperatures range from 25 to 29 C (77–85 °F), which support nearshore coral reefs. Prevailing Northeasterly Trade Winds drive waves to hit the Atlantic (Windward) sides of the islands, while the North Equatorial Current arrives from the southeast. Average wave heights range between 1 and 2 m, with strong North Atlantic winter storms generating swells up to 12 m along the north coasts. As with other small islands, waves tend to wrap around the islands, creating complex interference wave patterns on the southwest coasts.

6.3.4 Saba Coastal Landforms

Saba's outline shows a series of headlands separated by arcuate embayments (Fig. 6.9). These promontories consist of lava flows and domes, with bays (being) formed in the volcanoclastic host rocks themselves (Roobol and Smith 2004). The steep slopes on Saba continue underwater to approximately 500 m below sea level (Fig. 6.10). Saba's coast is roughly divided into thirds amongst sand and/or cobble beaches, rocky coast, and cliffs—especially steep cliffs because Saba has no shallow platform to prevent being constantly battered by wave action. There is only one permanent sandy beach at Cave of Rum Bay (Fig. 6.11), best accessible by boat.

Fig. 6.6 Aerial view of Statia's Culture Plain (Kultuurvlakte) and surrounding features. Below The Quill and its crater in the foreground, the Culture Plain (Kultuurvlakte) is visible *mid-photo*graph with Oranjestad along the left coast. The Northern Centers, seen in the background, are the remains of an extinct quaternary (500,000 BP) volcanic complex of unevenly eroded hills. Photograph by J. Haviser

This beach is maintained by sediment from hillslope failure of the rapidly eroding guts below Mary's Point.

Wells Bay hosts a seasonal sandy beach that usually appears March through October and disappears in the winter months, exposing well-rounded cobbles. The Wells Bay sandy beach can also disappear for years at a time, when sand sediments are washed offshore below wave base (Rahn et al. 2015). The northern end of the Well's Bay beach transitions into the Torren's Point formation with sea stacks, arches, swim-through tunnels, and caves (Fig. 6.12), and an overhanging >90° cliff of pyroclastic material serves as a backdrop to the beach, the bottom of which illustrates a classic wave cut notch (Fig. 6.13).

Meanwhile, Cove Bay beach—nourished (2010–2016) by white sand dredged from St. Martin and backed by large boulders as revetment—provides an accessible, public sandy beach. Sea Turtles have recently (2013–2015) nested on Cave of Rum Bay and Cove Bay beaches. The cobble beaches on Saba have rounded volcanic clasts and large coral rubble fragments broken from the reef and deposited by hurricane waves and subsequently modified by less energetic waves. In total, nine cobble/pebble beaches surround Saba, with Tent Reef beach being the most accessible and most widely used recreationally by residents. Some recreational swimming occurs at Fort Bay, but this bay is the harbor on the island, is a busy working port, and is primarily used for fishing, cargo, and dive boats. On the northeast coast, below the airport, a hiking/bouldering trail winds between jagged rust-red lava rocks. This area, called the Tide Pools, technically contains wave splash-pools since the tides are so small (Kjerfve 1981). The Tide Pools showcase resplendent tafoni, as well as a few fulgurites (Fig. 6.14).

6.3.5 Statia Coastal Landforms

The majority of St. Eustatius is steep cliff coast, but because a shallow water platform (~10 m) surrounds the island,

Fig. 6.7 The Quill Crater as seen from above. Tropical rain forest covers the walls and the crater floor. A small cloud forest exists on part of the crater rim near Mount Mazinga. Photograph by J. Haviser

waves are milder than on Saba. The Atlantic coast has average wave heights 1–2 m while the Caribbean, leeward coast, waves average less than 30 cm (St Eustatius Management Plan 2007). Monitoring of cliff erosion between 2004 and 2006 showed erosion up to 2.0 m in one year, resulting in major landslides with chunks of rock over 1 m falling regularly (STENAPA 2007). Six sandy beaches occur around the island adjacent to the Culture Plain, though "sandy" can be a loose term, as most beaches remain a mix of sand, gravel, cobble, and coral rubble. The north coast of Statia contains an escarpment with a series of five, 300-m, closely spaced, undulating, cliffed-coast headlands (Fig. 6.15).

6.3.6 Nearshore and offshore Landforms of Saba

Saba hosts five distinct geomorphic forms of coral reef: coral-encrusted colluvial debris, spur and groove, antecedent bar-beach ridge veneer, sea stacks surrounded by reef, and offshore seamounts/pinnacles. Coral-encrusted colluvial debris from the adjacent steep slopes are the most common reef structures surrounding Saba and consist of hard and soft coral and sponges built on top of cobble- to boulder-sized rocks (van't Hof 1991). Spur and groove reef formations occur on the island's leeward side between the Hot Springs and Babylon dive sites. In the Tent Bay area, a shore-parallel reef and wall called Tent Reef was exposed as an offshore bar and beach ridge system at sea level around 8000 years ago. As this system submerged with sea-level rise, corals kept up with water levels and formed a shallow one to two-meter-thick veneer on top of the rocks and beach sediments. While diving this site, you can often see the well-rounded former volcanic beach cobbles beneath the coral layer. At the west end, this reef becomes a series of coral outcrops topping a vertical wall that drops 30–65 m (van't Hof 1991).

A 900 m^3 sea stack, Diamond Rock rises from Saba's northwestern sea floor. It is a favorite bird roost site and so-called because its silhouette is diamond shaped, and shines from a distance because of the white bird gvano's high reflectivity. The entire subaqueous diameter of Diamond Rock is covered with corals and other coral reef ecosystem inhabitants. Between Diamond Rock and Torrens Point, there are a series of smaller, drowned sea stacks also covered with

Fig. 6.8 Sugar loaf ridge viewed from Fort de Windt, southern St. Eustatius. It is an uptilted wall and ridge of shallow marine limestone on the extreme south end of the island imbedded in the flanks of The Quill. This feature formed from the shallow-water carbonate banks and patch reefs around 500,000 BP. Photograph by J. Haviser

corals. The most spectacular reef formations of Saba are the offshore "seamounts" about one-half km to the west. These "seamount" formations are probably parasitic domes formed by magma chambers connected to the main one below Saba (see Fig. 6.3).

6.3.7 Saba Bank

About 5 km southwest of Saba, separated from the island by a 700-m deep trough, lies a large (2200 km^2 or 849 mi^2) submarine carbonate bank, or atoll, called the Saba Bank. It is the third largest of its kind in the world, and spectacularly rich in marine biodiversity (DCNA 2015). The flat top of this atoll ranges in depth from 20 to 50 m, elevated about 1800 m above the surrounding sea floor. Various oil companies, government agencies, and academic institutions researched Saba Bank geology between 1970 and 1999, with approximately 4300 km of seismic data acquired over the Saba Bank area (Church and Allison 2004). Church and Allison (2004) summarize the Saba Bank geochronology as remnants of volcanic islands from the Cretaceous volcanic island arc with a thin Tertiary section overlying a thick pre-Eocene sequence and an eastern area with a thick Tertiary sedimentary section overlying Eocene volcanics and an even older (perhaps Cretaceous?) sequence. The upper layers indicate early Miocene fluvial-deltaic volcaniclastics and late Miocene–Pliocene carbonate deposition, capped with Quaternary coral reefs. The coral reefs are found primarily along the east and southeast edges of the Bank and contain a rich cover and diversity of reef-building corals. The Saba Bank hosts various reef types, from patch reefs to spur and groove type reefs with sandy channels. Each of these provides a hard substrate for coral and other animals to settle on, which in turn attracts fish and an abundance of other invertebrates (Saba Bank National Park 2012). The extensive reef development of the Saba Bank (estimates put it

Fig. 6.9 Northeast coast of Saba. The peaks of Mt. Scenery (*right*) and Booby Hill (*left*) rise above the rugged northeast coast of Saba. The airport on Flat Point (the only large flat area on Saba) and the hairpin road going up from there to Hells Gate are on Saba's only visible basaltic andesitic lava flow (*right foreground*). Well-preserved lava levees can be seen cradling the zigzag road. On the coast in the *central part* of the photograph are Spring Bay (*left center*) and Cove Bay (*right center*, adjacent to airport Flat Point area). On the coast below Flat Point are the Tide Pools. Photograph by J. Haviser

around 150 km^2) provides a rich fishing ground for Saban fishermen and hosts large populations of reef fish and associated spawning grounds.

6.3.8 Nearshore and offshore Landforms of Statia

The nearshore landforms on Statia's surrounding shallow platform also include coral reefs. The platform is the narrowest in the north and southeast. In the south, the steep slope of The Quill volcano continues into the sea. Here, corals enhance a vertical wall of the Drop Off, Grand Canyon, and The Cliffs dive sites. Statia dive shops lay claim to areas of coral-encrusted lava flows, boulders, and patch reefs, as well as more than 100 sunken trading ships, submerged anchors, and cannons. A number of artificial reefs have been created by the Marine Park since active management commenced in 1997. Some of these artificial reefs have been created for fishing purposes, and others for divers (Statia Park 2015).

6.3.9 Landscape

Little is known of Saba and Statia's Amerindian occupance, though archaeological excavations continue and most evidence points to basic hunting and gathering (and fishing) occurring around and on the islands as early as 500 BCE (SABARC 2015). Mostly uninhabited until the seventeenth century, Saba and Statia remained untouched until Colonial powers began expanding. Saba's rugged landscape and treacherous coastline that makes boat landings difficult, kept its historic population small (no greater than 3000). Saba had

Fig. 6.10 Image of the west coast of Saba showcasing Mt Scenery (the *highest point* in the photograph), Great, Paris and, Bunker hills to the *right*, and Diamond Rock about 425 m (1400 ft) offshore in the foreground. The seabed between Torrens Point and Diamond Rock is very rugged with irregular outcrops of dome remnants that house abundant coral reef communities, making the area a favored dive site. To the *right* and *left* of Torrens Point are the deeply incised and eroded ridges and guts that are successions of massive lithified, coarse block, and ash flow deposits. Photograph by C. Meijvogel

a small agricultural economy mainly for local consumption, but the people themselves were in demand, even today, for their navigation skills and seamanship (Haviser 2001).

Although Mt. Scenery dominates the island, Saba also hosts numerous hills giving the island an irregular topography, and the island's four villages sit on the gentler slopes between the peaks of hills. The village of The Bottom, for example, sits in the horseshoe-shaped, collapse scar of a volcanic lateral blast. As you descend into The Bottom, from the road there is an excellent (and much photographed) view of some of the newer volcanic dome hills that looks like, and is called, the whale (Fig. 6.16). The Whale's Tail represents an outstanding example of a well-preserved volcanic spine (or spike), usually created by dome growth and collapse. The Whale's Tail is also the teepee tent-like feature after which Tent Bay is named.

To transport goods, for many years, locals trekked through grueling elevation changes on twisting trails with perhaps a lone donkey to help. In the 1930s, Sabans asked the Dutch government to build a road on the island. Primarily experienced with engineering roads on flat ground the Dutch government considered it a foolhardy task due to the island's extreme topography. Eschewing the opinion of the Dutch engineers, Sabans decided it *was* possible to build a road on Saba. Today, the 14 km road that half-circumnavigates the island stands as a testament to the impressive local terrain knowledge and clever application of design and construction that allowed for slope stabilization on tropical mountain roads where heavy rain, steep grades, and weak soils and rocks combine to create slope instability. The outer side of the road usually has a steep drop off, and the inside has a steep cliff rising above it. The sole main road on Saba, winding-up from the airport on the northeast side, through the four villages, and terminating at the southwest coast in Fort Bay, traverses four ecological zones from dry scrub to dense tropical vegetation. The other half of the island is actually too steep for road construction and consists primarily of spectacular successions of block and ash flow deposits forming steep and precipitous slopes (Roobol and Smith 2004). These western slopes are so steep that there are no settlements in the area and, although there is a hiking trail there called the North Coast Trail, it is dangerous and requires a local guide.

Today, Saba and Statia rely on tourism in the form of world-class scuba diving and oil transshipment. In fact, because the rugged topography of Saba permits only small-area development, and most of that occurs above 240 m, few terrestrial human impacts have affected the reefs. On the other hand, potentially the most conspicuous coastal

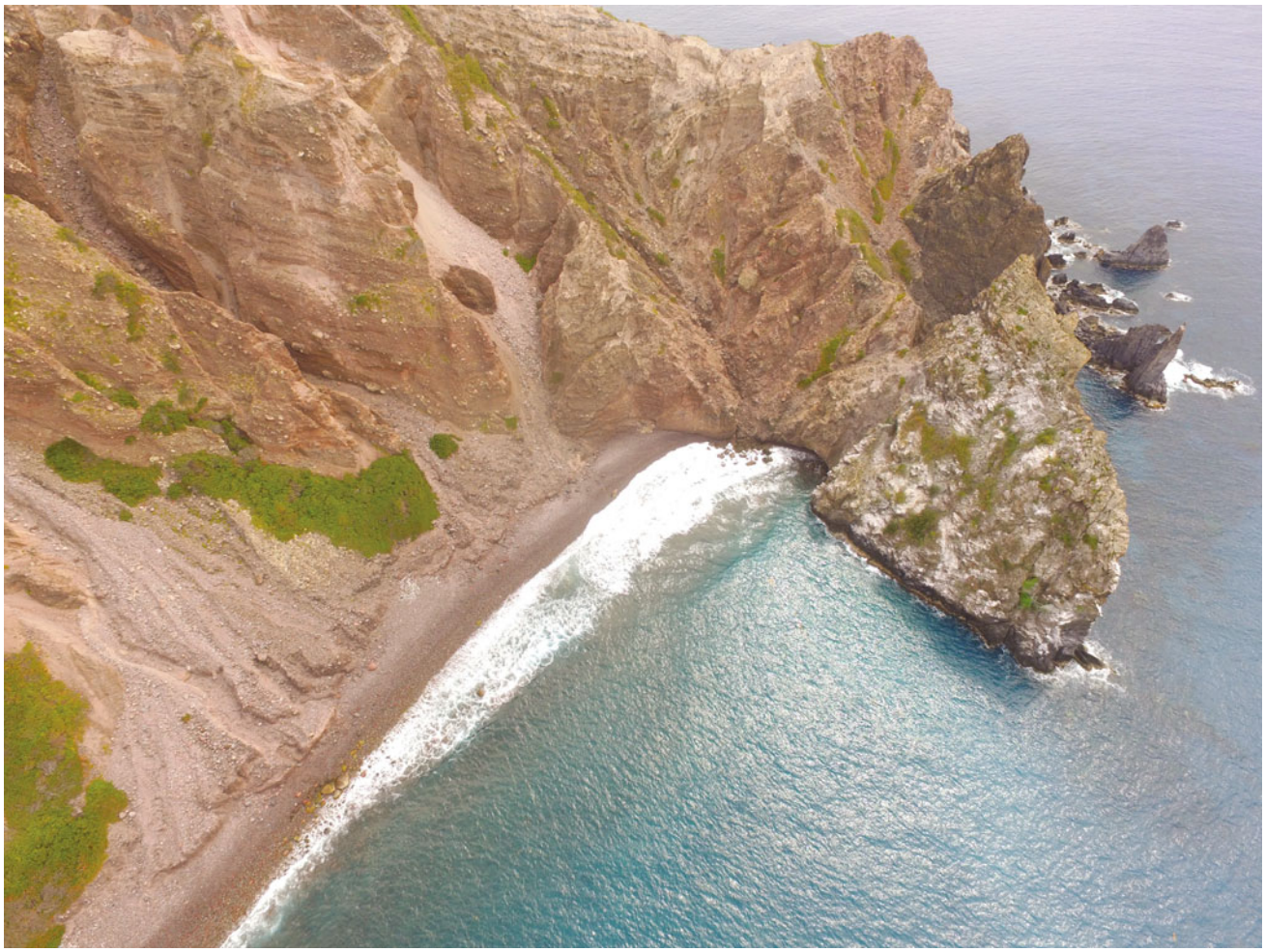

Fig. 6.11 Cave of Rum Bay on the northeast side of Saba taken from the air with a drone. Cave of Rum Bay beach is about 150 m long 15 m wide, nestled between the headlands of Torrens Point to the south (*right* of photo) and Great Point to the north (not in photo). Photograph b C. Meijvogel

feature on Statia is its oil terminal, located in the northeast corner of the island on Little Mountain. Here, oil is offloaded from large tankers from other countries, modified, and then reloaded back on tankers that can distribute it to other places. Typically, tens of tankers are lined up offshore waiting for their turn for this exchange.

Even though they are part of the Netherlands, English is the primary language on both Saba and Statia—a holdover from Colonial times. But more than this, Saba and Statia remain quite different from other Caribbean islands (including the other Dutch Caribbean islands) in terms of heritage and culture. For example, Saba's architecture has evolved differently from the majority of other Caribbean islands, displaying mostly white buildings, with red roofs and green shutters that give the island a fairy tale-like ambience. Though small in size, the islands retain distinct physical and cultural characteristics, often enhanced by their heritage and tourism-focused economies centered on geotourism (see Dowling and Newsome 2006a, b for overview).

6.4 Heritage and Tourism

6.4.1 Heritage on Saba and Statia

The human history of both islands began with Amerindian peoples utilizing the land and sea for fishing, hunting, and foraging around 500 BCE. Columbus sailed by the islands on his second voyage in 1493, but both islands were deserted when Europeans visited in the early seventeenth century, perhaps due to an extended drought (Statia History 2015). European settlement on Saba and Statia occurred in 1640 and 1636, respectively. The British were the majority of the early settlers on both islands, and English is still the primary language spoken on Saba and Statia. During colonial times, the islands' populations and ownership varied. Statia's geographic location and its landscape with an accessible harbor and flat central plain allowed for a robust commercial and maritime economy, and up to 100 plantations. Statia's plantation economy consisted of various crops

Fig. 6.12 Oldest exposed rocks on Saba at Torrens Point on the northwest shore. These rocks include sea stacks, arches, caves, and swim-troughs that are remnants of a Pelean dome heavily hydraulically eroded. Photograph by J. Rahn

including tobacco, cotton, coffee, indigo, and its most important crop, sugar (Haviser 2001). Numbers for Statia's largest population range from perhaps 10,000 to 20,000, though this was a largely transient population in the mid-1700s (Statia Tourism 2015). Other commercially exploited natural resources over the centuries included sulfur deposits on Saba and sisal and pumice on Statia (Haviser 2001).

Throughout the seventeenth and eighteenth centuries, both islands were claimed successively by the Dutch, French, English (and Saba by the Spanish), with Statia changing hands 22 times. The islands first became a Dutch West Indies Colony in 1828, before being included as a Dutch dependency in 1845 along with other Caribbean Islands. It was not until the mid-1950s that the islands became part of the Netherlands Antilles (Britannica 2015). Since then, and up to present, Saba and Statia remain quiet islands that rely heavily on tourism (primarily hiking and scuba diving) for disposable income. archaeological studies on the islands are recent, beginning just a few decades ago in the 1980s. The Saba Archaeological Center (SABARC) seeks to integrate archaeological work with community-oriented projects and have succeeded in attracting and training youth in their preservation activities while promoting pride in local heritage. In February 2016, SABARC opened the Saba Heritage Center in the villages of Windwardside. The center endeavors include "living history" demonstrations, artifact exhibitions, technical laboratory facilities for scientific research, and a public facility for lectures on heritage (SABARC 2015). SABARC also has ongoing excavations at several Amerindian and colonial sites and often conducts weekend digs with local youths.

6.4.2 Coastal and Marine Conservation and Tourism on Saba and Statia

The national parks of Saba have been under the domain of the nonprofit Saba Conservation Foundation (SCF).

Fig. 6.13 Wells Bay beach: a seasonal sandy pocket-beach that usually disappears in wither months, replaces by small (~20 cm) volcanic cobbles. Locally called "wandering beach "or "disappearing beach," it is the only road-accessible, natural sandy beach on the island. At the bottom of the dramatic cliff is a wave cut notch (*center* of photograph) and the northern end of Well's Bay (*left* side of photograph) transitions into Torren's Point. The cliff face is unstable and beachgoers need to be aware of the danger of falling rock. Photograph by J. Rahn

Institutionalized forms of nature conservation on Saba date back to 1987, when the first protected area, the Saba Marine Park (SMP), was established, coinciding with formal incorporation of the SCF. The SMP circles the entire island from the high watermark to a depth of 60 m, including the seabed and overlying waters, and comprising a total area of approximately 1300 ha (see Fig. 6.1). A zoning plan divides the park for various recreational and commercial uses, including a system of permanent mooring buoys to facilitate diving and prevent damage to corals across 30 different dive sites. One of the few self-sustaining marine parks anywhere in the world, the SMP raises revenue through visitor fees (visitors pay US $3 per dive and $1 per night in hotels), souvenir sales, and donations (Saba Park 2015). In 2010, the Saba Bank National Park (SBNP) became an additional underwater-protected area run by The Saba Bank Management Unit (SBMU). An independently operating organization under the SCF umbrella, the SBMU is designed to safeguard the wealth of biodiversity of the entire 2680 km^2 (268,000 ha), flat-topped seamount of the Saba Bank. In particular, it regulates the prime fisheries to ensure their sustainability since Saba Bank remains an important economic resource for Saba, with the fisheries on the Bank contributing about 8% to the island's economy and providing full-time employment to 20 people and part-time employment for an additional 30 people (Dilrosun 2002). In 2012, Saba Bank became the world's thirteenth Particularly Sensitive Sea Area (PSSA), with designation from the International Maritime Organization (IMO). In the past, many freighters, tankers, and cruise ships passed over the Saba Bank and frequently anchored in the shallows, causing significant damage to the coral reefs and other bottom-dwelling ecosystems such as conch feeding grounds. After the IMO declared it an area to be avoided, oil tankers (and other large ships) were no longer allowed to pass over it, which reduced anchor damage on the fragile reef ecosystems (Saba Bank National Park 2012). Scuba diving-related tourism, which includes hotels and restaurants, comprises nearly one-third of Saba's economy. There are three dive shops on the island, and dive tourist numbers

Fig. 6.14 Distal end of Saba's only visible basaltic andesitic lava flow in the Flat Point area is known as the Tide Pools. These sharp, red volcanic rocks are a great place to climb and watch the northern-swell waves crash against Saba's shore. Hikers and climbers should be very aware of rouge waves in this environment, as several Sabans have been swept away. Old Booby Hill is visible in the background. Photograph by J. Rahn

hover around 8000 divers completing as many as 20,000 dives annually.

The national parks of St. Eustatius, which comprise The Quill/Boven Park, the Botanical Garden, and the Marine Park, remain under the control of the nonprofit NGO, St. Eustatius National Parks (STENAPA). The St. Eustatius National Marine Park was created in 1996 and extends around the entire island from the high waterline to 30-m depth contour. The park covers an area of more than 27 km^2 and protects a variety of habitats, including pristine coral, eighteenth century shipwrecks, and modern-day artificial reefs to promote fishing and dive tourism (Statia Park 2015). Within the park are two actively managed reserves in which no fishing or anchoring is permitted in hopes of conserving marine biodiversity, protect fish stocks, and promote sustainable tourism. Annually, around 11,000 visitors visit St. Eustatius, staying an average of eight nights. Figures from Statia Park (2010) determined that approximately 80% of those visitors engage in coral reef related activities.

Both the Saba and St. Eustatius Marine Parks work closely with the three local dive centers on each island to ensure that diving practices minimize impact on the reefs. Saba and Statia's marine environments are also a home, migratory stop over, or breeding site for four IUCN Red List Species, 10 CITES Appendix I species, and 98 Appendix II species (St. Eustatius Marine Park Management Plan 2007). The Yarari Marine Mammal Sanctuary is the fourth Caribbean marine mammal sanctuary and includes the Caribbean Netherlands' territorial waters of Saba, St. Eustatius, and Bonaire. The waters surrounding Saba and Bonaire became

Fig. 6.15 Aerial photograph of Statias' windward coast with The Quill volcano surrounded by clouds. Oranjestad, the island's single town and capitol, is visible to the *right* of the image. The *center* of the photograph is dominated by the Culture Plain, Kultuurvlakte, where most of the agriculture occurs. Historically, cultivation went high up the slopes of The Quill. Photograph by J. Haviser

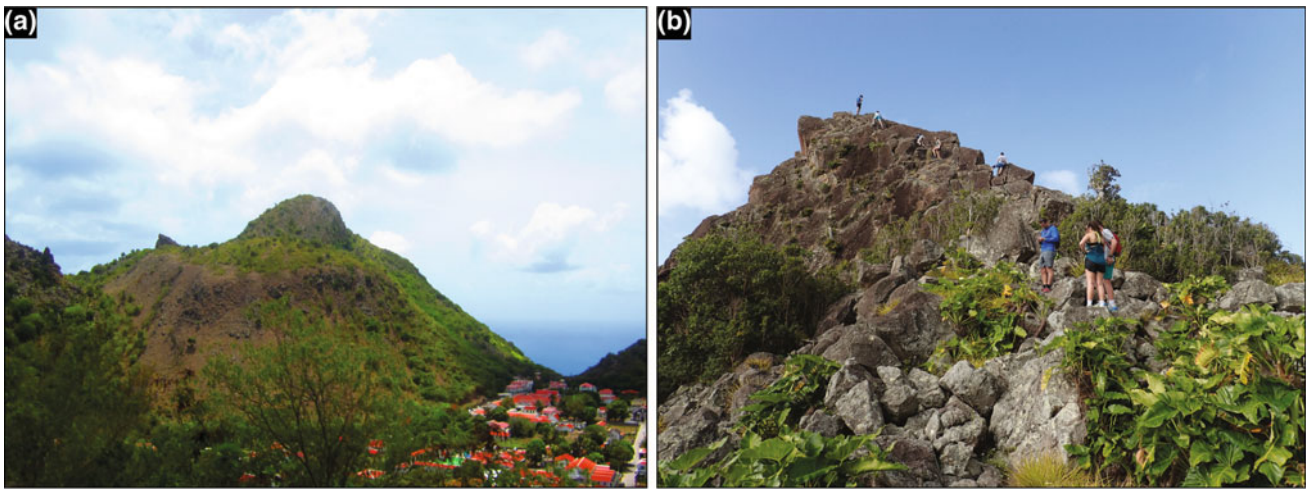

Fig. 6.16 Landform known as "The Whale" on Saba. **a** View of The Whale (*center left*) from the road descending from St. John's to The Bottom. The much-photographed anthropomorphized volcanic domes of Paris Hill and Great Hill create the whale's body and the well-preserved volcanic spine serves as the Whale's Tail. **b** Close-up view of climbers on the Whale's Tail displaying the ridge's rough volcanic geology and lush vegetation. Photographs by J. Rahn

shark sanctuaries in 2015 that cover the islands' full exclusive economic zones. All commercial shark fishing is prohibited up to 200 nautical miles from each island.

From a landform perspective, Saba offers underwater explorers a unique treat, with several dive sites encompassing underwater pinnacles covered completely by coral that begin at 150 m below sea level and rise to 30 m below sea level. Deep sea pelagics frequently swim by and rare corals, such as black coral (*Antipatharia*), grow at deeper depths. This combination of marine ecosystems and (semi-stable) subaerial geology make Saba and Statia one of the more unique Caribbean locations in terms of underwater attractions.

6.4.3 Terrestrial Conservation and Tourism on Saba and Statia

In 2012, the Saba Conservation Foundation created a terrestrial park, the Saba National Land Park, a pie-shaped, 43-ha tract of land on the north coast of Saba, formerly owned by the Sulfur Mining Company. The area has important biological, geological, and historical values, as well as encompassing all vegetation zones present on Saba, an abandoned sulfur mine, hot springs, and serving as an important nesting area for Red-billed tropicbirds (*Phaethon aethereus*) and several other species of seabirds (Saba Park 2015). At the top of Mt. Scenery (877 m), an 8.6-ha plot is being considered for acquisition as an Elfin Forest Reserve. Reached by climbing 1064 Saban-built, rock-hewn steps from the village of Windwardside (Fig. 6.17), this area hosts montane cloud forest, also known as elfin forest, and consists of two primary tropical rainforest areas that represent climax vegetation. Saba's cloud forest is unusual because the Mountain Mahogany (*Freziera undulata*) is the "signature tree" and because the canopy is significantly higher than in other cloud forests (van't Hof 2010). Van't Hof also believes that this was a climax forest of approximately 500 years until four hurricanes from 1989 to 1999 devastated the area and only a few survived.

The SCF is also responsible for hiking trails (the Saba Trail Network), and they staff the Saba Trail and Information Centre in the village of Windwardside. Mapping and maintenance of the more than one-dozen hiking trails is done by park rangers and a significant amount of volunteer help. The SCF fulfills an important role as advisory body for the government and as management agency for protected areas. They are also committed to the belief that a stronger island economy will result from the sustainable use of Saba's rich and virtually unspoiled resources (Saba Park 2015).

Other nonprofits on Saba include Sea and Learn, which sponsors a month-long event each October. Sea and Learn on Saba is a nonprofit foundation that "brings together the local community, diverse nature experts, and visitors to understand the value of preserving, protecting, and sustaining the local natural and cultural resources and heritage on Saba, and worldwide; and to educate the potential safe-keepers in order to sustain viability and infinitum as an ecotourism destination" (Sea and Learn 2015). There are also two other heritage museums on Saba in Windwardside: the Harry L. Johnson Museum and the Dutch Museum. The former includes an original Saban cottage in the middle of a garden highlighting Saba's marine heritage (and located in a public park), while the latter houses collections of Dutch antiques from the 1500s to 1900s.

On St. Eustatius, STENAPA protects The Quill/Boven Park and the Botanical Garden. The Quill/Boven National Park was pronounced the first national park of the Netherlands Antilles in 1998. The park was created "to protect Statia's unique biodiversity and to ensure sustainable use by all stakeholders." This 5.4 km^2 park consists of two subsectors, The Quill and White Wall, and the Boven area covering five hills in the north of St Eustatius. Varying types of habitat are protected, ranging from elfin forest at the top of The Quill volcano to thorny woodland on the lower slopes. The park gives guided tours to visitors and maintains a network of 10 trails in The Quill sector (Statia Park 2015). The Miriam Schmidt Botanical Garden was also established in 1998 to display the island's flora (and fauna). This garden is adjacent to The Quill National Park boundary and extends for over 5-ha across the southern slopes of The Quill.

Established in 2004, the St. Eustatius Center for Archaeological Research (SECAR) provides a permanent archaeological presence on Statia focusing on basic heritage resource management issues working with the locals. SECAR is an active and vibrant research group involved in education, pioneering research techniques, and protecting underwater and terrestrial cultural heritage resources, including more than 100 sunken trading ships, submerged anchors, and cannons off the shores of Statia and terrestrial Amerindian and colonial excavations (SECAR 2015).

6.5 Hazards

6.5.1 Meteorological Hazards

Meteorological events (as well as their secondary and tertiary effects) represent the greatest hazard each island faces, and as world and local climates continue to change, smaller islands such as Saba and Statia feel the alterations first. The most frequent and costly natural hazard to Saba and Statia are the effects of tropical storms, hurricanes, and increasingly, drought. Thought there is little to no meteorological data on either island, because of their small populations, preparedness, and community spirt, there has been little loss

Fig. 6.17 Sign at the bottom of the Mt Scenery trail in Windwardside. At the top of the trail, there is a plaque stating, in Dutch, that Mt Scenery is the highest point in the Netherlands. Photograph by J. Rahn

of life due to tropical storms on Saba or Statia. Historical damage has included the removal of roofs, flooding, tree and other airborne debris, soil erosion, and small landslides. Power, telecommunications services, and food deliveries can be disrupted for a few days to weeks, depending on the extent of the storm. Flash flooding can occur on steep slopes, and roads in these areas can become ephemeral streams directing fast-flowing water to lower elevations. On Saba, this becomes a travel hazard since there is only one road, while the only low-lying flood-prone areas on Statia occur in the Culture Plain.

Wet and dry periods on Saba and Statia can be pronounced. In the last decade, drought has become a problem, with climate change seeming to affect the frequency and magnitude of these events. This is especially a problem since most water on Saba and Statia is provided by roof catchment collection and subsequently stored in cisterns. Local islanders are very water-conscious and aware of the amount of water they have for daily use. Measures like 2 minute showers, dish-washing by hand, small-capacity washing machines (or hand-washing clothes), and flushing toilets only when necessary are common island-wide. However, groups of foreigners (including the approximately 400 people associated with the Saba Medical School, the hundreds of people connected with the Statia oil terminal, and tourists) have little care for their water consumption, and this exacerbates the problem. In severe droughts, water has to be shipped to the islands. Additional problems occur because of the lack of a distribution system for water, where the current distribution system relies on privately owned trucks with 1000-gallon tanks to move water across the islands. Both islands have desalinization plants, but they have limited production volumes, and Statia's has not been operational for three years (Ryan Espersen personal communication).

High winds can also be a problem, preventing flights from landing on the small airstrips for days at a time. Usually occurring in winter and accompanied by large ocean swells, the winds can often preclude boats from running as

well, exacerbating the problem further, as most food is shipped to the islands once per week.

Mass wasting can occur from high precipitation, ground shaking (earthquake or human- induced), and when gravity and time take their toll on the steep, thinly soiled, lightly vegetated slopes on both islands. On Saba, mass wasting occurs on both terrestrial and on steep submarine slopes. Most commonly, on both islands, it will occur along the coast where waves erode cliff bases.

6.5.2 Seismic and Volcanic Hazards

Historically, both islands have low-seismic dangers, and no damaging earthquakes or tsunamis have been recorded on Saba or Statia. The main risks would come from earthquakes in the Caribbean region possibly producing a tsunami (very rare: only two have been documented historically in the 1700's) or from local earthquake swarm precursor to a volcanic eruption. A seismic swarm occurred near Saba in 1992 (Ambeh and Lynch 1995), but the magnitudes were not large enough to cause any damage. In June of 2015, seismologists from the Dutch Meteorological Institute (KNMI) installed four seismometers each on Saba and Statia. The real-time feed can sometimes be viewed (http://www.knmidc.org/seismology/?NA_SEUT_—although some seismometers intermittently cease functioning and occasionally the Web site is down). Large earthquake induced mass movement events would hit Saba especially hard because it has only one road, and landslides could block access to the only two evacuation points at Fort Bay and the airport. All of Saba's infrastructure, except the Fort Bay port and the airport—both of which lie near sea level—would not be at risk to tsunami waves. For example, the power plant used to be at 3 m above sea level in Fort Bay, but was moved to a 100 m elevation (along the road above Fort Bay) in February 2016. Statia would receive more damage from a tsunami, and possible effects there would include oil spills from the terminal, as well as some infrastructure located at low elevations near the west coast.

For both Saba and St. Eustatius, there are no historical records of eruptive activity. The most recent eruption on Saba and Statia were 1600 AD and 400 AD, respectively, as determined geologically (Hartog 1975, 1976). Volcanic hazard and risk assessments were made for Saba and Statia in 1977 (Fournier and Tomblin) and again in 1997 (Roobol, Smith, and Tomblin). In 2005, the Volcanic Hazard Atlas of the Lesser Antilles was published by the University of the West Indies, where Roobol, Smith, and Tomblin wrote the Saba and Statia chapters that contained a summary of the work the authors carried out on these islands over the past 25 years. Saba is clearly an active volcano as indicated by the presence of hot springs with temperatures around 72 and 55 °C and The Quill, even though it has no external manifestations, is still regarded as an active volcano (Roobol et al. 1997). Using geohazard interpretations reconstructed from the stratigraphic records of the entire pyroclastic history, Roobol and Smith (1989) note that the present period of volcanic inactivity on Saba and Statia does not indicate the extinction of these volcanoes, but rather periods of dormancy. It should be stated, however, that the overall volcanic hazard for these two are similar to other Lesser Antilles Caribbean volcanoes, and Roobol et al. (1997) recommended that the governments should have plans and designated funds to evacuate each island in 1–2 days. As of December 2016, the local governments have been working with the Dutch on these plans, but they have not been released to the public. Additionally, continuous seismic and monthly hot springs monitoring should be taking place. Ash fall from other nearby Caribbean islands might also be a hazard on Saba and Statia as, for example, Montserrat's 1995 eruption column that spread an ash across Saba and Statia.

6.5.3 Other Hazards

Though small islands in size, Saba and Statia still face hazard challenges beyond storms and drought. Neither Saba nor Statia are self-sufficient as far as water, food, or energy are concerned, and the delicate balance of subsistence could easily be affected by a variety of environmental problems and hazards including coral reef bleaching, alien species invasion, land removal, solid waste, and oil refinery-related hazards. The coral reefs ecosystems of Saba and Statia have had little subaerial human effects since populations are so small and many of the reefs are not near human habitations. The largest aquatic impact has been various Caribbean coral reef diseases, large scale herbivore removal with the demise of the spiny sea urchin (*Diadema antillarum)* in the 1980s, and higher than normal sea surface temperatures. Coral bleaching has occurred on these reefs. The worst event happened in 2005, but there have been several minor cases. Beach erosion on Statia (especially Zeelandia Beach) could affect sea turtle nesting.

Additionally, free-roaming goats on both islands are a large problem, causing soil degradation, loss of organic matter, reduced water retention, and overall erosion in semiarid rangelands (Rojer 1997). Although goats occur mostly below the 300-m contour level, in arid times they often graze above 600 meters. According to Romeijn (1987) and Rojet (1997), areas where goats have influenced the vegetation on the major part of the island and large parts of Saba and Statia remain permanently deforested, and in some areas, a complete absence of herbaceous and shrub layers in the forest is due to excessive goat grazing (Debrot 2010).

There have been unsuccessful efforts on both islands to cull, restrict, and better manage the roaming goats.

Removal and movement of large amounts of land for private commercial purposes continues to have effects on the ecological integrity of both islands. On Saba, 1.6 ha (19,000 yds^3) of Fort Hill was removed as part of a rock crushing operation, resulting in approximately 100,000 tons of rock (by estimate of a Saban to the author). Continuing expansion of the stone crushing facility has consequences for the geological formations, scenery, biodiversity in the sea, and dive tourism (Sybesma and Visser 1996; Rojer 1997). On Statia, the top of Signal Hill was leveled about 0.23 km to situate the oil terminal tanks. Signal Hill and Fort Hill were prime sea bird nesting sites. On Saba construction debris dumping (of up to 500 dump truck loads) has occurred on the coastline adjacent to Tent Reef dive sites, and that much sediment, were it to wash onto the nearby reefs, could decimate the fragile ecosystem. Efforts by this author and the SCF resulted in a $100,000 federal grant to remove the fill, but the project has still not occurred. To this author's knowledge, although required by The Netherlands (and the EU), environmental impact assessments do not occur prior to large projects on either island.

A large oil spill potentially affecting both islands could be a hazard, considering the 11-million-gallon Nustar Energy oil storage and distribution facility on Statia. On a busy day, ten large tankers come and go off-loading and on-loading fuel. Based on prevailing winds and waves, the most likely oil spill scenario has the oil heading directly to Saba, with limited localized effect on Statia. Though no major damage resulted from them, there have been several small oil spills between 2009 and 2015, and in response, the Dutch government has provided Saba and Statia with oil spill cleanup, training, and equipment. In 2010, the Saba government and SCF, in consultation with Dutch and EU scientists, decided to not use dispersant if there is a large oil spill because Saba's coastal resources are primary subaqueous (the coral reefs) and dispersant would submerge the oil and harm the reefs. Instead, the plan centers on allowing oil to hit their shores and float past the island, where perhaps dispersant would then be used at sea. On Statia, the oil terminal has affected ecotourism on the island, at least from a visual standpoint, since the main inhabited area hosts many oil storage tanks.

6.6 Conclusion

The landforms of Saba and St. Eustatius originate from subduction in the Lesser Antilles, resulting in Pleistocene island arc volcanics. Both islands have stratovolcanic landscapes and many Pelean-type domes with adjacent pyroclastic flows. Saba is a single volcano whose steep slopes drop off precipitously into the sea, while St Eustatius lies on a shallow submarine bank. They both have similar geologic histories and landforms and are perhaps co-eruptive, but Statia is slightly older, has more erosional features, a flat central plain, and experienced some uplift. Both islands have young, visually predominant volcanos that represent the highest (Saba) and second-highest (Statia) elevations in the Kingdom of the Netherlands. Their steep slopes are embedded with ephemeral, waterworn ravines locally called guts—some of their volcanic landforms being obscured by dense tropical vegetation—and most of their coastlines are rocky (abrasional) cliffs. While other Caribbean Islands contain karst, lakes, continually flowing rivers, and even abundant aeolian features, Saba and Statia lack these. Climatological events of tropical storms, hurricanes, heavy precipitation, and drought have been the most impactful hazards. Changing regional climate regimes will likely be the biggest environmental hazard and geomorphic agent in the future. Like other Lesser Antilles islands, seismic and volcanic activity also poses possible risks, including landslides, but these are rare events on Saba and Statia. Some of the best coral reefs in the Caribbean surround both islands and are important for tourism, especially on Saba where scuba-related tourism accounts for about a third of the economy. Saba and Statia both have influential NGOs that work with the government to protect their natural environments and cultural history, with each island hosting active Amerindian and colonial archaeological sites and nonprofit archaeological organizations.

Saba and Statia are atypical of other Caribbean islands because of their small sizes, rugged topographies, and lack of large resorts, development, and industry. They have maintained their relatively pristine environments because of low human impact. A healthy natural environment is important to the priorities and pride of the local peoples. Indeed, Saba is known as "The Unspoiled Queen" in the Caribbean, and inhabitants of Saba and Statia form close knit, small-town like societies allowing them to interconnect with their environment and with each other. While Sabans and Statians are community-oriented, environmentally aware, inquisitive, and work together to be resilient in the face of adversity, finding solutions to current and future problems will require continued solidarity and good relations between communities, governments, and the rest of the Caribbean.

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