U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division

# Virgin Islands National Park

## *GRI Ancillary Map Information Document*

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Virgin Islands National Park

viis_geology.pdf

Version: 4/16/2019

# Geologic Resources Inventory Map Document for Virgin Islands National Park

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## Geologic Resources Inventory Map Document

# Virgin Islands National Park, Virgin Islands

## Document to Accompany Digital Geologic-GIS Data

viis_geology.pdf

Version: 4/16/2019

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Virgin Islands National Park, Virgin Islands (VIIS).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

This document contains the following information:

1) **About the NPS Geologic Resources Inventory Program** – A brief summary of the Geologic Resources Inventory (GRI) Program and its products. Included are web links to the GRI GIS data model, and to the GRI products page where digital geologic-GIS datasets, scoping reports and geology reports are available for download. In addition, web links to the NPS Data Store and GRI program home page, as well as contact information for the GRI coordinator, are also present.

2) **GRI Digital Maps and Source Map Citations** – A listing of all GRI digital geologic-GIS maps produced for this project along with sources used in their completion. In addition, a brief explanation of how each source map was used is provided.

3) **Map Unit List** – A listing of all geologic map units present on maps for this project, generally listed from youngest to oldest.

4) **Map Unit Descriptions** – Descriptions for all geologic map units. If a unit is present on multiple source maps the unit is listed with its source geologic unit symbol, unit name and unit age followed by the unit's description for each source map.

5) **Geologic Cross Sections** – Geologic cross section graphics with source geologic cross section abbreviations.

6) **Ancillary Source Map Information** – Additional source map information presented by source map. For each source map this may include a stratigraphic column, index map, map legend and/or map notes.

7) **GRI Digital Data Credits** – GRI digital geologic-GIS data and ancillary map information document production credits.

For information about using GRI digital geologic-GIS data contact:

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# About the NPS Geologic Resources Inventory Program

## Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

## Products

**Scoping Meetings:** These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

**Digital Geologic Maps:** Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: https://www.nps.gov/articles/gri-geodatabase-model.htm

**Geologic Reports:** Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage: http://go.nps.gov/gri_products

GRI geologic-GIS data is also available online at the NPS Data Store Search Application: http://irma.nps.gov/App/Reference/Search. To find GRI data for a specific park or parks select the appropriate park(s), enter □GRI□ as a Search Text term, and then select the Search Button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: https://www.nps.gov/subjects/geology/gri.htm, or contact:

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The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division.

# GRI Digital Map and Source Map Citation

The GRI digital geologic-GIS map for Virgin Islands National Park, Virgin Islands (VIIS):

**Digital Geologic-GIS Map of Virgin Islands National Park, Virgin Islands (*GRI MapCode VIIS*)**

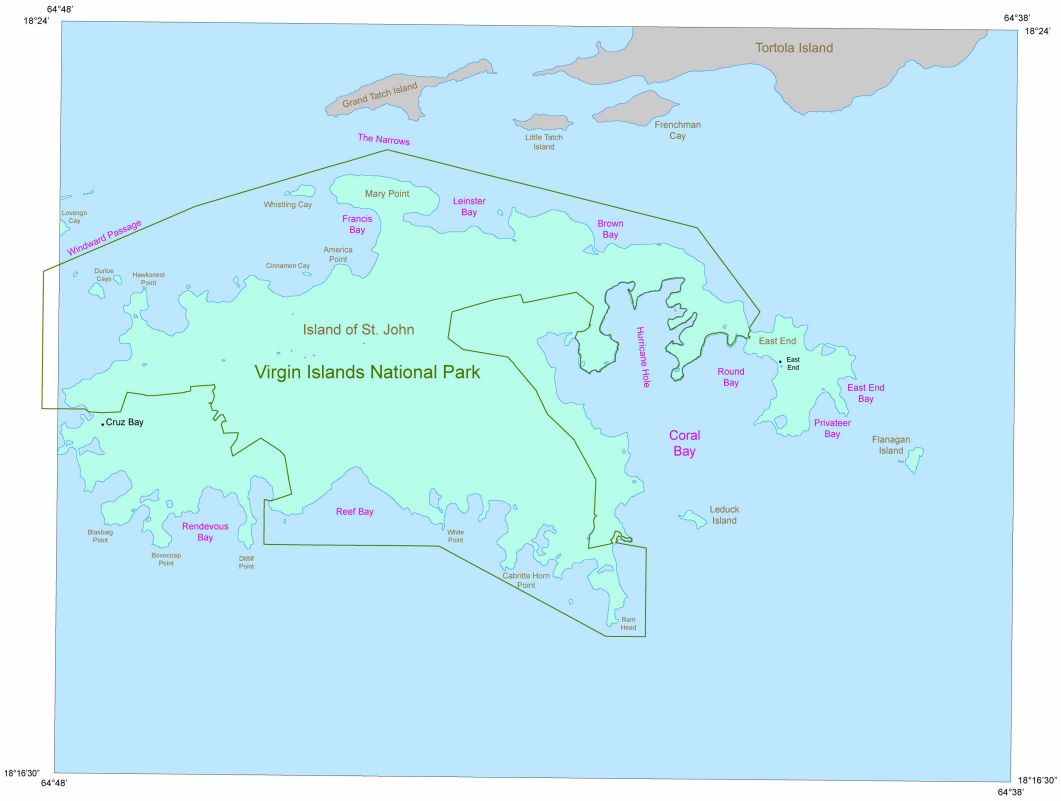
The map was produced from the following source map.

Rankin, D.W., 2002, Geology of St. John, U.S. Virgin, Islands: U.S. Geological Survey, Professional Paper 1631, scale 1:24,000 (Virgin Islands Geology (St. John)). (*GRI Source Map ID 4071*).

Additional information pertaining to the map is also presented in the GRI Source Map Information (VIISMAP) table included with the GRI geologic-GIS data.

## Index Map

The following index map displays the extent of the GRI digital geologic-GIS map produced for Virgin Islands National Park. Water is shown in light blue. Islands in dark gray within the map extent, defined by the latitude and longitude coordinates, were not mapped on the source map and thus have no geologic information in the GRI digital geologic-GIS data. The boundary for Virgin Islands National Park (as of April, 2019) is outlined in green. The extent of the park just outside the map extent is water. Prominent bays and channels are shown in purple, whereas island names and prominent coastal island features are shown in brown.




Index map produced by Stephanie O'Meara (Colorado State University).

# Map Unit List

The geologic units present in the digital geologic-GIS data produced for Virgin Islands National Park, Virgin Islands (VIIS) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qs - Surficial deposits). Units are listed from youngest to oldest. No description for water is provided. Information about each geologic unit is also presented in the GRI Geologic Unit Information (VIISUNIT) table included with the GRI geologic-GIS data. Units present in the listing that were not mapped have no unit symbol assigned to them (e.g., Tutu Formation).

## Cenozoic Era

### Quaternary Period

Qs - Surficial deposits

### Tertiary Period

Tr - Red Hook Tonalite Porphyry
Te - Explosion breccia
Tl - Hornblende lamprophyre
Tt - Biotite-hornblende tonalite
Td - Diabase, gabbro, and diorite

## Mesozoic Era

### Cretaceous Period

Tutu Formation
- Ktm - Tutu Formation, Mandal Member
  - Ktmc - Tutu Formation, Mandal Member, Congo Cay Limestone Lens
  - Ktml - Tutu Formation, Mandal Member, marble, calc-silicate rock, and marble conglomerate
- Ktp - Tutu Formation, Picara Member
  - Ktpl - Tutu Formation, Picara Member, marble conglomerate and calc-silicate-rich beds north of Maho Point
  - Ktpv - Tutu Formation, Picara Member, medium-dark-gray porphyritic meta-andesite south of Maho Point
- Ko - Outer Brass Limestone

Kl - Louisenhoj Formation, undivided
- Kla - Louisenhoj Formation, porphyritic locally vesicular andesite lava
- Klb - Louisenhoj Formation, porphyritic locally amygdaloidal basalt and pillow basalt

Klm - Lameshur Volcanic-Intrusive Complex, undivided

Lameshur Volcanic-Intrusive Complex, Careen Hill Intrusive Suite
- Kct - Lameshur Volcanic-Intrusive Complex, Careen Hill Intrusive Suite, trondhjemite
- Kcc - Lameshur Volcanic-Intrusive Complex, Careen Hill Intrusive Suite, coarsely porphyritic keratophyre
- Kcp - Lameshur Volcanic-Intrusive Complex, Careen Hill Intrusive Suite, porphyritic keratophyre
- Kca - Lameshur Volcanic-Intrusive Complex, Careen Hill Intrusive Suite, phenocryst-poor keratophyre
- Kcf - Lameshur Volcanic-Intrusive Complex, Careen Hill Intrusive Suite, plagioclase-phyric keratophyre
- Kcm - Lameshur Volcanic-Intrusive Complex, Careen Hill Intrusive Suite, gabbro
- Kcsd - Lameshur Volcanic-Intrusive Complex, Careen Hill Intrusive Suite, sheeted dike complex

Lameshur Volcanic-Intrusive Complex, Water Island Formation
- Kwp - Lameshur Volcanic-Intrusive Complex, Water Island Formation, porphyritic keratophyre
- Kwa - Lameshur Volcanic-Intrusive Complex, Water Island Formation, phenocryst-poor keratophyre

Kwf - Lameshur Volcanic-Intrusive Complex, Water Island Formation, plagioclase-phyric keratophyre
Kws - Lameshur Volcanic-Intrusive Complex, Water Island Formation, basalt and basaltic andesite
Kww - Lameshur Volcanic-Intrusive Complex, Water Island Formation, volcanic wacke and bedded tuff
Kwr - Lameshur Volcanic-Intrusive Complex, Water Island Formation, radiolarian chert

# Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below. Unit descriptions were taken from the source map (Virgin Islands Geology (St. John)) paper/report.

## Qs - Surficial deposits (Quaternary)

Alluvium, swamp deposits, beach deposits, beachrock (sedimentary rock formed in tidal zone), and artificial fill. Only alluvium is likely to contain material as old as Pleistocene.

## Tr - Red Hook Tonalite Porphyry (Tertiary)

Dikes and small hypabyssal intrusions of yellowish-gray (5*Y* 7/2), pinkish-gray (5*YR* 8/1), and grayish-yellow-green (5*GY* 6/2) porphyritic tonalite characterized by large bipyramidal quartz and barrel-shaped biotite phenocrysts. Groundmass aphanitic to fine grained and locally spherulitic. Phenocrysts, as abundant as 45 percent, of quartz, plagioclase, biotite, less commonly hornblende, and prominent apatite. Quartz and plagioclase commonly in growth aggregates, either singly or together. Bipyramidal and embayed quartz phenocrysts commonly 1 cm to as much as 3 cm across. Plagioclase phenocrysts complexly zoned with many reversals. Biotite typically completely replaced by vermiculite. Named for prominent dikes at Red Hook, Eastern St. Thomas quadrangle, where dikes are intruded along late brittle faults.

## Te - Explosion breccia (Tertiary?)

Mafic dike 15 to 20 cm thick contains 60 percent or more xenoliths of keratophyre, greenstone, gabbro, and tonalite. Observed only on east side of Dittlif Point where it can be traced for about 20 m across outcrop of Water Island Formation. Cuts diabase dike that is interpreted to be unit Td but could be unit Kcm. Shown only on inset map showing dike distribution and attitude on plate 1.

*The unit, as mentioned in the above unit description, is only present in the inset map showing dike distribution and attitude, and thus isn't present in the GRI digital geologic-GIS data.*

## Tl - Hornblende lamprophyre (Tertiary)

Dark, magnetite-bearing, aphanitic dikes with prominent hornblende phenocrysts as large as 3 cm by 1 cm and, in places, clinopyroxene phenocrysts as large as 1 cm. Typically smaller plagioclase phenocrysts are present. Most Tl dikes are younger than dikes of unit Td, but some Td mafic dikes cut Tl.

## Tt - Biotite-hornblende tonalite (late Eocene)

Very light gray to medium-light-gray, medium-grained, nonfoliated biotite-hornblende tonalite and minor gabbro, diorite, granite, and pegmatite. Tonalite composed of interstitial quartz (10 to 15 percent); subhedral, strongly and complexly zoned plagioclase, biotite partly altered to chlorite; hornblende; and magnetite. Gabbro composed of plagioclase, hornblende, clinopyroxene, apatite, and pyrite and (or) magnetite. Granite is very light gray, fine to medium grained and contains quartz, orthoclase (about 35 percent), strongly zoned plagioclase, biotite altering to chlorite, zircon, and magnetite. White pegmatite contains quartz, slightly perthitic orthoclase (poikilitic crystals up to 1.5 cm across), reddish isotropic garnet, and minor diopside, sphene, allanite, and calcite. Shows copper stain. Contains may xenoliths of stratified country rock (gray, fine-grained granofels, siliceous hornfels, and calc-silicate) and gabbro (Unit Td?); also contains pockets of skarn with massive sulfide and copper stain. Sharp contacts; post-kinematic to tight folding and cleavage in country rock.

Produces contact-metamorphic aureole as wide as 2 km.

## Td - Diabase, gabbro, and diorite (Tertiary)

Nearly vertical dikes ranging in thickness from a few cm to several tens of meters and complex bodies of multiple dikes, some with internal layering parallel to dike walls. Chilled margins typical; columnar jointing not typical. Color index, grain size, and texture vary; mostly diabase or gabbro with diabase margins. Amygdules present locally. Primary minerals include plagioclase, clinopyroxene, commonly hornblende, magnetite, and (or) pyrite, and, in some rocks, quartz. May be porphyritic with phenocrysts of plagioclase, clinopyroxene, and (or) hornblende. Thicker bodies commonly contain epidosite nodules and disseminated epidote. Secondary, pale, commonly fibrous amphibole, chlorite, and epidote are common. In northern half of St. John, progressively metamorphosed to amphibolite-facies assemblages. Also toward the north, many dikes carry the same penetrative cleavage as the enclosing stratified rocks; some broken into segments aligned parallel to cleavage. Other dikes are post-cleavage. Dikes intrude all stratified units except surficial deposits and are intruded by tonalite (Tt ). Probably includes dikes of more than one age. Some may be intrusive equivalents of extrusive rocks in enclosing or overlying stratified units. Others may be part of tonalite (Tt) intrusive cycle, and a very few cut hornblende lamprophyre (Tl). Most interpreted to be part of early Tertiary pre-tonalite (Tt) magmatic cycle, as suggested by Donnelly and others (1990).

*The unit Td is mapped as both an area (polygon) feature and a linear feature, and thus is present in both the Geologic Units (GLG) and Linear Dikes (DKE) feature classes in the GRI digital geologic-GIS data.*

## Tutu Formation (Upper Cretaceous)

Volcanic wacke, shale, conglomerate, calcareous siltstone, sparse limestone, and rare basalt and andesite or their metamorphosed equivalents. Many rocks are calcareous. All rocks are within contact aureole of tonalite (Tt); hornfels, calc-silicate rock, and marble common. Clasts in conglomerate dominantly basalt and andesite; limestone clasts locally abundant; clasts of plutonic rocks rare, but present. Graded beds, slump folds, and disrupted slabs of metasandstone and metasiltstone in metaconglomerate indicate deposition by turbidity currents on an unstable slope, perhaps a trench wall. Tight tectonic folds with axial-plane cleavage also present, as well as boudins of competent thermally metamorphosed sandstone and silt beds in marble. Distinguishing between soft-sediment and tectonic folds difficult in places where cleavage is not apparent. Basal contact not exposed; in apparent conformity with underlying Outer Brass Limestone (Ko).

## Ktm - Tutu Formation, Mandal Member (Upper Cretaceous)

Medium- to thin-bedded, metamorphosed sandstone, siltstone, shale, and limestone. Siltstone typically calcareous and sandstone commonly with a calcareous matrix. Sparse conglomerate, mostly limestone conglomerate in beds as thick as 3 m. Marble contains calcite, plagioclase, tremolite, brown garnet, epidote, and opaque minerals. Metamorphosed calcareous siltstone and sandstone contain brownish garnet (locally as large as 3.5 cm), diopside, tremolite, plagioclase, calcite, opaque minerals, and minor quartz. On Whistling Cay, bedded, garnet-rich calc-silicate rock contains isotropic reddish garnet, bright-green diopside, plagioclase, wollastonite, phlogopite, sphene, pleochroic amphibole, and quartz. Dark-grayish-red (5*R* 3/2), very fine grained metasandstone contains abundant reddish-brown biotite and cordierite clouded with tiny inclusions. Named for exposures on the east side of Mandal Point, Eastern St. Thomas quadrangle. About 750 m exposed on St. John.

### Ktmc - Tutu Formation, Mandal Member, Congo Cay Limestone Lens (Upper Cretaceous)

Tightly folded, vertical beds of marble, calc-silicate rock, and siliceous hornfels exposed on Congo Cay and Carval Rock. Dominantly white to medium-light-bluish-gray (5B 6/1) marble that is 98 percent calcite and either accessory plagioclase, white mica, and opaque minerals, or accessories plagioclase, tremolite, wollastonite, sphene, and opaque minerals. Calcite grain size typically 1 to 3 mm, but may be as large as 1 cm. Stratigraphic position of rocks on Congo Cay within the Tutu Formation (Ktm) not known. Here correlated with similar rocks on Whistling Cay and Mary Point that are within the Mandal Member.

### Ktml - Tutu Formation, Mandal Member, marble, calc-silicate rock, and marble conglomerate (Upper Cretaceous)

No additional unit description present on source map.

## Ktp - Tutu Formation, Picara Member (Upper Cretaceous)

Thick- to medium-bedded, metamorphosed volcanic wacke, conglomerate, siltstone, limestone, and rare andesite or basalt. Locally calcareous. Clasts in conglomerate of metamorphosed andesite, basalt, and limestone. Pebble and cobble conglomerate more common than boulder conglomerate. Ribby outcrops of metasiltstone and metawacke common; calcareous nodules locally present. Named for exposures on the peninsula of Picara Point, Central St. Thomas quadrangle. About 600 m thick on St. John.

### Ktpl - Tutu Formation, Picara Member, marble conglomerate and calc-silicate-rich beds north of Maho Point (Upper Cretaceous)

Calc-silicate assemblages include plagioclase-biotite-hornblende and plagioclase-hornblende-diopside-calcite. Two layers of marble and calc-silicate rock on Waterlemon Cay not mapped separately. Assemblage there includes brown garnet (some anisotropic and as large as 2 cm), diopside, wollastonite (blades as long as 2 cm), sphene, calcite, monazite, and sulfide.

### Ktpv - Tutu Formation, Picara Member, medium-dark-gray porphyritic meta-andesite south of Maho Point (Upper Cretaceous)

Contains relict phenocrysts of glomerophyric plagioclase and prominent clinopyroxene as large as 3 by 6 mm. Metamorphic amphibole replaces clinopyroxene; fibrous amphibole and chlorite abundant in groundmass and impart foliation.

## Ko - Outer Brass Limestone (Upper Cretaceous)

Thin-bedded calc-silicate rock, beds of white to blue-gray calcite marble ($H_2S$ odor when broken) as thick as 3m, and metamorphosed, matrix-supported cobble conglomerate with andesite clasts in carbonate matrix. Heterogeneous calc-silicate at Annaberg Point includes, in various assemblages, calcite, plagioclase, epidote, brown isotropic garnet, diopside, vesuvianite, and wollastonite. About 100 m thick.

## Kl - Louisenhoj Formation, undivided (Cretaceous)

Strongly cemented volcanic conglomerate, breccia, volcanic wacke, shale, chert, andesite, basalt, tuff, and rare limestone. Overlies Water Island Formation with apparent conformity. Detrital units dominantly volcaniclastic. Lavas and flow breccias present but sparse. Conglomerate, breccia, and coarse sandstone typically pale green, greenish gray, or grayish blue green. Matrix may be

calcareous. Xenocrysts of plagioclase and pyroxene are notable constituents of some clastic rocks. Dominated by thick, clast- or matrix-supported conglomerate beds typically interlayered with sequences a few to several meters thick of siltstone and sandstone. Graded beds as thick as 6 m; some crossbedding. Soft sediment deformation and rafts of broken, finer grained beds common. Clasts larger than 0.5 m abundant throughout the formation; largest subrounded clast 3 m across. Breccia blocks may be as large as tens of meters. Clasts of porphyritic clinopyroxene andesite and basalt constitute bulk of formation. Typically contain about 20 percent prominent phenocrysts, commonly 5 to 10 mm across, of clinopyroxene and stubby, zoned plagioclase, either singly or together. In some rocks, pyroxene phenocrysts overgrown by hornblende; a few rocks have hornblende phenocrysts as well. Small amygdules pervasive in some clasts. Other clast lithologies include pumice (not common), limestone, keratophyre, and phenocryst-poor basalt like that in Water Island Formation. Differences in clast populations suggest local sources. Keratophyre and phenocryst-poor basalt are locally abundant near basal contact. Limestone clasts, some fossiliferous, on Rata and Ramgoat Cays. Metamorphism increases to the northeast. Biotite, pale amphibole, and epidote appear in andesite; epidote, hornblende, and lesser amounts of biotite appear in basalt. From central St. John to the north and east, most rocks are foliated. At least 1.5 km thick on west coast of St. John, may be as thin as 0.5 km at Leinster Bay.

## Kla - Louisenhoj Formation, porphyritic locally vesicular andesite lava (Cretaceous)

Phenocrysts of stubby plagioclase and pyroxene. Pillowed on Ramgoat Cay. Highly brecciated on Camelberg Peak and could be aa lava. May be more abundant than shown on map because of difficulty in the field distinguishing between conglomerate/breccia and homogeneous lava.

## Klb - Louisenhoj Formation, porphyritic locally amygdaloidal basalt and pillow basalt (Cretaceous)

Abundant (as mush as 40 percent) stubby plagioclase phenocrysts, typically 3 to 4 mm but as much as 15 mm long; and less abundant clinopyroxene. Near Ajax Peak, recrystallized to green-schist-facies assemblages. Appears to be restricted to base of formation.

## Klm - Lameshur Volcanic-Intrusive Complex, undivided (Lower Cretaceous)

Includes Water Island Formation and Careen Hill Intrusive Suite. Dominantly keratophyre and volcaniclastic rock derived from it, but includes basalt and basaltic andesite, and unknown volume of trondhjemite and gabbro, and minor chert. Several varieties of keratophyre distinguished by size and mineralogy of phenocrysts and mode of emplacement. Keratophyre occurs as lava flows, breccia, layered tuff, dikes, and small hypabyssal intrusive rock. In all varieties, quartz phenocrysts embayed, if present, and phenocrysts of plagioclase (albite as determined by Donnelly, 1963, 1966) and quartz form growth aggregates, either singly or together. Plagioclase phenocrysts not zoned or weakly zoned. Groundmass medium grayish blue (5PB 4/2) to medium dark gray (N4). Keratophyres become progressively lighter colored as content of albite phenocrysts and (or) weathering increases. Mafic rocks occur as pillow lava, pillow breccia, dikes, and rare small plutons. All rocks may exhibit local intense, deuteric, hydrothermal alteration, which may include silicification, oxidation, sulfidization, and development of boxwork textures and, locally, gossan. Named for locality of Lameshur on the southern coast of St. John. Mapped where size and mineralogy of phenocrysts vary over short distances and distraction between extrusive and intrusive rocks is not readily apparent.

## Lameshur Volcanic-Intrusive Complex, Careen Hill Intrusive Suite

Hypabyssal trondhjemite (Kct), coarsely porphyritic keratophyre (Kcc), intrusive equivalents of all keratophyre units of Water Island Formation, gabbro and sheeted dikes intrusive into the Water Island Formation or isolated on islands. No sequence of intrusion recognized. Except for some bodies of Kct

and Kcc, columnar jointing characterizes keratophyre and is used as one criteria for mapping these bodies as intrusive rocks. Larger keratophyre intrusive bodies form sharp, isolated hills along south coast of St. John and around harbor of Charlotte Amalie, St. Thomas. Name is taken from Careen Hill in Charlotte Amalie.

### Kct - Lameshur Volcanic-Intrusive Complex, Careen Hill Intrusive Suite, trondhjemite (Early Cretaceous)

Fine- to medium-grained, commonly porphyritic with quartz and twinned, non-zoned albite phenocrysts. Groundmass typically granophyric intergrowth between quartz and albite. Common granophyric intergrowths radiate from albite phenocrysts. Forms Leduck Island (where columnar jointing is prominent) and Flanagan Island. Also occurs as clasts in tuff breccia of Water Island Formation in eastern St. John. On Leduck Island, is light bluish gray (5B 7/1) and coarsely porphyritic with less well-developed granophyric texture in groundmass that contains subhedral albite and equant quartz. Grain size is about 0.1 mm. On Flanagan Island, is medium-bluish-white (5B 9/1); contains a few percent clinozoisite and chlorite.

### Kcc - Lameshur Volcanic-Intrusive Complex, Careen Hill Intrusive Suite, coarsely porphyritic keratophyre (Early Cretaceous)

Consists of 20 to 30 percent prominent quartz and plagioclase phenocrysts, typically 5 to 10 mm across. Groundmass varies from exceedingly fine grained, similar to extrusive keratophyre, to coarser grained, similar to extrusive keratophyre, to coarser grained with plagioclase laths up to 0.3 mm long. At higher metamorphic grade, coarse epidote appears in plagioclase phenocrysts and epidote, pale amphibole, and shreddy biotite appear in groundmass. Blue-green amphibole is in groundmass along Center Line Road at elevation of 320 ft. Widespread as dikes in Water Island Formation; cuts tonalite (Kct) of Flanagan Island. Plugs form sharp hills of Maria Bluff, northeast of Chocolate Hole and north of Cocoloba Cay.

*The unit Kcc is mapped as both an area (polygon) feature and a linear feature, and thus is present in both the Geologic Units (GLG) and Linear Dikes (DKE) feature classes in the GRI digital geologic-GIS data.*

### Kcp - Lameshur Volcanic-Intrusive Complex, Careen Hill Intrusive Suite, porphyritic keratophyre (Early Cretaceous)

About 20 percent conspicuous quartz and albite phenocrysts up to 3 mm across in a medium-dark-bluish-gray (5*B* 4/1), aphanitic groundmass of randomly oriented plagioclase laths 0.1 mm long, interstitial quartz, and magnetite dust. Accessory apatite and allanite. Glomerophyric plagioclase surrounded by granophyric intergrowths. Forms small unaltered plug west of Lameshur and sparse dikes.

### Kca - Lameshur Volcanic-Intrusive Complex, Careen Hill Intrusive Suite, phenocryst-poor keratophyre (Early Cretaceous)

May contain up to 10 percent small (generally less than 2 mm across) phenocrysts of quartz and plagioclase. Forms small pluton north of Bovocoap Point and sparse dikes.

### Kcf - Lameshur Volcanic-Intrusive Complex, Careen Hill Intrusive Suite, plagioclase-phyric keratophyre (Early Cretaceous)

Consists of 5 to 15 percent plagioclase phenocrysts, 1 to 3 mm long, in groundmass of typically felted plagioclase microlites and interstitial quartz. Forms small plutons on Ram Hill and on peninsula of Dittlif Point, and sparse dikes.

### Kcm - Lameshur Volcanic-Intrusive Complex, Careen Hill Intrusive Suite, gabbro (Early Cretaceous)

Dark-greenish-gray, fine-grained, porphyritic, with small (2 mm or less) subhedral phenocrysts of clinopyroxene and plagioclase in groundmass randomly oriented plagioclase laths about 0.5 mm long, clinopyroxene, chlorite, leucoxene, and opaque minerals. Forms intrusive body on Bovocoap Point; some mafic dikes in Water Island Formation are probably unit Kcm. May be more abundant than shown on map.

### Kcsd - Lameshur Volcanic-Intrusive Complex, Careen Hill Intrusive Suite, sheeted dike complex (Early Cretaceous)

Dominantly keratophyre, but includes diabase as well. Dikes trend north-east (as does the diagrammatic overprint pattern) and dip moderately to steeply northwest. Mapped southwest of Salt Pond and at Harbor Point. Better developed on St. Thomas than on St. John.

*The unit Kcsd is present in the Dike Swarms (DKS) feature class in the GRI digital geologic-GIS data.*

## Lameshur Volcanic-Intrusive Complex, Water Island Formation

Dominantly (80 percent) extrusive keratophyre and volcaniclastic rock derived from it, about 20 percent basaltic lava, breccia, and hyaloclastite, minor radiolarian chert. No internal stratigraphic order recognized. Groundmass of keratophyre commonly spherulitic. With increasing metamorphic grade to the north and east, spherulites are recrystallized and stand out as ovoids, some as large as 4 cm, on weathered surface. Lower contact of formation not exposed. Interpreted to have been deposited on oceanic plateau crust. Upper contact conformable and is exposed at several localities in southwestern St. John and nearly exposed south of Ajax Peak. Thickness at least 2 km. Several varieties of keratophyre distinguished by size and mineralogy of phenocrysts; all have intrusive equivalents in Careen Hill Intrusive Suite. Ash-flow tuffs notably absent.

### Kwp - Lameshur Volcanic-Intrusive Complex, Water Island Formation, porphyritic keratophyre (Lower Cretaceous)

Consists of 10 to 25 percent conspicuous quartz and plagioclase phenocrysts, typically less than 5 mm across, in aphanitic groundmass. Flow layering present locally. Mapped distribution is approximate; appears to constitute less than 10 percent of formation on St. John.

### Kwa - Lameshur Volcanic-Intrusive Complex, Water Island Formation, phenocryst-poor keratophyre (Lower Cretaceous)

May contain up to 10 percent small (generally less than 2 mm across) phenocrysts of quartz and plagioclase. Some rocks are aphyric on the scale of thin section. Many outcrops untextured but may display flow layering and flow folds. Includes lava, flow breccia, some bedded tuff, and some volcaniclastic rock. Dominant unit of Water Island Formation on St. John.

### Kwf - Lameshur Volcanic-Intrusive Complex, Water Island Formation, plagioclase-phyric keratophyre (Lower Cretaceous)

Consists of 5 to 10 percent plagioclase phenocrysts 1 to 3 mm long in groundmass that is commonly felted mass of oriented aphanitic feldspar laths. Flow layering visible in some outcrops. Exposed in vicinity of Great and Little Lameshur Bays. Because phenocrysts are small and sparse, some areas mapped as phenocryst-poor keratophyre (Kwa) could be Kwf.

### Kws - Lameshur Volcanic-Intrusive Complex, Water Island Formation, basalt and basaltic andesite (Lower Cretaceous)

Amygdaloidal pillow lava, pillow breccia, and hyaloclastite. Called spilite by Donnelly (1966). Na2O and CaO contents, however, are in the range of basalt. Pillows typically about 1 m across. Tubular bodies as long as 3 m have been observed. Amygdules commonly in concentric shells within pillows. Interstices between pillows and filled with calcite and epidosite. Bedding and topping direction determined from pillow asymmetry at Harbor Point, peninsula between Elk Bay and Haul Over, and eastern Red Point, all in eastern St. John. Bedding, but no topping direction, observed at several other localities. Excellent exposures of pillow breccia and hyaloclastite found in coastal outcrops between Saltpond Bay and Ram Head and on Dittlif and Contant Points. Fragments of breccia are commonly deformed against one another. Groundmass of least altered basalt consists of plagioclase microlites (typically randomly oriented) and opaque dust in a cryptocrystalline mesostasis. Small (millimeter range), sparse phenocrysts of glomerophyric plagioclase and clinopyroxene. Epidosite segregations common and, in places, pillows have epidosite cores. Secondary minerals in southern St. John include prehnite and pumpellyite (identified optically only), chlorite, calcite, and leucoxene. Zeolites probably the result of burial metamorphism. To the north and east toward Tertiary plutons, pale amphibole and finally pleochroic amphibole appear in groundmass. Clinopyroxene replaced by epidote and pale amphibole; farther north by pleochroic amphibole. Metamorphic assemblage adjacent to tonalite at Please horizontal control marker, north of More Hill in eastern St. John, includes quartz, plagioclase, hornblende, diopside, garnet, and calcite. Most basalt, including breccia fragments, is amygdaloidal; some is scoriaceous (amygdules a few millimeters across make up 30 or more percent of rock). Flattened amygdules in Kiddel Point are as long as 10 cm. Amygdules filled with combinations of quartz, calcite, chlorite, epidote, and plagioclase, as well as local prehnite and pumpellyite; at higher grade, filled with pale amphibole and clinozoisite in radiating sheaves.

### Kww - Lameshur Volcanic-Intrusive Complex, Water Island Formation, volcanic wacke and bedded tuff (Lower Cretaceous)

Volcanic wacke consists of subrounded to angular clasts of keratophyre of all varieties, basalt, and trondhjemite in a matrix that is probably comminuted keratophyre but includes xenocrysts of quartz and plagioclase. Constituents poorly sorted and up to more than 1 m across; bedding may be poorly sorted and up to more than 1 m across; bedding may be poorly defined. Graded bedding rare but present. Pumiceous keratophyre clasts rare except between Grootpan and Kiddel Bays where submarine pumice flows may be present. Trondhjemite clasts up to boulder size, thought to be from Kct, found in cove 250 m northeast of Long Point and easternmost Privateer Point. Bedded tuff locally; no shards seen in the few thin sections available. Difficult to distinguish between tuff and chert in the field.

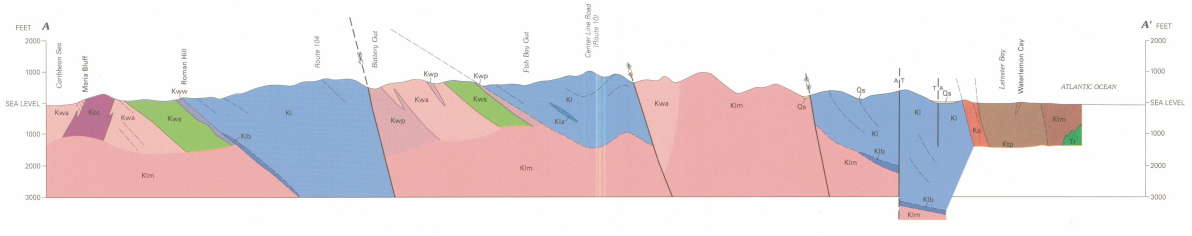
### Kwr - Lameshur Volcanic-Intrusive Complex, Water Island Formation, radiolarian chert (Lower Cretaceous)

Light-blue-gray to dark-gray, bedded chert containing Radiolaria. Mapped where Radiolaria have been observed, such as at Kiddel Point on the shore of Saltpond Bay.

# Geologic Cross Sections

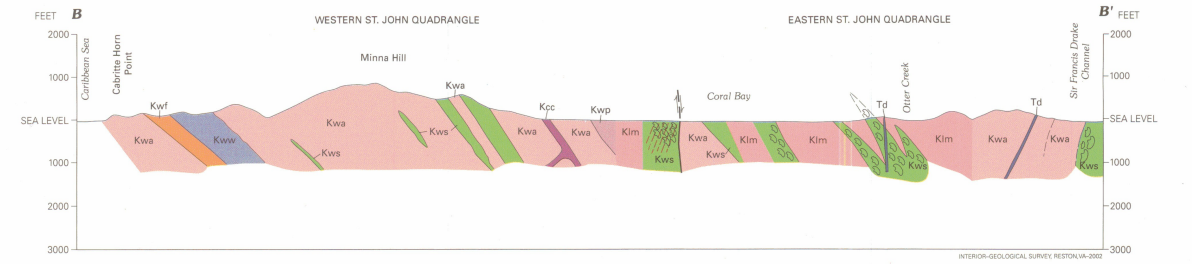
The geologic cross sections present in the GRI digital geologic-GIS data produced for Virgin Islands National Park, Virgin Islands (VIIS) are presented below. Cross section graphics were scanned at a high resolution and can be viewed in more detail by zooming in (if viewing the digital format of this document). Cross section lengths are not to scale relative to one another as to display each graphic in the width of the document page Cross Section A-A' was shortened more than Cross Section B-B'.

## Cross Section A-A'




*Graphic from source map:* Virgin Islands Geology (St. John)

## Cross Section B-B'




*Graphic from source map:* Virgin Islands Geology (St. John)

# GRI Ancillary Source Map Information

The following section presents ancillary source map information associated with source used for this project.

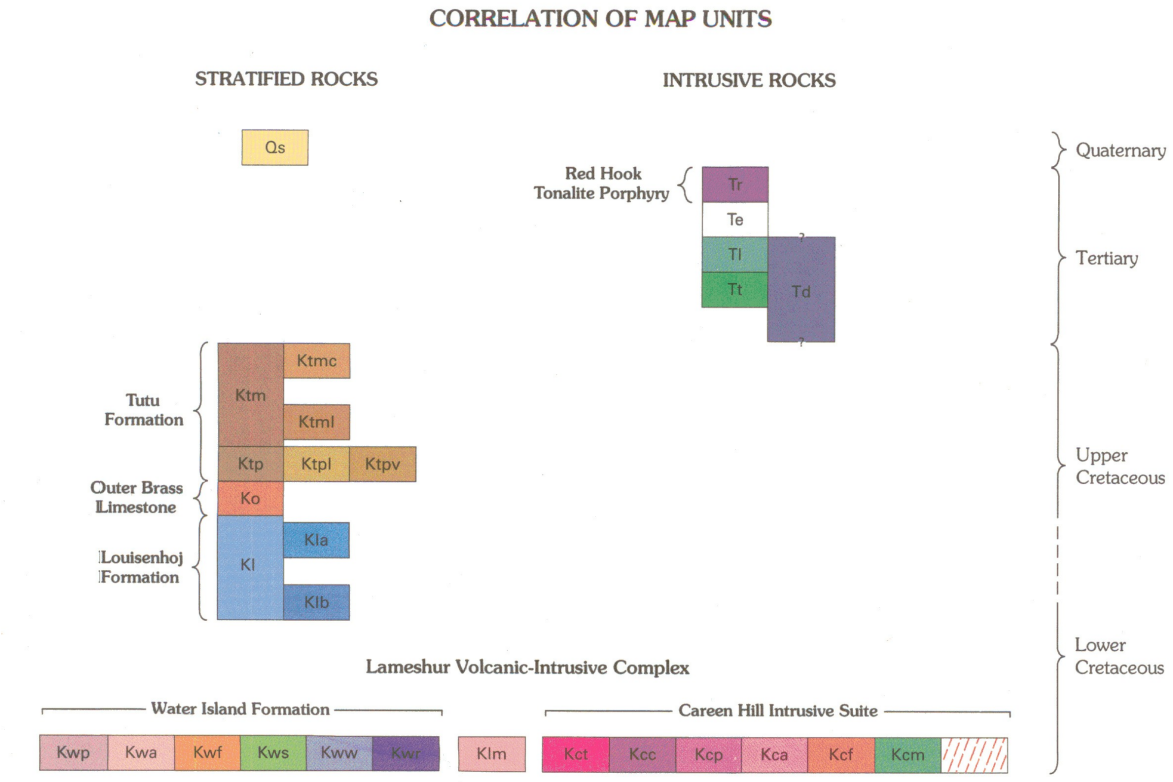
## Virgin Islands Geology (St. John)

The formal citation for this source.

Rankin, D.W., 2002, Geology of St. John, U.S. Virgin, Islands: U.S. Geological Survey, Professional Paper 1631, scale 1:24,000 (*GRI Source Map ID 4071*).

Prominent graphics and text associated with this source are presented below.

## Correlation of Map Units




*Graphic from source map:* Virgin Islands Geology (St. John)

## Explanation of Map Symbols

### EXPLANATION OF MAP SYMBOLS

[Where two or more symbols for planar or linear features are combined, their intersection marks the point of observation. Where a single planar feature and a single linear feature are combined, the center of the planar feature marks the point of observation. For a linear symbol alone, the base of the arrow marks the point of observation.]

**Contact**—Dashed where approximately located; dotted where concealed

**Faults**—Tick shows dip where known. Dashed where approximately located; dotted where concealed

**Ductile fault or local shear zone**




**Brittle fault**—Sense of movement shown if known. Strike-slip motion shown by arrows, or T (toward) and A (away) in cross section. For dip-slip motion: U (up) and D (down)



**High-angle reverse fault**—Teeth on upper plate

#### FOLDS



**Anticline**—Showing trace of axial surface



**Syncline**—Showing trace of axial surface

#### MINOR FOLDS

[May be combined with planar features]




**Bearing and plunge of fold axis**




**Bearing and plunge of sinistral fold**




**Bearing and plunge of dextral fold**

#### PLANAR FEATURES

**Strike and dip of bedding**—Ball indicates younging direction of beds known from sedimentary features: graded bedding; crossbedding; channelling




Inclined



Vertical




Overturned



Horizontal



Generalized strike of vertical bedding

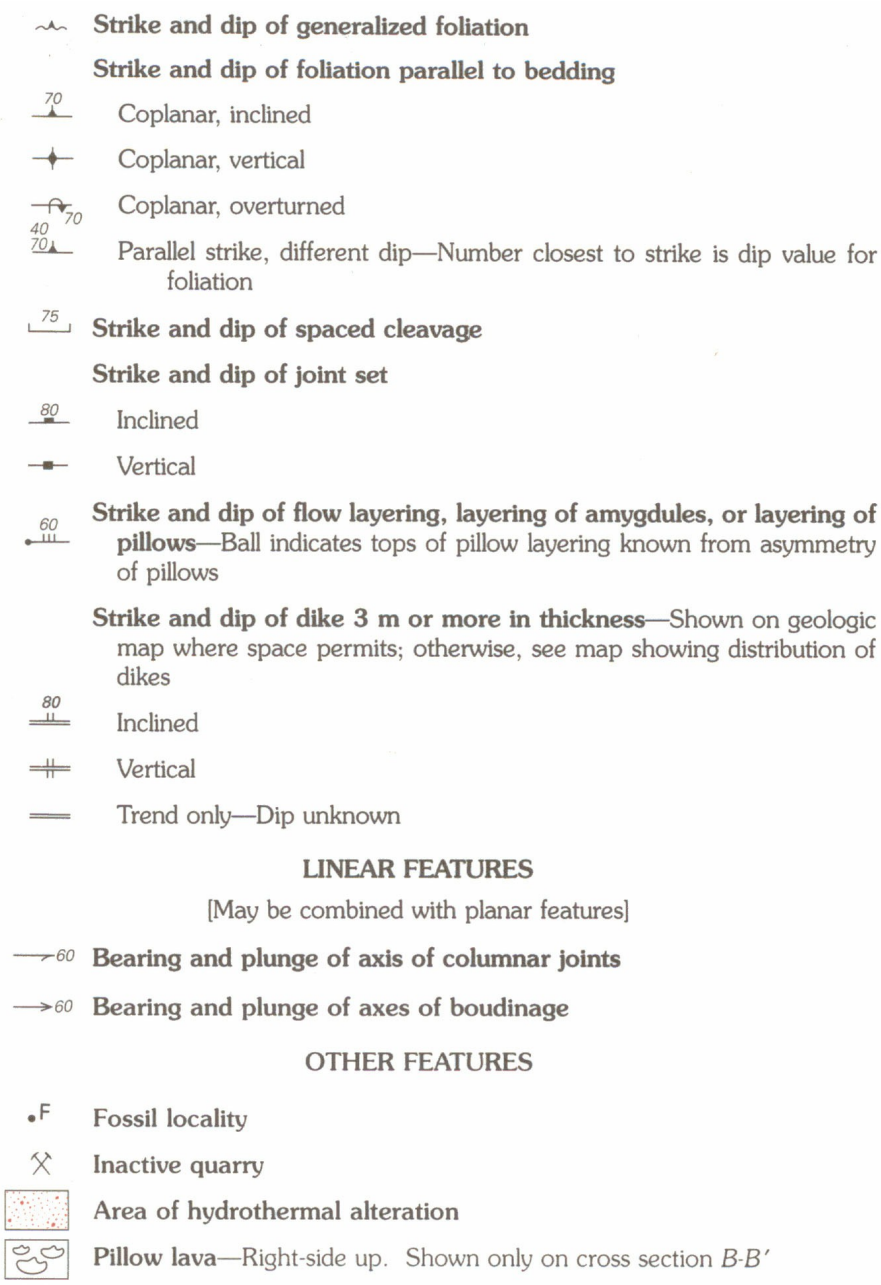
**Strike and dip of foliation**




Inclined

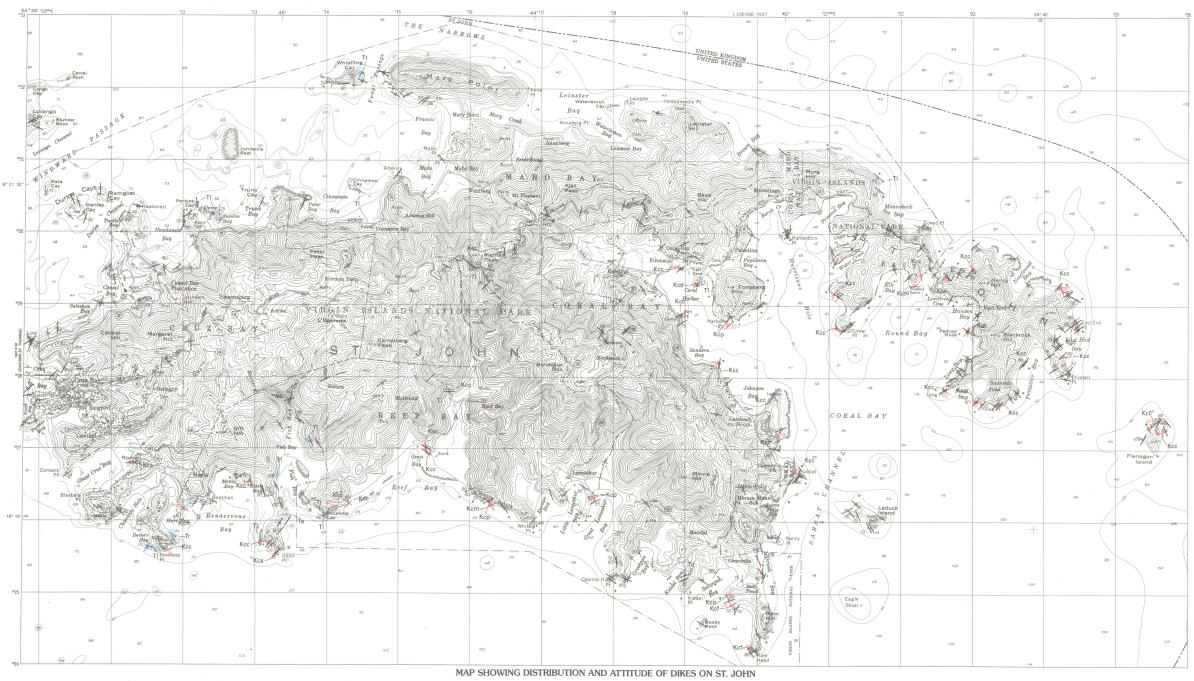


Vertical




*Graphic from source map:* Virgin Islands Geology (St. John)

## Map Showing Distribution and Attitude of Dikes on St. John




MAP SHOWING DISTRIBUTION AND ATTITUDE OF DIKES ON ST. JOHN

*Graphic from source map:* Virgin Islands Geology (St. John)

*Dikes present on the above map are present in the Linear Dikes (DKE) feature class in the GRI digital geologic-GIS data. Attitude observations associated with dikes present on the above map are present in the Geologic Attitude Observation Localities (ATD) feature class in the GRI digital geologic-GIS data.*

## Legend for the Map Showing Distribution and Attitude of Dikes on St. John

**EXPLANATION**

**Strike and dip of dikes**—For some dikes, only strike is shown because dip cannot be measured. For unit name, see classification of dikes

80 — Strike and dip of inclined dike 3 m or more thick

Strike and dip of vertical dike 3 m or more thick

80 — Strike and dip of inclined dike less than 3 m thick

Strike and dip of vertical dike less than 3 m thick

**Classification of dikes**

Tr — Red Hook Tonalite Porphyry

Te — Explosion breccia

Tl — Hornblende lamprophyre

Tt — Tonalite

Td — Diabase, gabbro, and diorite—Mapped as Td on geologic map

Careen Hill Intrusive Suite (no sequence of intrusion implied)

Kct — Trondhjemite

Kcc — Coarsely porphyritic keratophyre

Kcp — Phenocryst-poor keratophyre

Kcf — Plagioclase-phyric keratophyre

Kcm — Diabase

*Graphic from source map:* Virgin Islands Geology (St. John)

## Index Map




*Graphic from source map:* Virgin Islands Geology (St. John)

## Report

The paper (report) associated with the source publication is available as an embedded document within this document. Double-click the following link to open the report: P1631-paper_report.pdf

The contents of the report are shown below. Note that the description of map units (Appendix A) has been extracted from report, and is also presented in this document in the Map Unit Descriptions section.

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*Graphic taken from source map paper/report:* Virgin Islands Geology (St. John)

## GRI Digital Data Credits

This document was developed and completed by Stephanie O'Meara (Colorado State University) for the NPS Geologic Resources Division (GRD) Geologic Resources Inventory (GRI) Program. Quality control of this document by Stephanie O'Meara and James Winter (Colorado State University).

The information in this document was compiled from the source map, and is intended to accompany the digital geologic-GIS map and other digital data for Virgin Islands National Park, Virgin Islands (VIIS) developed by Stephanie O'Meara and Georgia Hybels (Colorado State University) (see the GRI Digital Map and Source Map Citation section of this document for all sources used by the GRI in the completion of this document and related GRI digital geologic-GIS map).

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