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ON THE GEOLOGY OF THE NORTH-EASTERN WEST INDIA ISLANDS

BY

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WITH 2 PLATES.

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The following pages contain some of the scientific results of a geological voyage in the northeastern West-Indian Archipelago, which I made in the winter 1868—69. I expected that this part of the West-Indies would offer the greatest geological variety, as two different lines of elevation cross each other there. For this reason I visited first the Virgin Islands, and proceeded afterwards to S:t Bartholomew and the surrounding islands of Anguilla, S:t Martin, Saba, S:t Eustatius and S:t Kitts. In Puerto Rico I had hopes of meeting united the different geological formations, that I had studied in the smaller islands, and I had a great wish to explore that large and beautiful island, but the short time, I was able to stay in the West-Indies, and the many difficulties in the geological study of a large and mountainous tropical island without any good topographical map, did not allow me to get more than a very incomplete acquaintance of the geological structure of this island.

As I have not yet had time for a careful study of my collections of fossils, I reserve the paleontology for a future communication and here treat only of the geology, the mineralogy, and the petrography of the West-India islands.

All the measures of the hight of the mountains or the extent and situation of the islands, given in this treatise, are taken from the maps published by Messrs LAURENCE, PARSON and BARNETT as well as from some Danish Maps.

I have added to my own observations a short summary of the geology of the other parts of the West-Indies, as far as it is known from publications.

I. Virgin—Islands.

The group of islands east of Puerto Rico is called the Virgin Islands; they have a general direction from west to east. The largest among them are *Culebra, Crab Island, S:t Thomas, S:t John, Tortola, Virgin Gorda* and *Anegada.* Beside those larger islands are more than fifty smaller islets or cays. The sea between the islands and Puerto Rico is generally only 30—50 metres deep, but at a short distance north and south of the archipelago the bottom is not reached for several hundred metres. The islands may consequently be regarded as the summits of a submarine chain of mountains, continued to the

westward by Puerto Rico and the greater Antilles. The geology of those islands is very little known. A general account of them was given in 1837 by ROB. SCHOMBURGK*) and S:t Thomas was described by Dr HORNBECK**) in 1840.

1. *S:t Thomas,* situated at 18° 20′ 40″ N. Lat. and 64° 55′ 38″ Long. fr. Greenw. (at the town of Charlotte Amalia) is narrow and its greatest length from east to west is about 22 kilometres. From north to south S:t Thomas is scarcely more than from 3 to 6 kilometres in breadth. The middle part of the island forms a tolerably high ridge, with summits of 470 met. above the sea-level. The ridge is highest north of John Bruce Bay and slopes gradually to the west and east, branching off in two low series of hills. The north side dips down more suddenly in the sea, than the more hilly southern part. Fresh water is very scarce, most of the rivulets being periodically dried up; the only permanent spring is near Lilljendal. Along the coasts, especially on the south side, are several shallow lagoons with brackish water. The nature of the rock, of which the greatest part of the island consists, may easily be studied in the harbour of CHARLOTTE AMALIA. It is a conglomerate, called by the inhabitants »*Bluebeache*», and is sometimes found distinctly stratified. Its colour is a dark bluish-green. This conglomerate or breccia consists of angular pieces of dark porphyry or felsite and also rounded scoriacious stones with the cavities commonly filled by quartz or calcarious spar. The cementing part of the stone has a dark greenish colour, probably derived from decomposed hornblend. In the harbour near the fort and on the small cay of *Prins Rupert* the rock forms regular strata of half a metre in thickness. Their strike it S. S. E. — N. N. W. and dip 30° to the E. N. E. The rock has evidently been exposed to a strong metamorphic action so that the stratification in most other places can scarcely be seen. In the town and near *Fredriksberg* the rock is very hard and solid, often penetrated by veins containing white quartz, calcarious spar and some epidote or pyrites. On the high ridge in the middle of S:t Thomas several interesting varieties occur, resembling diorite or syenite. Where the rock is more fine-grained it has a great resemblance to trap. The latter variety occurs in the hills north of *Mosquito-Bay,* where it has a beautiful concentric spheroidal structure, visible when the surface has been exposed to atmospherical action. Some of the globules are ½—1 metre in diameter. Through alteration the rock is sometimes decomposed into a white clay, called marl, as near *Altona.* The rock is often penetrated by dikes of felsite or diabase. The ocurrence of scoriacious pieces in the conglomerate indicates its volcanic origin and the stratification, as well as some large limestone-nodules with fossils found in one spot, proves that the material is heaped under the sea. Near *John Bruce Bay* the conglomerate has a red or brownish colour and contains many smaller scoriacious pieces. The hills and mountains in the western part of the island consist of bluebeache and the same rock also occurs east of the town often associated with large masses of felsite, as near *Donoë.* The bluebeache seems to me to be at least 2,000 metres thick. Near *Löwenlund* on the north

*) Die Jungfrau Inseln in Geologische und Klimatologische Hinsicht in BERGHAUS Almanach für Erdkunde 1837 p. 366.

**) Nogle bemærkninger over S:t Thomas' geognosie. Skandinav. Naturforskere andet Möde 1840 p. 364. (Kjöbenhavn 1841).

side of the island there are almost vertical strata of black clay-slate. One can trace the stratum to the *North-side Bay*, where it is covered by a loose clay, containing shells of living species. It continues towards the east to *Mandal* and is seen near *Coki Point*. The clay-slate bears a perfect resemblance to silurian slate, but I have not been able to find any trace of fossils in it. In some places the rock is associated with limestone nodules, containing pieces of bluebeache-conglomerate. In the coast-cliffs by *Tutu-Bay*, north of the clay-slate band, is to be seen a regularly stratified rock dipping 70° north and striking east to west. In the cliff west of *Tutu-Bay* the strata are almost vertical, and in the point between *Tutu-Bay* and *Mandal-Bay* the dip is southerly. The rock is composed of smaller granules or pieces of a gray compact felsite, bedded together to a sandstone-like flagstone. When the rock is fine-grained it resembles clay-slate of a light colour. In the large branch north of *Bucks Bay* occur bluebeache, black and sometimes metamorphosed clay-slate and flagstones alternating. Near *Coki Point* the bluebeache conglemerate appears again, but here it contains large masses of calcarious nodules and marble of a white or gray colour. The limestone occasionally contains fossils, mostly in a very bad state and sometimes silicified. The most common are *Nerinæa* and fragments of a large *Bulla* or *Acteonella*. Beside those fossils I have found an *Ammonite*, *Trochus*, *Pectunculus*, *Limopsis*, *Opis*, *Venus*, *Astarte*, *Corbula* etc. Some of them have a remarkable affinity to cretaceous species, and I have no doubt that the rocks of S:t Thomas and the other Virgin Islands are of the cretaceous age.

The *Favosites Dietzii* and *S:t Thomæ* Mich. Duchas*) are said to have been found on the spot, but I have not found any fossil of paleozoic appearance near Coki Point. The *Favosites Dietzii*, of which I recieved one silicified specimen from Mr DIETZ of S:t Thomas, is scarcely different from the silurian F. FORBESI, and, when I dissolved the specimen in hydrochloric acid, I found some other silicified fossils, fragments of small brachiopode-shells and encrinite-stalks etc. There is no doubt that the *Favosites Dietzii* is of paleozoic origin, and I can scarcely believe that this coral is found in the West-Indies.

Following the coast from *Coki Point* to *Red Hook* one meets with another kind of rocks, often distinguished at a distance by its red colour. It occurs in *Cabrite Point* and along the southern shore of *S:t Thomas*, by *Long Bay* and *Coculus Bay* to the entrance of the harbour. It continues in *Water Island*, *Regis Point*, *Mosquito Bay Point* and *Red Point*, but does not extend west of the latter spot. The chief component of this rock is felsite or a mixture of quartz and feldspar. In different places it has a variable appearance. At *Red Point* it is a breccia or conglomerate, sometimes so fine-grained, that the rock resembles chalk or domite. At *Mosquito-Bay Point* and at *Regis Point* it is a hard, compact rock of a beautiful basaltic structure. Near *Coculus Bay* and on the small *Grass Cay* the rock contains quartz in pyramids and is a kind of quartz-porphyry. In some other places, smaller feldspar-crystals occur in a homogeneous mass, and the rock is then a kind of felsite-porphyry. The rock produces by alteration a kind of white clay or kaolin often penetrated by veins or fissures filled with red or brownish-red hydrate of iron and

*) Mem della Acad. dell. Scien. di Torino II Ser T. XIX pag. 84. 1860 and. T. XXIII (1866) pag. 199.

manganese. At the southern point of *Water Island* the felsite rests upon bluebeache. In some parts of the island diabase occurs. Thus the felsite at *Red Point* is traversed by a dike of diabase of spheroidal structure. Near *Coki Point* the bluebeache is penetrated by a dike of augitic-porphyry, a black fine-grained rock with crystals of augite.

The whole surface of the island is covered by a quantity of angular stones, large boulders or a more fine-grained detrital mass, formed by alteration of the surface-rock. In those newer beds occur several shells of still living species of terrestrial mollusca and also shells of an extinct species, the *Helix incerta* Fér, closely related to the *Helix notabilis* Sh. living in Tortola.

A recent clay deposit of marine origin occurs on the north side, near *Buck's Bay*. It is a plain overgrown by *Coccoloba, Cocos,* etc., and scattered over the surface occur many shells of still living species. I found on the spot *Ostrea Frons* Lin, *Cardium muricatum* Lin, *Donax denticulatus* Lin, *Mytilus exustus* Lin, *Arca umbonata* Lamk, *A. lactea* Lin. *Murex brevifrons* Lamk and *Oliva reticularis* Lk.

2. *Smaller islands around S:t Thomas.* S:t *Thomas* is surrounded by several small islets. To the west lies *Cabrita* or *Savana Island*, which I have been very near. It seems to be a bluebeache rock. *Little Saba* south of S:t Thomas is believed to have been a volcano, but this is not correct, the rock being of the same kind as at Red Point, or a fine-grained felsite, sometimes altered to kaolin. *Flat Cay,* between Saba and S:t Thomas, is a small rock of a coarse felsitic breccia. *Water Island* consists of a compact yellowish-brown felsite mixed with spots of quartz. At the southern bluff the felsite rests upon bluebeache. *Buck's Island* is a low island, south of S:t Thomas. The rock is a light coloured diorite resembling syenite and penetrated by numerous dikes of diabase or granular granite.

The diorite is composed of triclinic feldspar, black hornblend and some green talc or mica. It contains nodules of epidote. The rock is massive and has a distinct spheroidal structure. The diabase is black and fine-grained and sometimes contains crystals of augite or nodules of compact epidote. The granular granite is a mixture of feldspar (oligoklase), glassy quartz in pyramides, and hexagonal leaves of greenish mica or talc. In one spot I have seen the granite intersecting dikes of diabase.

Sketch of *Bucks Island* from E. S. E. Diabasdikes intersecting diorite.

S:t Jame's Island seems to consist of bluebeache and felsitic breccia, penetrated by very altered trap-like rocks. I have only visited *Little S:t James Island.*

North of S:t Thomas, and, connecting the Tutu Bay Point with *Whisling Cay* and *Mary's Point* in *S:t John's,* is a band of long and narrow islets: *Thachts Cay, Grass Cay, Singo Cay, Levango Cay* and *Congo Cay.*

They consist of more or less altered clay-slate or flagstones, which are stratified, striking E—W and dipping 70° to the north. *Congo Cay* north of *Lovango-Cay* is a ridge

of beautiful, hard and crystaline limestone or marble, of a bluish-gray colour and parallelopipedic structure.

The sketch is taken from S:t John.

Hans Lollik. North of S:t Thomas are two smaller islands called Hans Lollik. The rock is a hard and compact dark green diabase with crystals of augite and sometimes impregnated with magnetic pyrite. No trace of stratification is visible, but the structure of the rock is distinctly parallelopipedic.

West of Hans Lollik are two smaller islets *Inside Bras* and *Outside Bras.* Neither of them was visited by me, but I have sailed very close by them. The former islet seems to be composed of bluebeache rock; in the latter stratified rocks occur, striking E—W and dipping at an angle of 70° to the north. I have not landed at the small islets N. W. of S:t Thomas, the *Cockroach Islands* and *Dutch-man Cape,* but I have passed very near *Salt Cay* and *West Cay,* which are probably bluebeache-rocks.

3. *Culebra* or *Passage Island* is a Spanish possession about 20 kilometres from S:t Thomas. The island is uninhabited and covered with a thick vegetation of prickly shrubs, cacti, etc., almost impossible to penetrate. The island is not very high, being only 198 metres above the sea, and, to judge from the rocks on different parts of the coast, entirely composed of a dark-gray or brown labrador-porphyry. I have seen a darkgreen trap-like rock only on the small island of *Culebrita.* The labrador-porphyry has a fine spheroidal polygonal structure, so that the seacliffs look as if they were constructed of large polygonal boulders. The rock is traversed by numerous veins, containing white quartz and often beautiful transparent rock-crystals. Sometimes the veins are filled with calcarious spar and epidote, or a green or red quartz, or iron-silex.

4. *S:t John,* situated at a short distance from S:t Thomas, is, like the other Virgin-Islands, most extended from east to west, or about 15 kilometres. Its greatest breadth is about 7 kilometres. The south-eastern point of S:t John forms a triangular promontory, and the north-eastern a long, narrow head-land, between which lies the large and beautiful Coral Bay. On the northern coast there is a promontory called *Mary's Point,* which is connected with the island by a low and narrow isthmus. The whole island is mountainous and consists of branching ridges, separated by narrow and deep vallies of delightful beauty. The highest point is the *Camel Peak* in the centre of the island. It reaches an elevation of 373 metres above the sea and *Bordeaux Peak* near the middle of the western coast is almost equal in hight. Permanent springs are rare, as are also lagoons near the shores, as the rocks commonly dip down abruptly into the sea. The geology of the island bears a great resemblance to that of S:t Thomas, of which S:t John is a continuation. The middle part of the land consists of the same green conglomerate as in S:t Thomas; the southern hills with their shining red sea-cliffs are composed of felsitic rock, and in the northern part stratified metamorphic rocks are visible.

The small flat cays near *Cruz Bay* are bluebeache-rocks and *Cruz Bay* is also built upon the same kind of rock, which extends southwards to *Marie Bluff*, where felsitic rocks commence. At the point east of Marie Bluff the felsite is interrupted by a dark-coloured amygdaloid trap. The felsite extends to *Ram's Head*, and the small *Duck's Island**) at the opening of Coral Bay seems also to be composed of a felsite of basaltic structure. The large branch north of Coral Bay consists of different kinds of rocks, principally of felsite, often with a kind of slaty cleavage and interrupted by trap-like rocks. The same slaty felsite, graduating to fine-grained mica or talc-slate is visible by the Moravian Church near *Caroline Estate* in almost vertical strata, striking east to west. On Caroline-Estate the rock is hard, compact, felsitic stone, in which lighter coloured spots indicate the original stratification. The hills around Caroline Estate are, to judge from the very altered surface, stratified slaty rocks. Near the coast south of Caroline Estate black clay-slate occurs. Near *Mount Pleasant* occurs bluebeache; it continues to *Little Maho Bay* and the whole way to *Cruz Bay*. The bluebeache conglomerate has some trace of stratification. The strata are almost vertical and strike E—W. The surface of the rock is very denudated, and sometimes table-like, vertical parts of strata, often of considerable size, project from the ground, as north of Cruz Bay. On the shore near Little Maho Bay are regular strata of a black clay-slate striking E—W. and dipping to the north. Around the path-way near Maho Bay are many loose fragments of a gray, crystaline limestone. The latter rock is visible »in situ» near *Anna Bay*, where it contains some *Wollastonite* in long and flat crystals. The limestone is enclosed between strata of various rocks, mostly clay-slate, impure calcarious silex, hornblend or garnet rocks. These rocks form the small *Whisling* cay and a part of *Mary's Point*. They are often intersected by diabase dikes, and contain much garnet and epidote, and smaller veins or fissures filled with desmine and calcarious spar. Some of the hornblend-rocks graduate into diorite. In the north part of *Mary's Point* is a large mass of syenite-like diorite, which rock is also visible near *Brown's Bay*. The rock is a middling coarse granular mixture of white lime-oligoklase (Hafnefjordite), black hornblend and black or bronze-coloured mica. Near *Brown's Bay* the diorite-mass separates into branching and anastomosing veins and dikes, that run into the surrounding rocks. The diorite contains some epidote, brown garnet, small yellow crystals of spén, and, on the fissures, desmine or quartz and feldspar. The rock also contains traces of copper. Near *Menuebecks Bay* stratified rocks are visible among the seacliffs. They strike E—W and dip 60° to the south. South of Menuebecks Bay are felsitic and trap-like rocks, containing white quartz with spén and titanitic iron.

5. *Tortola* is an island of about the same size as S:t Thomas and extends from east to west. It is mountainous and the highest peak *Mount Sage* reaches 543 metres above the sea. The mountains are generally very steep and the rock in the middle of the island is bluebeache as in S:t Thomas. At the east-end diorite occurs, and from *Buck's Island* to *Brandwine Bay* the cliffs along the shore are composed of a dark, fine-grained, amphibolic and micaceous stratified rock. West of the *Seacow Bay* occur stratified metamorphic rocks of an occasionally garnetiferous silicious limestone. The common strike of

*) I did not go ashore on the island, but passed very near to it.

the rocks is east to west and the dip is almost vertical or somewhat to the south. Near the Seacow Bay are found some small veins of copper-ore. Near *Coxheat* occurs a fine-grained black clay-slate of the same kind as the slate in S:t Thomas. The south-western part of Tortola consists of a ridge of hard crystaline limestone, sometimes containing brown garnets. The rock does not contain fossils and continues through the hill near Coxheat. At the shore below Coxheat, according to Mr SCHOMBURGK, diorite is found. North of the limestone-ridge of the west-end are stratified flagstones with garnet, epidote and specular iron. Near *Belmont* the strata are penetrated by veins of quartz or pegmatite granite. At that place the strike of the strata is E—W. and the dip about 45° to the south. West of *Cappoon Bay* a dike of diorite is visible; it has a direction from N—S., and east of the same place are dark stratified rocks containing scoriæ and graduating into bluebeache. The latter have the strike E. N. E. — W. S. W. and dip 70° to the south. The bluebeache extends over the centre of the island and has the same appearance as in S:t Thomas. It is often intersected by large veins of quartz, coloured by iron, and sometimes containing smaller laminæ of black specular iron. Such a vein extends across the bay between *Buck's Island* and *Beef Island,* another is visible near *Road Town.* It is not improbable that gold may be found in these veins. I have not visited the north side of the island, except the coast opposite to Guana-Island. At this place the rock is felsitic.

6. *Smaller islands around Tortola. Sandy Cay* is a small rock between Tortola and *Iost van Dyck.* Most of the island is covered with shell-and coral-sand. The rock is a dark, trap-like mass, not stratified, with crystals of hornblend and quartz in veins or nodules. It has a parallelopipedic structure and seems to me either a variety of the rock near Cappoon Bay in Tortola, or diabase.

Iost van Dyck is a tolerably large island, 326 meters in hight. I have only visited the middle part of the southern coast, where I found bluebeache-conglomerate.

Great Tabago, west of Iost van Dyck, is a small island, the northern part of which is composed of a kind of dark felsitic conglomerate, and in the southern parts there are stratified flagstones striking E—W. and dipping 70° southwards.

Little Tabago, between Great Tabago and Hans Lollik, is a rounded rock, very hard and not stratified. Its colour is dark and it may be perhaps a continuation of the diabase-mass of Hans Lollik.

Great Thacht Island near the west end of Tortola is a high ridge and a continuation of the strata of the latter island. The middle of the island is a continuation of the crystaline limestone of Tortola. The rock is very hard, does not contain fossils, and has a distinct parallelopipedic structure. North of the limestone-rock are almost vertical metamorphic strata. On the small promontory opposite to Mary's Point also occur stratified flagstones, penetrated by a vein of pegmatite.

Little Thacht Cay, near the west end of Tortola, is a stratified and garnetiferous silicious limestone-rock. Its strike is E—W. and dip southerly.

Frenchman Cay has about the same geological structure as Little Thach Cay. The strata strike E. N. E. — W. S. W. and dip to the south.

Buck's Island, near the east end of Tortola, is a small islet of stratified, amphibolic, and micaceous dark-gray rock. The strata strike N. W. — S. E. and dip to the S. W. about 45°.

Beef Island is separated from the eastern end of Tortola by a shallow strait. It has a length of 4 kilometers. The highest point is 201 meters. The rock of the island is diorite. Only in the west end some trap-like rocks occur, and in the south-eastern corner is to be found an interesting variety of diorite, composed of hornblend, anorthite and magnetic (titaniferous) iron-ore. The anorthite-diorite has a dark colour and a beautiful spheroidal structure, so that the mountains in some spots seem to be built of large polygonal boulders, between which there are numerous veins of quartz or granite. The granite is a pegmatite of white oligoklase, red orthoklase, half-transparent quartz and bronze-coloured mica. It contains crystals of epidote, nodules of prehnite, rock-crystals and a little magnetic iron. It can scarcely have been an eruptive rock. The oligoklase-diorite resembles the diorite of Mary's Point in S:t John and of Virgin Gorda. I cannot exactly say if the anorthite-diorite is only a local variety of the diorite, or if it forms a large dike in the diorite. The former seems to me more probable.

Scrub Island, near Beef Island, is long and narrow, reaching the hight of 137 meters above the sea in the eastern part. The west end of the island contains felsitic rocks of a gray or greenish colour, and in the eastern part are dark, not stratified, trap-like rocks sometimes of porphyritic appearance and sometimes resembling a conglomerate. Between Scrub Island and Beef Island lies a small cay, the *Dog,* of a dark crystaline rock, perhaps anorthite-diorite.

Great Camanoë, near Scrub Island, has the length from N to S, of 4½ kilometers. The mountains reach the hight of 162—172 meters above the sea. The southern point, the only part of the island I visited, is formed of a yellowish-gray felsitic rock, which contains some hornblend. The northern part probably consists of bluebeache.

Little Camanoë seems to be a felsitic rock.

Guana Island north of Tortola has the hight of 247 meters. I have only landed on the southern coast, where the cliffs are composed of a kind of felsite. The rock is dark and conpact, somewhat variolitic, and shows some traces of stratification. The strike seems to be E—W and the dip to the south. Judging from the colour of the seacliffs the northern part of the island seems to contain bluebeache.

7. *Virgin Gorda* is a long and narrow island, extending from east to west to the lenght of about 16 kilometers. The southern part is full of low hills, but in the middle of the island is a mountain called *Virgin Peak,* rising to the considerable hight of 418 meters. The northern part is a very long and narrow branch of this mountain. One may easily distinguish three kinds of rock in Virgin Gorda, viz: diorite in the south, quartzite or metamorphic sandstone in the middle, and felsite in the northern part. The diorite is a middling coarse granular mixture of white lime oligoklase, black hornblend and some mica. The rock has no stratification, but a beautiful spheroidal structure. The surface of the rock is covered with a great number of loose round boulders, sometimes as large as small houses. They are nothing but the harder diorite balls, which have resisted the denudating action, when the softer diorite-mass between them has been swept away. The

diorite contains a large number of veins with the general direction from N—S. They are filled with white, sometimes crystaline quartz, sometimes with carbonate of iron and contain native copper, and gray, red, yellow or green copper-ore and molybdena. They have formerly been worked in the south-eastern corner of the island, where there are some smaller mines.

North of the diorite is a mass of quartzite, very hard, dirty coloured, fine-grained and broken on the surface in angular pieces. It seems to have been a kind of sandstone, but no stratification is visible. Near *Plum Bay* I have found a small mass of a dark trap-like rock, probably anorthite-diorite. Along the coasts af *Long Bay* are gray felsitic rocks, containing some hornblend. The rocks on the shores at the *Sound* are also felsite. In the latter place the rock has a yellowish-gray colour and a distinct parallelopipedic structure; it is very hard and crystaline and contains a little hornblend.

8. *Smaller islands around Virgin Gorda.* North of Virgin Gorda are three smaller islands *Necker Island, Prickly Pear*, and *Mosquito Island.* In the west end of *Necker Island* are very altered porphyritic rocks and in the east end occur strata of tufflike conglomerates and breccia. The strata strike N. W. — S. E. and dip about 30° S. W. In the southern part of the island are large quantities of coral-and shell-sand, overgrown by Coccoloba, Cactus etc. *Prickly pear.* In this island the rock is a kind of greenish claystone, without distinct stratification and probably a variety of Bluebeache. I did not land at Mosquito Island, but I passed very close by it and to judge from the dark-green colour of the seacliffs the rock seems to be bluebeache. The small islets of »Saeldog» seem also to be bluebeache rocks.

Between Tortola and Scrub Island there are some smaller cays, the *Dog Islands,* of which I only visited the *George Dog.* The latter cay is a rock of granite-like felsite and the others seem to be the same.

9. *Smaller islets between Virgin Gorda and S:t John.* In a direction from N. E. to S. W. extend from Virgin Gorda to the south-eastern corner of S:t John a row of islets, separated from Tortola by *Sir Francis Drake's Channel. Broken Jerusalem*, near Virgin Gorda, is a low flat cay, covered with numberless large boulders, looking at a distance like a town fallen in ruins. The rock is diorite of a spheroidal structure. By alteration the softer parts of the rock have been swept away and the harder, large concretions, left in the form of boulders.

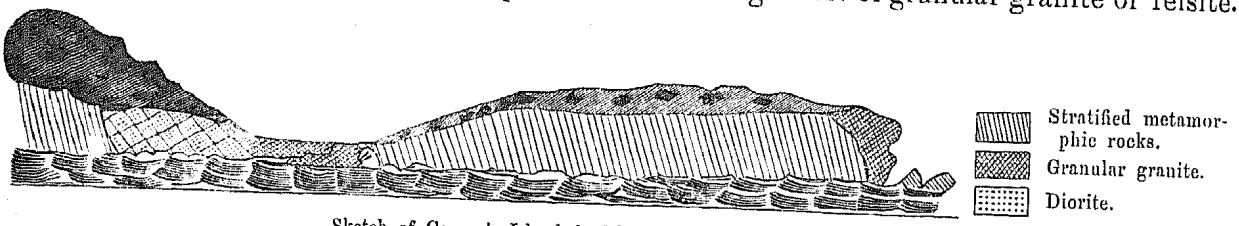
Round Rock is a conical, barren rock, consisting, in the northern part, of diorite, penetrated by veins of quartz or oligoklase-pegmatite, and by numerous trap-dikes. The diorite contains some small spots with copper-minerals. The southern part of the cay is composed of stratified rocks, gray or green silicious limestone with red garnets, or amphibolitic and feldspathic flagstones.

Ginger Island. In the middle of the northern shore is a mass of diorite, which is interstratified by, and gradually passes over into well stratified amphibolitic and feldspathic rocks. The strata strike E. N. E. — W. S. W. and dip 70° to the south. At the points of contact between the diorite and the stratified rock I could not find any traces of a violent intrusion of the diorite. The latter rock contains, on the contrary, fragments of the stratified rocks, which have the same direction as the flagstone. The flagstones are

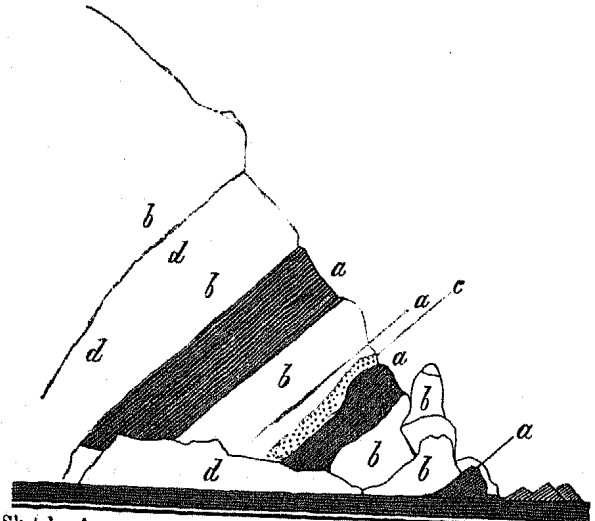
composed of feldspar and hornblend. They are intersected by numerous veins of quartz or pegmatite, sometimes containing some copper-minerals In the centre of the islet is a mass of gray crystaline limestone or marble.

Sketch form the shore of Ginger Island to show the contact between the diorite and the stratified rocks.
The darker bands are stratified diorite (feldspathic-amphibolitic flagstones). The dotted space is occupied by unstratified diorite.

Cooper's Island. The geological structure of this little island is very intricate. In the northern part there is diorite with numerous dikes of diabase and of granular granite. The rock is also intersected by veins of carbonate of iron. On the eastern coast south of the diorite mass, are metamorphic rocks containing garnet, epidote, wollastonite and numerous veins of white quartz with copper-minerals. That rock is intersected by a large dike of granular granite, and south of that dike are dark, metamorphic rocks in strata, striking S. S. E. — N. N. W. and dipping W. S. W. about 70°. On the north-western shore of the island there is diorite. In the middle part are strongly raised metamorphic rocks interrupted by diorite of a beautiful parallelopipedic structure. The strata are intersected from N—S. by a dike of felsite or granular granite. In the south-eastern point of the island I have seen black, not stratified rocks, containing some epidote and enclosing a dike of granular granite or felsite.



Sketch of Cooper's Island fr. W. S. W.

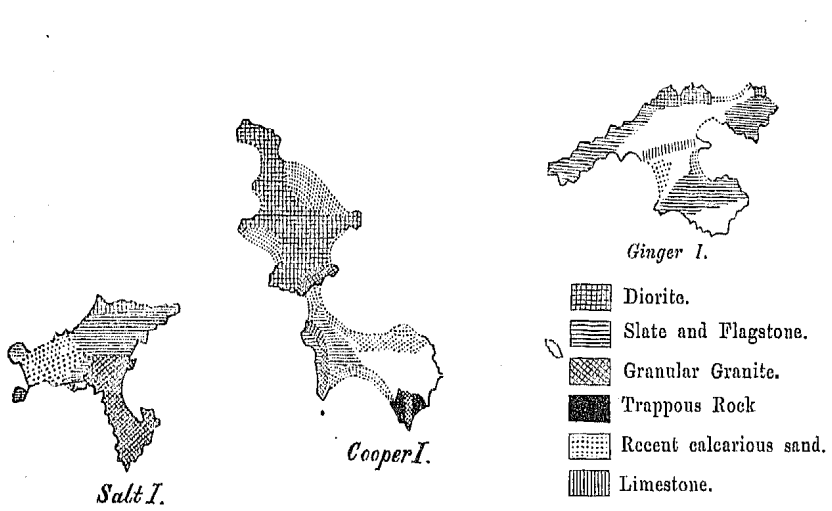


Sketch of a seacliff on Salt Id. *a* amphibolitic schist, *b* diorite, *c* felsite, *d* vein with carbonate of iron.

Salt Island. The middle of the northern coast is composed of diorite alternating in regular beds with mica-and hornblend-schists. East and west of the diorite are amphibolitic and micaceous schists, sometimes intersected by quartz viens. The strata strike E. N. E. — W. S. W. and dip 45° southward. The southern part of the island projects in a long and narrow promontory, formed by a mass of granular granite or felsite.

Dead-man's chest is a small cay, looking at a distance like a coffin, which has probably given rise to the name. The rocks com-

posing this island are stratified, micaceous, and amphibolitic schists and beds of compact felsite. The strata strike E. N. E. — W. S. W. and dip 70° southward.



(Map of Salt Id. Cooper Id, Ginger Id and Round Rock).

Peter's Island. I have only visited the northern part of the island, but sailed very near the southern part. The rocks on the north-eastern shore are micaceous and amphibolitic schists, intersected by dikes of granular granite. The stratified rocks have a strike E—W. and dip southward at a very high angle. The southern part of the island is a long and narrow promontory, probably composed of felsite or granular granite.

Norman's Island, between Peter's and S:t John, is a tolerably large islet of felsitic rock, (quartz-porphyry and protogin-felsite). Near Norman's Island there are some smaller cays, as *Pelican's Island* and *Flanagan Cay.* I have not been ashore in any of them but by their appearance from the sea one may judge them to be felsitic rocks.

10. *Anegada**), has about the same size as Tortola, but is in all respects different from the other Virgin Islands. Its extent from N. W. to S. E. is about 17 kilometers. It is very narrow, being scarcely more than 3½ kilometers broad. The surface is flat and only 9 meters above the sea-level. All the shore of the island is a hard, compact limestone with numerous fossils, which all belong to species still living in the Caribbean sea. The fossils are well preserved, and in one specimen of *Conus Leoninus* Rewe the coloured spots were still visible. The fossil shells are all of shallow-water species. The most abundant are *Bulla striata* Brug, *Oliva reticularis* Lk. *Lucina pennsylvanica* Lin etc. The limestone is consequently of a very recent date, probably post-pliocene. The rock contains many natural pits and caverns, at the bottom of which there is a mass of soft black earth. The island has many large and shallow lagoons with brackish water. On the northern coast are large and high masses of loose calcarious shells-and.

11. *Crab Island* or *Vieques*, a Spanish possession near Puerto Rico, and south of Culebra. It extends E—W. about 33 kilometers, and is not more than 7 kilom. in breadth

*) The island of Anegada is described by R. H. SCHOMBURGK in the *Journal of the Geographical Society of London.* Vol. II 1832 p. 152.

from N—S. I did not remain in Crab Island more than a few days, and under very unfavourable circumstances, for which reason I do not know much about the geology of the island. Near the shore of *Puerto Mula* an altered dark green rock is visible, but at a short distance from the coast occurs syenite-like diorite, which seems to be the most important rock of the island, producing by alteration a very fertile soil. The diorite has the same appearance as the rock of Virgin Gorda, and has also a spheroidal structure. In the eastern part of the island some stratified white rock seems to occur, but having seem them only from the sea, at a considerable distance, I cannot give any description of them.

II. Puerto Rico.

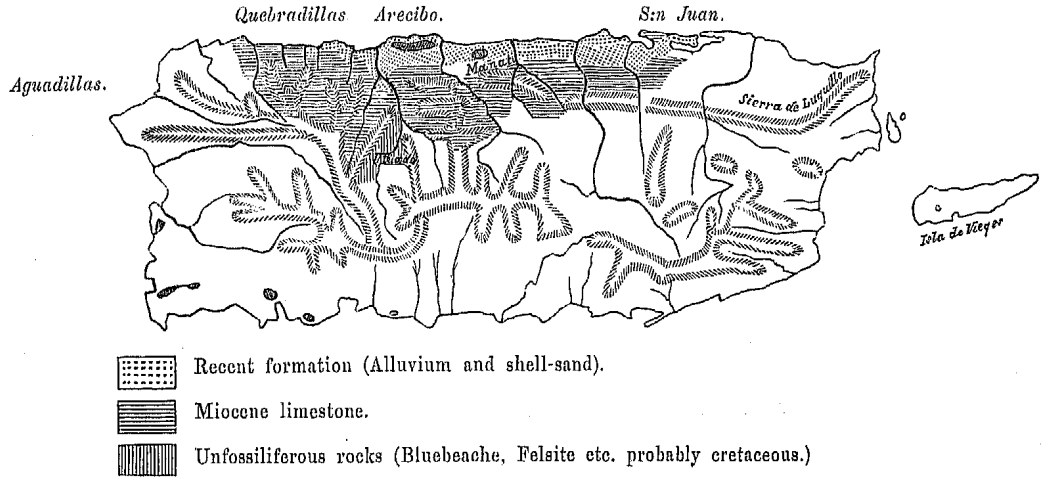
In this large and beautiful island I unfortunately passed too short a time, and in an almost insupportable heat, so that I have not been able to get more than a very incomplete acquaintance with its geology. I have visited the northern coast-line from the capital *S:t Juan* to *Quebradillas* and in the interior the mountains around *Utuado.*

Near the northern coast the island is a hilly land, gradually rising in the interior to mountains of a considerable height. The hills along the coast are fragments of a very thick series of strata, which have been cut through by rivulets and by denudation. The strata are very little inclined, and the dip, from the axis of the island to the sea, is only a few degrees. In the high mountains I have seen the summits still covered by limestone formation. The bottom of the valleys between the hills are generally covered by detritus and a reddish clay containing shells of still living species as *Helix caracolla* L. *H. marginella* Gm and *Megalostoma cylindraceum.* Chemn etc. Near the capital the limestone-rock is soft and I have found there some fossil claws of crabs and casts of bivalves. In most other places the limestone is a yellowish white and very hard rock. It contains fossils in the form of casts or impressions.

Near Quebradillas I made a little collection of fossils, but not having had time for a careful determination of them, I can for the present only say concerning them, that some of the fossil shells belong to species still living in the Caribbean Sea, as *Latirus infundibulum* Gm., *Arca squamosa* Lmk, *Cancellaria reticulata* Lin, and some belong to species found in a fossil slate in Cuba, as *Venus caribæa* d'Orb and *Tellina Gruneri,* Say *(Tellina Sagræ* d'Orb), the latter of which is still living in the West-Indies, though very rare. Some are found in the miocene beds of Jamaica, as *Pleurotoma Barettii* Guppy, *Phos Moorei* Guppy, *Cancellaria lævescens* Guppy, *Malea Camura* Guppy, and *Venus Woodwardii* Guppy. Very common is a species of *Bulla,* which I believe is identical with *B. granosa Sow* from the miocene beds of S:t Domingo. I have also found some fossils, which occur in the miocene beds of Anguilla, as a species of *Thracia* and the calcarious tubes of a large *Teredo.* There can be no doubt then that the age of the rock is the *miocene.* Below that formation occurs an older one, visible in the mountainous part of the interior, and where rivers have cut through the limestone-rock. That formation consists of conglomerates resembling bluebeache, felsite and metamorphic stratified rocks, very similar to the rocks of the Virgin

Islands, of which they probably are the continuation, but I have not found any fossils in them. To judge from their petrographical resemblance to the rocks of the Virgin Islands, one may find it very probable that they are of the cretaceous age. By a careful exploration of the island there is also a great probability of finding an eocene formation. The very slightly disturbed appearance of the miocene limestone strata and the strongly metamorphosed rocks below them evidently prove that the cretaceous rocks were bent and metamorphosed before the miocene time, which has been here, as in most other parts of the West-Indies, a long period of calm, undisturbed by volcanic eruptions.

In the capital I have seen a fine collection of specimens of minerals from the island, the property of Don PEDRO RESANO, a distinguished mineralogist. Among them were gold, mercury, silicates and carbonates of copper, etc., which proves that a geological survey of the island probably would discover many treasures in the high moutains of the interior. I sincerely regret that I could not find time to visit *Sierra Luquillo* as I intended, where probably much would be found possessing considerable geological interest.



III. S:te Croix*) or S:ta Cruz.

This island situated at 17°, 44′ 32″ Lat., and 64° 41′ Long. (at the capital), has an elongated outline, extending from E. to W. 36 kilom., and is 10 kil. in breadth. The northern part of the island is traversed from east to west by a mountain-ridge, of which the highest peaks *Mount Eagle* (350 met.) and *Blue Mountain* (332 met.) are situated between the north-western corner and the town of *Christianstæd*. East of Christianstæd the ridge is not so high, but has still peaks of 183—260 meters. The south-western part of the island is a flat, slightly undulating and well cultivated level country. The shores around the island are surrounded by large coral-reefs except on the north-western coast, where the bottom, quite near the shore, is first reached at a depth two thousand metres

*) A description of its geology was given in 1839 by S. HOVEY SILLIM, Am. Journ. Vol. XXXV p. 64.

The sea between S:t Croix and the Virgin-Islands is very deep, about four thousand meters according to soundings taken by R. HAMILTON*).

The island has some smaller rivulets, the most important is *Salt River* in the northern part.

The geological formations of the island belong to different ages. The northern mountain ridge is the oldest, and to judge from its great petrographical resemblance with the rocks of the Virgin-Islands it would seem to belong to the same geological age as the latter, or the cretaceous. Upon those highly disturbed strata very little disturbed beds of coralline limestone and white marls rest; they are probably of the miocene age. The youngest formation consists of detritus swept down from the mountains by rains and mixed with the white marls, and in a recent formation of calcarious sand around the shores. *The oldest formation* is composed of different kinds of rocks, igneous or igneo-sedimentary, as diabase, diorite, bluebeache-conglomerate and felsite. or sedimentary stratified rocks as clay-slate and limestone.

The igneous or igneo-sedimentary rocks are very difficult to describe, the surface of the mountain often being very much altered and covered with shrubs or detritus. Still the resemblance of the rocks in the mountains west of *Christianstæd* to the bluebeache-conglomerate of the Virgin-Islands seems to be very great. Around *Christianstæd* the preponderating rock is felsitic. The felsite is here a compact, hard rock, commonly breaking in angular pieces. It has a white, yellowish or greenish colour, and contains some small black crystals of hornblend. In the vicinity of Christianstæd and in the town the rock has a distinct variolitic structure, easily visible when the surface has been exposed some time to the air. It seems then to be composed of balls of the size of a pea densely imbedded in a soft mass. The rock has some indication of a stratified structure; in Christianstæd the strata strike E. N. E. — W. S. W. and dip S. S. E. Near *Beeston Hill* their strike is N. N. W. — S. S. E. and dip W. S. W. at about 50°. In the latter place the rock is irregularly broken into angular pieces by fissures at right angles to the surface of stratification. Near the harbour of Christianstæd I have seen felsite alternating with black, somewhat silicified, clay-slate in regular strata from E—W., dipping southward at about 45°. The felsite is easily altered and transformed to a loose stone called by the inhabitants »rotten-stone». The old Caribbean savages have employed the felsite for making their implements. *Diabase* occurs in some places in dikes penetrating the older rocks as the clay-slate near Christianstæd and at *La Vallée*. Near estate *Lebanon Hill* are many loose round boulders scattered on the ground. They seem to be diabase, but I have not seen the rock »in situ». *Diorite* also occurs in the island as near *South-gate*, where it is a granular, whitish mixture of white feldspar and greenish-black hornblend. Loose blocks of the same rock are scattered over the plain south of South-gate. In the small *Green-Cay* there is a remarkable variety of diorite with enormous masses of white feldspar, mixed with some quartz and large crystals of black hornblend. The rock contains some epidote and granules of pyrite. Almost the whole eastern part of S:t Croix is occupied by steep and picturesque mountains of *clay-slate*, of which, also, the hills north and north

*) Kindly communicated by the Governor of the island M. BERCH.

east of *Frœderikstæd* consist. Some smaller spots near the coast by *La Vallée* and east of *Christianstæd* are occupied by the same rock. The clay-slate has a dark, grayish-black colour, is fine-grained and perfectly cleavable. I have nowhere been able to find any trace of organic remains in the slate. The rock is perfectly stratified. The dip is generally very considerable, sometimes the strata are almost vertical but commonly dip 70°—80°. Near la Vallée the strata are almost horizontal. The strike and dip are subject to great variations in different spots and generally very difficult to determine exactly. Near *Annaly* I have seen strata striking W. N. W. — E. S. E. or nearly W—E. and dipping to the north, near *Cotton Grove* N. N. E. — S. S. W and dipping E. S. E., by *Christianstæd* N—S. and dipping to the east. By *Cookely Bay* in the north side the nearly vertical clay-slate strata strike N. N. W. — S. S. E. Sometimes the clay-slate is transformed to a kind of lydian stone as by the lagoon near Christianstæd, where the rock is penetrated by diabase-dikes. In some spots in the eastern end of S:t Croix the clay-slate is impregnated with silex. There it is a very hard chert-like rock (hornstein) of grayish colour and emits sparks when struck by the hammer. In *Buck's Island* are several varieties of slaty rocks, commonly with much lime and I have seen there a band of grayish limestone with plenty of small grains of epidote. The rocks in *Buck's Island* contain some obliteratad traces of fossils. Grayish compact limestone is found, as far I know, only in one spot, near *Judith's Fancy*. The rock is hard, dark-gray and fine-grained. It contains a great number of badly preserved fossils, so altered that I have not been able to find out of what kind they are.

The *tertiary formation* covers the flat lowland of the south-western part of the island. The formation contains two different groups: the lower, composed of broken pieces of coral, and the upper, a white chalk-like marl. The lower part is seen near *Frœderikstæd*, where it is broken by several quarries formed for the purpose of obtaining building-stone. It is a porous, white rock, almost entirely composed of casts of corals and shells. The rock contains also many rounded and worn pebbles of slate and metamorphic rocks. The fossil shells occur in the form of casts. I have collected casts belonging to the genera *Conus, Strombus, Natica, Trochus, Venus* and *Chama*. One cast af a Cypræa has exactly the same size and appearance as the cast of *C. exanthema* L., and some impressions of a Cerithium seem to belong to the still living *C. litteratum* Born. But some extinct species also seem to occur here, and among them one *Bulla* closely resembling *B. granosa* Sow of the miocene strata in S:t Domingo. I have also found the impression of a *Turbo*, certainly living no longer in the Caribbean Sea and belonging to the same type as *T. Cookii* Chemn of the Pacific Ocean. Unfortunately I have not yet examined the corals collected, but still think it most likely that the formation is of the miocene age. Above the coral-limestone are thick beds of a soft white marl, mostly without fossils*). Those beds seem to me to be about 200 met. in thickness. The recent formations of the island are partly terrestrial, partly marine. The former covers a great deal of the surface of the island in the plains below the mountains. It consists of detritus and clay, sometimes mixed with

*) Near *Mary's Fancy* I have found some fragments of spicula of echinoderms and pieces of sea-shells.

white marl. In this detrital mass are found shells of terrestrial mollusca, some of which are of extinct species and some no more extant in S:t Croix, but found living in the island of Viéques and Puerto Rico. Among the former, that is the extinct species, are *Helix Santa cruz ensis* Pfr, *Bulimus extinctus* Pfr, *B. Riiseii* Pfr, *Pupa rudis* Pfr, *Cyclostoma basicarinatum* Pfr, and *C. chordiferum* Pfr. Among the latter are *Helix caracolla* L., and *H. marginella* Gm.

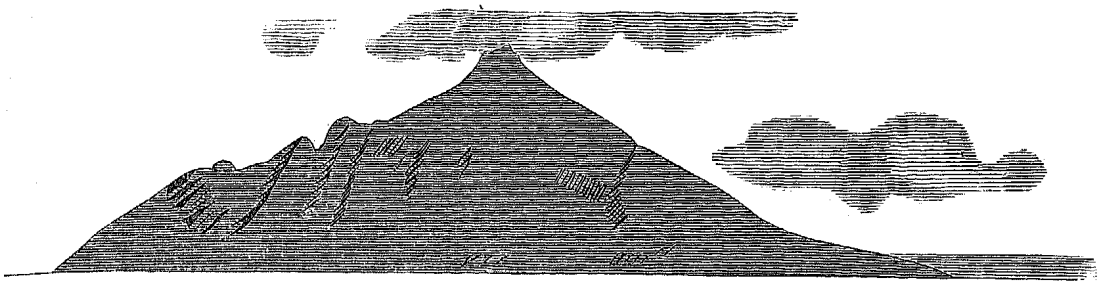
In the detrital or alluvial beds, which cover the estates of *Glynn* and *Concordia* around *Salt-River*, I have found many shells of *Venus flexuosa* Lin. and *Lucina Jamaicensis* Spgl., species still abounding in the Caribbean Sea

The recent marine formation is, in S:t Croix, as in most of the other West-Indian islands, a calcarious sandstone, composed of small rounded pieces of shells, corals and calcarious algæ, fixed together into tolerably firm and hard banks. In that limestone, often employed as buildingstone, are imbedded shells of *Turbo Pica* L., *Strombus Gigas* L., and other very common West-Indian shells, mostly with well preserved colours.

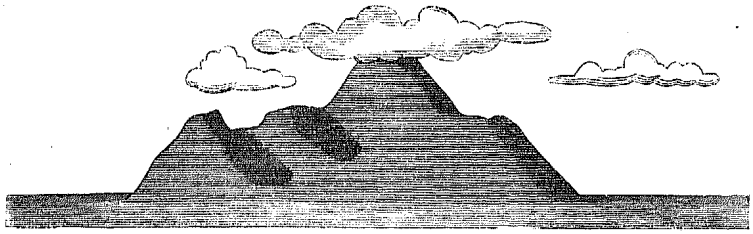
IV. Leeward Islands.

The islands north of Guadeloupe form two parallel chains from North-west to South-east. The western chain commences with *Saba* and consists of *S:t Eustatius, S:t Kitts, Nevis, Redonda* and *Montserrat*. All of those islands are volcanos and if the line were extended farther to the north it would reach the island of Anegada, of postpliocene date and all the volcanos seem to be of the same or nearly the same geological time. The Bahama Islands, which are also most probably of postpliocene date, have the same direction and seem to be the continuation of the same or of a parallel line of elevation. East of the volcanic range is another completely different range of islands. They are not volcanic and commence with *Sombrero* comprising *Anguilla, S:t Martin, S:t Bartholomew, Barbuda* and *Antigua*. All of these islands are of the tertiary age, *eocene, miocene* and *pliocene*.

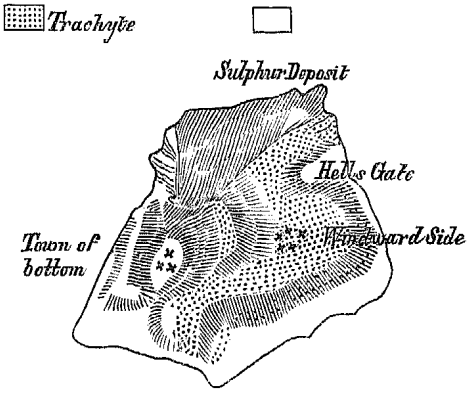
Saba, a Dutch possession, is a small conical island rising abruptly from the surrounding deep sea to the hight of 859 meters. The rock of the island is a more or less irregularly stratified trachytic tufa, or in the eastern and north-eastern part trachytic lava (microtinit), The trachyte has a reddish brown colour and contains white crystals of glassy oligoklase and small black needles of hornblend. Near *Hell's Gate* there occurs in the tufa a sulphur deposit with gypsum and alum-stone. The sulphur is evidently a remnant of an old fumarol. I could not reach the highest point of the island, which is covered by dense forests of arborescent ferns, but I do not believe that there is any crater, the summit being terminated by a crest. From S:t Eustatius the island has the appearance of a pointed cone, and from S:t Bartholomew the summit is terminated by a horizontal line. The settlement »*the town of bottom*» is a flat, almost circular space at the hight of 2—300 meters above the sea, surrounded in all directions, by high steep hills of tufa. To me it appears very probable that this is the true crater.



The island of Saba seen from S:t Eustatius.



Saba seen from S:t Bartholomew.

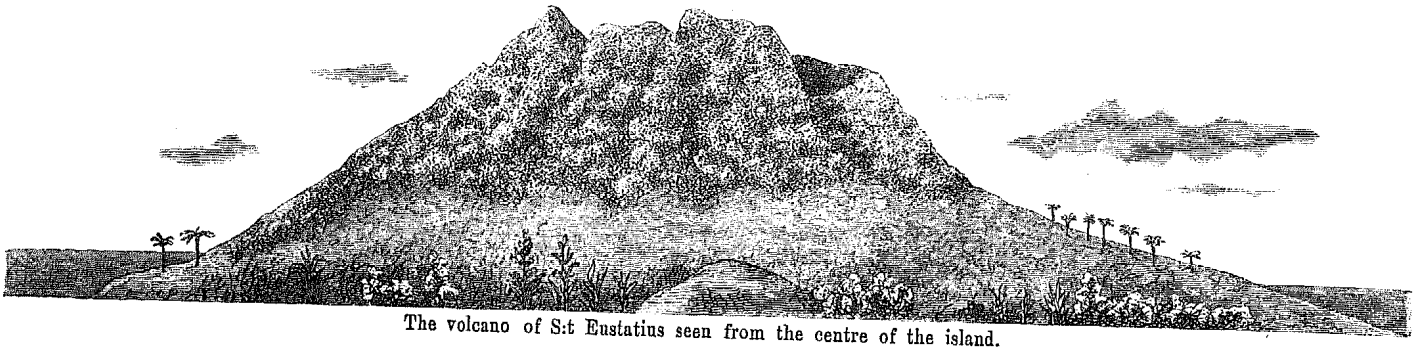


S:t Eustatius, also a Dutch possession, is a small, entirely volcanic, island, 6,7 kilometers in length and 4,7 kil. in breadth. In the southern part is a conical volcanic mountain called »the Quill» or the Punch Bowl. The summit is one of the most regular craters. The mountain reaches about 594 meters above the sea-level, and the opening of the crater is about 740 meters in diameter. The whole crater is overgrown with a rich tropical vegetation. The slope of the mountain is very steep, in the higher parts about 45°, but on an average about 25°. The exterior surface of the volcano is grooved by radiating furrows hollowed by rain-water. The volcano, of which no eruption is recorded, seems never to have emitted lava-currents, the whole cone being constructed of loose materials, boulders and trachytic tufa. In the lower parts surrounding the mountain the tufas is disposed in very regular strata. On the western slope is a small hill called *Round Hill*, which seems to be a parasitical cone.

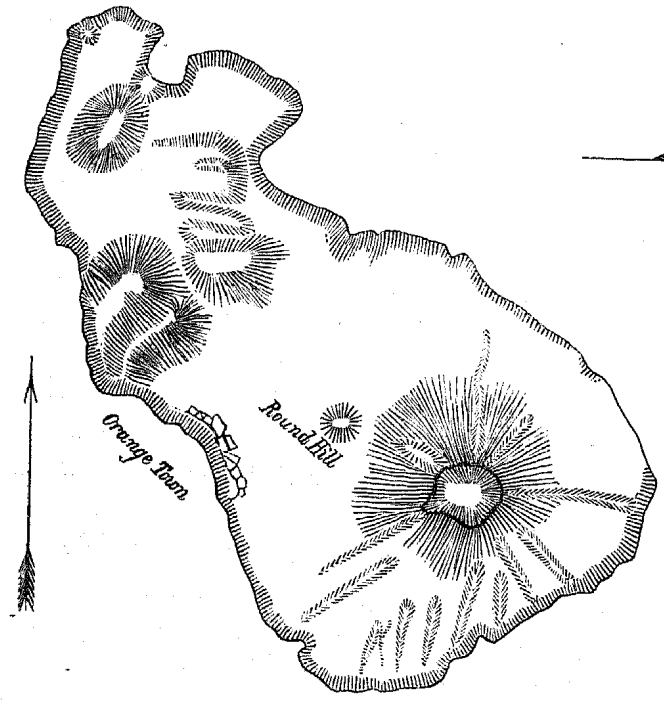
According to *Maclure**) there is on the south-east slope of the cone a lime-deposit of corals and shells, »similar to those found in the sea». He gives the following description: »The whole of this marine deposition dips to the southwest at an angle of upwards of 45 degrees from the horizon, resting upon a bed of cinders, full of pumice and other volcanic rocks, and is immediately covered by a bed of madrepore, sand and cinders mixed together, with blocks of volcanic rocks so disseminated that there can be no doubt of the volcanic origin of the substance above and below the madrepore rock, which may be from five to six hundred yards thick». I have not visited the spot, but to judge from the de-

*) Journal of the Acad. of Nat. Sc. of Philadelphia, Vol. I Part I p. 147.

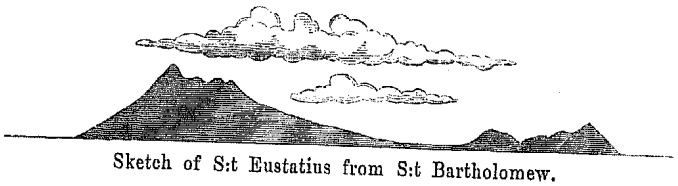
scription, the formation may be of the same kind as the limestone formation at Brimstone Hill in S:t Kitts. That fossiliferous deposit, as well as the regular stratification of the tufa in the land around the cone, seem to prove that the lower part of the volcano is formed by submarine eruptions and that the island has been raised afterwards. In the northern part of the island are several hills and rocks, all of volcanic origin. Some consist of trachyte or old lava-currents, and others of trachytic tufas. They are evidently of an older date than the Quill, as tufas from the latter cover some parts of the trachytic rocks. No regular craters are visible in the northern part, only crests and hills, which have probably been parts of volcanic cones or lava-currents, partially destroyed by denudation. No fossils are found in that part of the island.



The volcano of S:t Eustatius seen from the centre of the island.



Map of S:t Eustatius.



Sketch of S:t Eustatius from S:t Bartholomew.

S:t Kitts or S:t Christopher, situated at a distance of 12 kilom. S. E. of S:t Eustatius, is also a volcanic island of an elongated form measuring from N. W.—S. E. about 32 kil. Its greatest breadth is about 10 kil. In the southeastern part the land is very low, contains several lagoons and has only insignificant trachytic rocks, the fields being covered with a fertile soil of dark gray volcanic ashes. North-west of the capital of the island, *Basseterre,* is a small hill, with the outline of a truncated cone, called *Monkey Hill,* which has the appearance of a volcanic mountain, but I cannot tell if there is any crater as I have not ascended to its summit. In the sugar-cane fields below Monkey Hill occur many shells of fresh appearance and belonging to still living species, as *Chama arcinella* L. *Plicatula ramosa* Lamk *Arca antiquata* Lin *Arca Noe* Lin *Murex pomiformis* Mart *Turbo Pica*

Lin, *Crepidula aculeata* Chemn, *Strombus Gigas* Lin and some corals. This proves that at a recent time the island has been elevated from the sea. Along the whole southern coast, from *Basseterre* to the old town of *Old Road,* occur only volcanic tufas, cinders and boulders, sometimes of a considerable size. Northwest of Basseterre and above Old-Road is a wild, picturesque mountain, S:t Patrick's Hill, of about 1,010 meters. It seems to be a volcanic centre. Northwest of S:t Patrick's Hill is situated the highest mountain in the island, *Mount Misery,* with summits of 1,131 meters. The mountain is described as having in the summit a crater with a lake, hot springs and fumarols, exhaling sulphuretted hydrogen, which by oxydation produces beautiful crystals of sulphur.

At the foot of Mount Misery there is in *Brimstone Hill* a white limestone rock of considerable size, surrounded in all directions by loose volcanic rocks. I have not seem in it any trace of stratification. The rock has the appearance of chalk and contains many fossil shells and corals, the greatest number in the form of casts. I have found about 43 different mollusca, all of species still living in the Caribbean Sea, except a single specimen of a *Modiolaria,* closely related to a northern still living species. Among the fossil shells one of the most common is *Tellina Gruneri* Phil., also occurring in the miocene strata of Cuba (T. Sagræ d'Orb) and Puerto Rico, and still living in the Caribbean Sea, but very rare. The greatest number of still living species indicate the recent time, at which the deposit was formed, and the formation may probably be dertermined as the newest pliocene, or post-pliocene. The volcanic rocks of S:t Kitts are trachytic, probably oligoklase-trachyte. They have a grayish or reddish colour and contain white crystals of glassy feldspar and some hornblend.

Not having visited the other volcanic islands belonging to the same range as S:t Kitts, viz. Nevis, Redonda and Montserrat, I will now discribe the eastern leeward islands.

Sombrero. During my travels in the West-Indies I had no opportunity to visit this small island, remarkable for the phosphate of lime, which in latter years has been taken from it, but from *Dr* A. v. Goës of S:t Bartholomew I have obtained some information about the geology of the island as well as several specimens. This small island is a very flat cay formed of a hard white limestone, full of fossils in the form of casts or impressions. The limestone is intersected by veins running N. W. — S. E. and containing phosphate of lime of variable appearance. Some of the specimens are transparent yellow, without any trace of crystalization, some have been corals and shells whose carbonate of lime is metamorphosed to phosphate. The origin of the phosphoric acid is difficult to explain, but it is supposed that the island, which was formerly inhabited by numerous birds, has been covered by guano, of which the phosphoric acid has been dissolved and penetrated the limestone-rock.

The fossils of the limestone rock are very difficult to determine, as most of the specimens are fragments of casts and impressions. Nevertheless most of the mollusca seem to belong to species still living in the Caribbean Sea as *Tellina fausta* Gold, *Cerithium litteratum* Born, *C. caudatum* Sow., *Fissurella Listeri* d'Orb. etc.; but among these shells occurs in great numbers one species of *Bulla,* which seems to be *B. granosa* Sow, now extinct and found in the miocene beds of S:t Domingo and Puerto Rico. On this

account I would believe that the formation belongs to the youngest division of the miocene age, or to the pliocene time.

Anguilla is a long and narrow island stretching from northeast to southwest about 26 kilometers. It is a flat limestone plateau of about 70 meters in hight at the northern end and slowly dipping down to the sea in the southern part. At the abrupt sea-cliffs on the northern coast it is easiest to get information about the geology of the island. In one cliff north of *Sandy Bay* the bottom-rock is visible. It is a dark amygaloidal trappous rock, containing nodules of Thomsonite and Laumontite. This trappous rock is covered by a yellowish soft limestone-bed containing many fossil corals and echinoderms etc. South of Sandy Bay there are, near the sea, cliffs composed of almost horizontal strata. Furthest down near the sea are beds of a grayish or yellowish marl with many casts of shells, fragments of crabs etc.; they are covered by beds of coral-fragments and shells of Pecten. Above that bed occur strata of marls covered by coralline limestone and a hard white limestone-rock with very few fossils. The latter stratum is the surface-rock of the island and it contains many fissures filled with a breccia of angular limestone pieces and a red hard rock. In that breccia, which contains phosphate of lime, are found landshells of species still living in the island and bones and teeth of an extinct rodent *Amblyrhiza inundata* Cope. of a very large size.

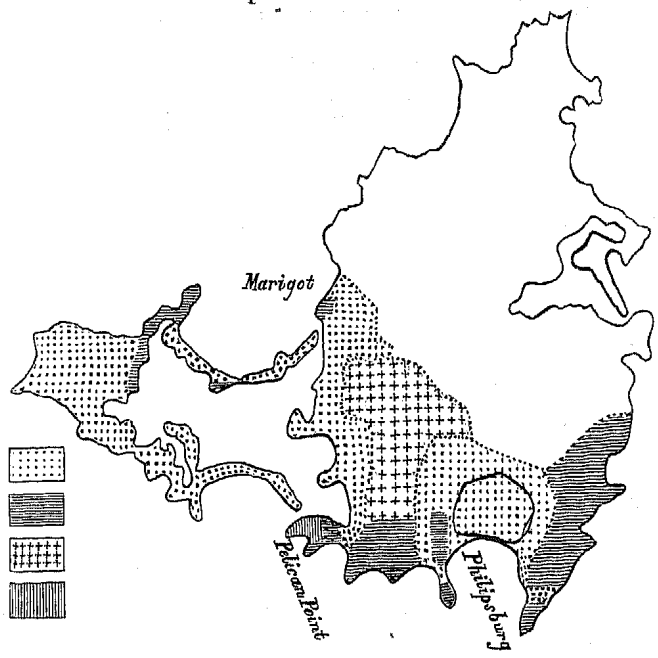
The fossils of the marls and limestones of Anguilla are generally badly preserved, most of them being only casts, which makes their determination very difficult. Among the fossils are *Natica phasianelloides* d'Orb, widely distributed in the miocene beds of the West-Indies, *Natica Canrena* L., and species of *Strombus, Cassis, Conus, Cypræa, Turritella, Scalaria, Solarium, Oliva, Ficula, Pecten, Venus, Lucina, Lima, Cardium, Cardita* etc. Very numerous are the echinoderms, and mostly well preserved. They have already been described by *Guppy*. Of corals a great number is found, and also several foraminifera. Among the fossils are large calcarious tubes of *Teredo,* also found in Puerto Rico. The formation of Anguilla may be classed as miocene, as is made probable by the paleontological researches of *Guppy**).

S:t Martin is an island of almost triangular outline, formed by conical hills, some of which are about 400 meters high. From north to south the island is about 14 kilometers long. Around the shores are many large lagoons and in the interior several rivulets and permanent springs. Having visited only the southern part of the island I can only give an account of that part. In the southeastern corner rise abrupt seacliffs of regularly stratified rocks, mostly of a kind of silicious limestone of a darker or lighter grayish or greenish colour, and often very hard. The strata are almost horizontal and do not contain fossils. In many places I have seen black, brown or greenish garnet in these rocks. The strata are sometimes intersected by dikes of greenstone or in some spots by veins with silicates of copper. Between the Dutch town of Philipsburg and the southeastern point the strata are penetrated by a dike of light coloured diorite resembling syenite, sending branching veins into the surrounding rock, intruded between the strata and deranging them, so that they dip southward 40° and strike E—W. On the southeastern

*) Quart Journ. Geol. Soc. Lond. Vol. XXII pag. 297.

coast the seacliffs are also composed of the same kind of stratified, metamorphic silicious limestones, but near the sea they are covered by a more recent formation of white granular limestone, in which I could find no fossils, so that the age of that rock is unknown. In some places occur large masses of modern formations, detrital fragments of older rocks carried down by rains or rivulets, and along the shores recent calcarious sand. The Dutch town of Philipsburg is built upon a flat land covered by such modern deposits. The hills west of the town consist chiefly of igneo-sedimentary rocks, old tufas and breccias greatly resembling the rocks of S:t Bartholomew. Among the detritus at the foot of the hills I have seen loose blocks of syenite-porphyry of the same kind as that rock in S:t Bartholomew. I have seen nowhere in these mountains the same kind of gray limestone, which occurs so plentifully in S:t Bartholomew, but I have no doubt that it may be found, as near the French settlement I have met with some loose blocks of gray, hard and solid limestone of the same petrographical character as the rock of S:t Bartholomew.

The stratified beds of tufas and breccias in the hills west of Philipsburg strike N. E. — S. W. and dip S. E. about 30°—20°. On the southern coast, west of the same town, the cliffs are composed of regular strata of metamorphic, silicious limestone, striking E—W and dipping southwards 20°—30°. These strata are often penetrated by dikes of greenstone; they have a reddish colour and are interstratified with large beds of a black heavy rock containing much manganese and constituting a kind of impure *psilomelane.* In cavities in the strata I have found a black crystalized mineral resembling *Cronstedtite,* epidote, chalcedony, magnetic iron in octahedrons and specular iron. At Pelican Point the last described strata are covered by beds of a hard, white limestone, without any other fossil than some scarcely recognizable traces and casts of shells. This limestone has exactly the same character as the surface-stratum of Anguilla, of which I suppose it may have been the continuation. The stratum runs N. E. — S. W. and dips 15° to the N. W., and it is incongruously imposed upon the elder strata below. The western part of the island around the French settlement of *Marigot* is almost entirely covered by recent shell-sand and detrital masses, having only a few uncovered rocks of stratified silicious limestone. I have not visited the northern part of the island, but from the general configuration of that



Map of S:t Martin.

part one may conclude that the geological formations are the same as in the southern part.

From the want of fossils in the older rocks of S:t Martin it is not possible to decide on the exact age of the S:t Martin formation, but to judge from the petrographical resemblance between the rocks of S:t Martin and S:t Bartholomew, one may conclude that they belong to the same geological time, which the fossils in the latter island prove to be the eocene. The general dip of the strata of S:t Martin is also southerly, as in S:t Bartholomew. The small flat cay of *Tintamarre* near S:t Martin I have not visited but it may probably prove to be a continuation of the miocene formation of Anguilla.

S:t Bartholomew, situated 62°, 51′, 6″ Long W. from Greenwich and 17° 53′ 50″ Lat. (at the town of Gustavia), is a narrow island, extending east to west about 10 kilometers. The whole island is mountainous and has no fresh water. Around the coasts are several lagoons with brackish water. The mountains in the western part of the island form a long ridge, but in the eastern part they are more isolated, conical peaks, of which some reach 302—250 meters hight above the sea-level. All the geological formations of the island except the modern detrital masses in the vallies and on the plains, or recent calcarious sand along the shores, belong to the elder tertiary age or the eocene time.

The surface of the island is a very stony soil composed of rock-fragments and boulders, sometimes of very large size, which remain to prove the strong denudation to which the island has been subjected. In the places where syenite-porphyry occurs the soil is covered with numerous large round boulders of this rock, which has a beautiful spheroidal structure.

The mountain masses of the island are composed of very different kinds of rocks. One kind, the syenite-porphyry, is evidently eruptive, the others are partly igneo-sedimentary breccias and conglomerates, partly fossiliferous limestone*).

The syenite-porphyry occurs in several places as around the town of Gustavia, near Grandfond, near S:t Jean, and in several other places. The rock has a greenish gray colour, it contains small crystals of white feldspar and small black shining needles of hornblend in a greenish mass. The rock is massive and has a flat or conchoidal cleavage. Generally it has a fine concentric-spheroidal structure. By alteration the spherical boulders have become very visible, and at the places, where the rock occurs, the soil is generally covered with large round balls of syenite-porphyry. Sometimes it contains darker angular or rounded concretions of a more fine-grained composition and in some few places I have found enclosed in the rock smaller noduli of quartz, which does not otherwise belong to the ingredients of the rock.

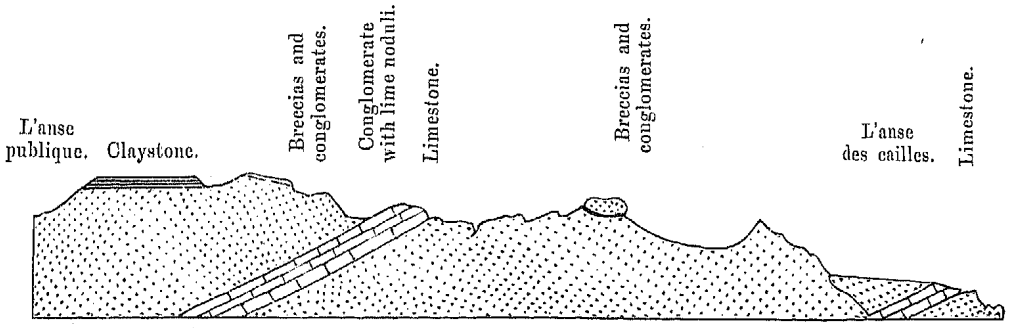
In the hill behind the fort of Gustavia the porphyry is covered by a stratified fine-grained claystone dipping to the north, though elsewhere the stratified rocks of S:t Bar-

*) I was told that in the eastern part of the island is found a white fine-grained and soft limestone, employed as buildingstone. I have not seen the rock on the spot, but in the loose stones I have seen no fossils remains.

tholomew dip to the south. It seems to me very probable that the change of the dip in that place is occasioned by the eruption of the porphyry.

a Syenite porphyry. *b* conglomerate. *c* variolithe. *d* claystone.

The igneo-sedimentary strata of tufas and breccias alternate with beds of the fossiliferous limestone. They generally strike E—W. and dip to the south 20°. That system of rocks has been subjected to a powerful denudation, through which it has been divided by numerous vallies, so that now only fragments in form of conical hills remain. For that reason it is very difficult to decide which of those spots of limestone originally formed continuous strata.



Section across S:t Bartholomew.

The conglomerates and breccias occur in numberless varieties. Some of them have a great resemblance with the bluebeache of the Virgin-Islands, and contain angular or rounded pieces of porphyritic rocks, alveolary scoriæ, and smaller pieces of a rock resembling slate. All these fragments are mixed together to a more or less coarse conglomerate, which has often undergone strong alteration.

Near the contact with the limestone-beds are often found rounded concretions of gray limestone with fossils. In some parts of the island as in the west end and near *L'Orient* the conglomerate is not so coarse and is composed of small angular pieces of various colours. A very fine-grained, almost sandy, variety, resembling puzzuolana and of a dark brown colour, is found near *L'Orient*. Another variety of distinct variolitic structure occurs in strata of about 1 metre in thickness in the hills between S:t Jean and the Fort of Gustavia. The latter variety contains a greenish granular mass, and round concretions of a lighter colour. The very finegrained conglomerate can scarcely be distinguished from a lighter coloured clayslate. This variety, which may be termed claystone, is found in many places in the island and generally caps the hills. In some places the claystone contains smaller crystals of feldspar and there it graduates into a kind of stratified porphyry. In the valley between *Grand-fond* and the eastern coast of the island occur a great number of interesting varieties of breccias and conglomerates. They have

often been strongly altered, probably by infiltration of water containing silex in a state of solution. In some places, as near the mines, I have seen specimens of breccia transformed to quartz with many small spots of pyrite, but still with the structure of breccia perfectly well conserved. The hills around *Grand-fond* consist chiefly of chert, which has originally been a breccia. North of Grand-fond some metalliferous veins are found, containing lead-minerals, and some copper. The vein-stone is quartz containing some epidote, heavy spar, pyrite, hematite etc. The vein strikes from North to South and has been worked lately. The mines were opened in June 1868 and on my visit to the island in Febr. 1869 there was a mine of the depth of 14 fathoms. The quantity of lead-ore extracted from this mine was 4 tons. Another mine, the working of which had been commenced in Oct. 1868, was at the time of my visit 9 fathoms in depth, and about 3 tons of ore had been found there. The lead-ore is said to contain 10 ounces of silver in the ton.

In the point west of Grand-fond there is also a vein, excavated in the seacliffs to a cave, whose walls, continually moistened by spray from the breaking sea, are covered by gypsum and in some spots by a white soluble salt, containing a compound of sulphate of sodium and alumina. I found there, also, a new compound of sulphate of sodium with basic sulphate of peroxide of iron for which I propose the name of *Bartholomite*. It occurs in yellow masses and is distinctly crystaline. The mineral probably originates from the action of seawater and air upon pyrite and feldspathic rocks.

The limestone of S:t Bartholomew is a very hard and compact rock with a flat, even cleavage. It has a decided tendency to break in parallelopipedic or cubic pieces, separated by fissures generally containing fine crystals of calcarious spar or rock-crystals. That peculiar structure often gives the rock, when viewed from a distance, the appearance of basalt. The limestone sometimes contains numerous fossils, which are generally very badly preserved. Among the fossils are numerous echinoderms, among which is found a species of *Macropneustes* and *Echinolampas Ovum serpentis* Guppy, also found in the S:t Fernando beds of Trinidad. I found, too, a fine specimen of a decapodous crustacean of the genus *Ranina*, of which there is also one species in Trinidad. The foraminifera are very abundant and also many different species of corals. Among the brachiopodous mollusca I found one specimen of *Argiope* and many specimens of a *Terebratula*, resembling *T. carnea* of the cretaceous formation, or the still living *T. hyalina*. It seems to be the same as *T. carneoides* Guppy of the S:t Fernando beds of Trinidad.

The gastropodous shells are very numerous and belong to the genera: *Voluta, Rostellaria, Natica Phorus, Cypræa* etc. Among them I found many specimens of a large *Nerita* closely resembling, if not identical with the *N. conoidea* Lam. of the eocene beds around Paris and other places. One large species of the genus *Cerithium* seems to me to be identical with the *C. Giganteum* Lamk from the eocene beds of Paris.

The bivalves are very numerous. They are represented by large oysters, one *Pinna, Spondylus, Plicatula, Inoceramus,* (?), *Lucina, Tellina, Cardita, Cardium* etc.

The fossil fauna has a decidedly eocene appearance and may be classed as equivalent to the middle eocene beds of Europe *(Calcaire grossier, Bracklesham beds)*. The occurrence of fossils of the same species as well in S:t Bartholomew as in the San Fernando beds of Trinidad seems to me to prove that the latter also are of eocene date.

Having now concluded the report on the geology of the north eastern West-India islands, visited by me, I will in the following enumerate and describe the minerals and rocks found in those islands.

V. Minerals and Rocks found in the Northeastern West-India Islands*).

1. *Sulphur* of volcanic origin is found in the volcanic islands of Saba, Nevis and S:t Kitts. It is formed by oxidation of sulphuretted hydrogen and commonly accompanied by gypsum and alum-stone etc. In Puerto Rico sulphur is found at Mameyes (Sierra Luquillo) It seems here to be derived from the decomposition of pyrite.

2. *Gold* is found in loose pieces in the rivers of Sierra Luquillo and Corazal in the island of Puerto Rico.

3. *Mercury* in Puerto Rico (Rio grande, Luquillo).

4. *Copper.* Virgin Gorda. The metal is dendritic. It occurs in veins of white quartz, traversing diorite, and is accompanied by several copper minerals as well as by molybdena.

5. *Pyrite* is very common in most of the islands. Large crystals are found on *Puerto Rico* (Sierra Luquillo) on *S:t Bartholomew* (cubes enclosed in volcanic tufas of eocene date, near L'anse publique and near the mines) and on Virgin Gorda in the copper-mines, crystalized in pentagonal dodecahedrons.

6. *Blend.* S:t Bartholomew in the mines; very scarce.

7. *Galena* is found in S:t Bartholomew, sometimes crystalized in cubes; also in Puerto Rico (Sabana grande, camino de Iauro).

8. *Molybdena* occurs in Virgin Gorda and in Puerto Rico (Mameyes).

9. *Magnetic pyrite* is observed at Rio blanco on Puerto Rico.

10. *Chalco-pyrite* is found in S:t Bartholomew in smaller pieces, in Tortola, and also in Virgin Gorda.

11. *Gray Copper-ore.* Smaller pieces are found in S:t Bartholomew and in Virgin Gorda.

12. *Red Copper-ore* occurs in Puerto Rico (Corozal) and in Virgin Gorda.

13. *Black Oxide of Copper* (Kupferschwärtze) very scarce in S:t Bartholomew and in Virgin Gorda.

14. *Specular Iron* is found in several places on Puerto Rico (Rio Cugull) in *Tortola* in veins of quartz in the eastern part of the island; in *S:t Martin* accompanied by manganese in stratified rocks on the southern coast; in *S:t Bartholomew* near the mines in small scales.

15. *Manganite* Puerto Rico (Corozal) not found in crystaline form.

16. *Limonite* is found in S:t Bartholomew in stalactitic form. In S:t Martin in colloid state and also observed in Puerto Rico (Rio blanco).

*) For the acount of the minerals of Porto Rico I am entirely indebted to *Don Pedro Resano* of San Juan.

17. *Psilomelane* (?) very impure, compact, not crystaline, and of black colour is found on the southern coast of S:t Martin in large masses in stratified rocks.

Composition according to an analysis by Mr. L. J. WESTMAN.

S̈i; 31,01 F̈e 4,56 Ä̇l 5,03 Ṁn 15,14 M̈n 28,16 Ċa 5,62 Ṁg 5,09 Ḣ 3,67 Sum. 98,28.

18. *Quartz.* Large and fine crystals are found in Puerto Rico (Rio Prieto); small transparent crystals in cavities and fissures in the labrador-porphyry of Culebra. Smaller rock-crystals are also found in fissures in felsitic breccia in S:t Thomas, Tortola etc. In S:t Bartholomew quartz is found in fissures of hard, gray limestone. Quartz crystalized into double pyramids occurs in some varieties of the felsite of S:t Thomas and in the granular granite of Bucks Island near S:t Thomas.

Uncrystalized quartz of white colour is very common in veins of different kinds of rocks in the Virgin Islands.

Ironsilex of red colour is found in S:t Bartholomew and Culebra. *Green Quartz* occurs in fissures in the labrador-porphyry of Culebra.

Chert is found in large masses in S:t Bartholomew, where it has been formed by metamorphic action on volcanic breccias.

Chalcedony in smaller nests occurs in stratified rocks on the southern coast of S:t Martin. It is also found in S:t Bartholomew enclosed in compact gray limestone.

Agate of brownish colour is found in Puerto Rico (Caja de Meustos).

19. *Molybdic acid* occurs in Molybdena in form of thin layers at Mamayes (Puerto Rico).

20. *Magnetic Iron-ore* is observed in Puerto Rico (Gurabo, Ciales), in S:t Martin in small octahedrons, in S:t Bartholomew, Tortola etc.

Titaniferous Magnetic Iron-ore is an ingredient of the anorthite-diorite of Beef Island near Tortola, where it occurs in small grains or in the form of black loose iron sand, washed down by rains.

21. *Talc* is observed in form of small hexagonal leaves in the granular granite of Bucks Island (S:t Thomas).

22. *Wollastonite* is found in long whitish gray prisms enclosed in compact limestone, near Anna Bay (S:t John, Virgin Ids.) also in Cooper's Island in radiating crystaline masses, accompanied by garnet and pistacite in a strongly metamorphic limestone.

23. *Augite* occurs in the diabase or augitic porphyry, in black crystals, in Bucks-Island, near Coki Point and on Hans Lollic near S:t Thomas, also in small greenish-black needles in the labrador-porphyry of Culebra.

24. *Hornblend* is very common in the rocks of the Virgin-Islands. Large crystaline masses are found near S:ta Cruz in the small Green Cay, and in the anorthite diorite of Beef Island near Tortola, also in Puerto Rico (Rio de la plata). Small black needles of hornblend occur in the trachyte of Saba and in the syenite-porphyry of S:t Bartholomew. — It is a constituent mineral in the diorites of the Virgin-Islands.

25. *Chrysocolla* is found in Puerto Rico (Rico Blanco), in S:t Martin, and in Cooper's Island.

26. *Resanite.* By this name I propose to call a trisilicate of copper and iron with water found in Puerto Rico (Luquillo) by *Don Pedro Resano.* It occurs in olive green,

not crystaline masses, accompanied by malachite and chrysocolla. The mineral is very loose and has the sp. gr. 2,06. It is easily decomposed by hydrochloric acid.

Composition according to an analysis by Mr TH. FIEBELKORN.

S̈i; 35,08; Ċu 23,18; F̈e 9,91; Ḣ (volatilized by 100°) 23,15; water vaporized by ignition 8,53; Sum. 99,85.

All the iron occurs as peroxide, but if, as is very probable, it originally has been in the mineral as protoxide, one may calculate from the analysis the formula $\dot{R}_2\ \ddot{S}i_3 +$ qaq., in which $\dot{R} = {}^1/_3$ Ḟe and ${}^2/_3$ Ċu.

This formula requires.

S̈i 36,33 Ċu 21,30, Ḟe 9,68 Ḣ 32,69, Sum. 100,00.

Of the nine equiv. of water in the mineral six seem to be lost at 100°.

27. *Orthoklase*, red crystaline feldspar occurs as an ingredient in pegmatite-granite in several places in the Virgin Islands, as near Belmont on Tortola, in Beef-Island and Great Thacht Island near Tortola. The glassy feldspar of the trachyte of Saba etc. seems to be oligoklase.

28. *Oligoklase* occurs in tolerably large crystaline pieces in pegmatite-granite in several places, as in Beef-Island near Tortola, in Round Rock near Virgin Gorda etc. Oligoklase is an ingredient of the granular granite and felsite of the Virgin-Islands as also in the syenite-like diorite of these islands. The oligoklase occuring in the latter rock is lime-oligoklase or *Hafnefjordite*. The *Hafnefjordite* from the diorite in *Mary's Point* at S:t John has a sp. gr. of 2,687, and contains according to an analysis by P. T. CLEVE:

S̈i, 59,45; Ä̈l 25,52; F̈e 0,70; Ċa 7,88; Ṅa 4,57 Loss by ignition 0,62 Sum. 98,74.

The ratio of oxygen in $\dot{R} : \ddot{R} : \ddot{S}i :: 1 : 3{,}5 : 9{,}3$ and the formula is consequently $2\ (Na\ Ca)\ O, 3\ Si\ O_2 + 2\ (Al_2\ O_3 . 3\ Si\ O_2)$.

29. *Labradorite* probably occurs as an ingredient in the diabases of the Virgin-Islands, and also in the *Labrador Porphyry* of Culebra, in which rock it forms small white crystals.

30. *Anorthite* is found as an ingredient in the *Anorthite-Diorite* of Beef-Island. The mineral is whitish-gray semi-transparent, crystaline and has the sp. gr. of 2,78.

Analysis by P. T. CLEVE.

S̈i 45,60; Ä̈l 31,96; F̈e 2,08; Ċa 17,50; Ṁg 0,59; K̇ 0,47: Ṅa 1,10 loss by ignition 0,45. Sum. 99,75.

The ratio of oxygen in $\dot{R} : \ddot{R} : \ddot{S}i :: 1 : 2{,}76 : 4{,}33$. or $1 : 3 : 4$ and the formula is consequently $Ca\ O, Si\ O_2 + Al_2\ O_3 . Si\ O_2$.

Anorthite from S:t Eustatius is analysed by *H. S:t Claire Deville* (Ann. de Chim. et de Phys. [3] 40 p. 286).

31. *Epidote* is very common. Fine crystals are found in Puerto Rico (Rio blanco and Rio Prieto); in S:t John (Virg. Isds) at Brown's Bay in syenite, at Belmont (Tortola) commonly accompanied by garnet; on Bucks Island (S:t Thomas) uncrystalized in diabase. On Bucks Island near S:t Croix smaller granules of epidote occur densely imbedded in a

stratum of gray limestone. Epidote also occurs in the granite of Beef-Island (near Tortola) and in quartz-veins on Culebra and S:t Thomas etc.

32. *Garnet* is found in handsome crystals in Puerto Rico (at Rio blanco in dodecahedrons of greenish or brown colour). Brown crystals of this mineral are found in the diorite of Brown's Bay in S:t John. In the limestone at the westend of Tortola there are numerous granules of garnet, and in the stratified rocks of Mary's Point (S:t John) and of the smaller Virgin Islands (Cooper's Island, Ginger Island etc.), it is an important ingredient. Garnet (black and greenish) is found also, in the stratified silicious limestone of S:t Martin.

33. *Mica.* Dark mica in small leaves enters into the composition of the diorite of the Virgin Islands, and occurs also in the granite and pegmatite of these islands.

34. *Desmine* occurs in small, transparent crystals in fissures in the diorite at *Brown's Bay* (S:t John), and also in fissures in metamorphic, stratified rocks at *Mary's Point* (S:t John), accompanied by calcarious spar. It is found also in crystals near *Brandwyn Bay* (Tortola).

According to an analysis by Mr TH. FIEBELKORN the desmine from Mary's Point is composed of:

S̈i 56,02; Ä̈l 17,23; Ċa 5,68; Ṅa 2,15; Ḣ (before 100°) 2,36 Ḣ (by ignition) 17,06. Sum, 100,50.

Ratio of oxygen in Ṙ : R̈ : S̈i : Ḣ . . 1 : 3,8 : 13,7 : 7.

35. *Laumontite* is found on *S:t Bartholomew*, (near S:t Johns), in fissures of conglomerates in whitish, opake, crystals. It occurs also, in Anguilla together with calcarious spar and Thomsonite in a kind of black amygdaloid rock.

Analysis 1. of Laumontite from *S:t Bartholomew* sp. gr. 2,28, by Dr TH. NORDSTRÖM.

2. Laumontite from *Anguilla*, by Mr L. J. WESTMAN.

	S̈i	Ä̈l	Ċa	Ṅa	K̇	Ḣ (before 100)	Ḣ (ignition)	F̈e	ĊaC̈	Sum.
1.	53,67	20,44	9,79	0,59	1,25	2,20 »	11,32 »	0,59	—	99,75.
2.	47,60	17,95	8,77	1,39	2,82	2,20 »	11,33 »	—	7,72	99,78.

36. *Prehnite* occurs in small whitish, radiating, masses in the pegmatite-granite of Beef-Island (Tortola) sp. gr. 2,98.

Analysis (of mineral dried at 100°) by P. T. CLEVE.

S̈i 44,06; Ä̈l 22,94; F̈e 1,98; Ċa 26,62; Ḣ 4,44; Sum. 100,04.

37. *Thomsonite* is found in black amygdaloid near Sandy Bay on Anguilla. It forms whitish, radiating nodules.

Analysis by Mr NORDSTRÖM.

S̈i 38,20; Ä̈l 31,29; Ċa 12,33; Ṅa 3,59; Ḣ (before 100°) 0,83; Loss by ignition 12,86; Sum. 99,10.

38. *Calcarious spar* is very common in the north-eastern islands. Fine crystals are found in the fissures of gray limestone in *S:t Bartholomew*. Large crystaline and transparent masses in *Anguilla*. In *S:t Eustatius* I have found fibrous lime in fissures of trachyte.

39. *Carbonate of Iron* occurs in fissures of the felsite-conglomerate of S:t Thomas and in the diorite of Virgin Gorda, Cooper's Island etc.

40. *Carbonate of Lead* is found in the lead-mines of S:t Bartholomew in small white or reddish-white crystals.

41. *Malachite* occurs in Puerto Rico (Rio Blanco) Virgin Gorda, and S:t Bartholomew.

42. *Blue carbonate of Copper* is found in small fine crystals and also uncrystalized in the lead-mines of S:t Bartholomew.

43. *Titanite* (Sphe'n) is very rare and found in almost microscopical yellow crystals in the diorite of Brown's Bay (S:t John), and in quartz-veins in the same island.

44. *Barytes* (Heavy Spar) occurs in large white masses in the lead-mines of S:t Bartholomew.

45. *Celestine* is found in small fine transparent and colourless crystals in the interior of fossil shells at Brimstone Hill (S:t Kitts). The crystals have the form $P\breve{\infty} . P\bar{\infty} . \infty P$.

46. *Anglesite* is found in S:t Bartholomew in the form of grayish white, scarcely crystaline, masses. It has evidently been originated by oxydation of galena.

47. *Double sulphate of sodium and alumina (Natronalaun)* is found in S:t Bartholomew in the walls of a cave near the sea, not far from Grand fond. It occurs here together with Gypsum and Bartholomite. The mineral is produced by alteration of pyrites, imbedded in rocks containing alumina and continually irrigated by spray from the sea. The mineral occurs in small snow-white crystaline masses of thin scales. It is very soluble in water.

According to an analysis by P. T. CLEVE it contains:

$\ddot{S}$ 45,64; $\ddot{A}l$ 14,50; $\dot{N}a$ 9,25; $\dot{H}$ 31,11 Sum. 100,50.

From the formula $\dot{N}a\ \ddot{S} + \ddot{A}l\ \ddot{S}_3 + 12\ \dot{H}$ one may calculate:

$\ddot{S}$ 45,68; $\ddot{A}l$ 14,63; $\dot{N}a$ 8,85. $\dot{H}$ 30,84 Sum. 100,00.

48. *Bartholomite*, a new compound of basic sulphate of iron and sulphate of sodium. It occurs together with the preceding mineral in S:t Bartholomew and is also produced by alteration of pyrites. It forms yellow nodules composed of small needles.

The analysis of this mineral by P. T. CLEVE has given:

Na Cl 2,88; Insoluble matter 3,56; $\ddot{S}$ 44,75; $\ddot{F}e$ 22,71; $\dot{N}a$ 17,08; $\dot{H}$ 8,08; $\dot{M}g$ 0,63 Sum. 99,69. — If we subtract from the result 2,88 Na Cl; 3,87 $\dot{M}g\ \ddot{S} + 7$ aq; 3,56 insoluble matter, and calculate the rest in 100 parts we get $\ddot{S}$ 48,66; $\ddot{F}e$ 25,41; $\dot{N}a$ 19,11; $\dot{H}$ 6,82 Sum. 100,00.

The formula $2\ \dot{N}a\ \ddot{S} + \ddot{F}e\ \ddot{S}_2 + 2\ \dot{H}$ requires $\ddot{S}$ 50,00 $\ddot{F}e$ 25,00 $\dot{N}a$ 19,38; $\dot{H}$ 5,62. Sum. 100.

The mineral is thus closely related to *Botryogen*.

49. *Gipsum* is found in very different kinds of rocks. In volcanic and trachytic rocks it occurs in several islands as Saba, S:t Eustatius etc. In clay or marl it is found in Anguilla, and also in S:t Bartholomew.

50. *Sombrerite (Collophane* of SANDBERGER) $3\ Ca\ O, PO_5 + HO$. Phosphate of lime is found in the small island of Sombrero, where it occurs in many different forms. Some

of it has the appearance of amber and is half transparent; other specimens have formerly been corals or limestone full of fossils; the carbonate of lime having been exchanged for phosphate.

Concerning the composition of the phosphate of Sombrero and of other West-Indain Islands see:

PHIPSON and JULIEN in Sill. Am. J. Sc. and Arts Vol. XXXVI (1863) p. 423.

TAYLOR Sill. Am. J. Sc. and Arts (1857) p. 177.

SANDBERGER Leonh. & Gein. Neu. Jahrb. für Min. (1870) H 3. p. 308.

D'ADHEMAR Bull. Soc. chimique de Paris 1868 p. 315.

See also for the formation of the phosphate HAGUE: On Phosphatic Guano-Islands of the Pacific Ocean (Sill. Am. Journ. [11] 34. 1862) p. 224.

Rocks from the North-eastern West-India Islands.

1. *Limestone* without fossils occurs in the Virgin Islands, as in Ginger Island (light-gray crystaline), Congo Cay (grayish-blue crystaline with parallelopipedic cleavage), S:t John between Brown's Bay and Mary's-Point (hard gray sometimes with Wollastonite,), Tortola (the west-end) and Great Thacht Island (hard, gray, crystaline and often containing numerous garnets).

Compact limestone with traces of fossils and of grayish colour is found at Judith's Fancy on the island of S:te Croix. Gray, compact limestone with fossils occurs in S:t Bartholomew.

White, hard and compact limestone with fossils occurs in Puerto Rico, Anguilla, Anegada, Sombrero etc.

Soft and chalk-like limestone is the constituent of Brimstone Hill in S:t Kitts.

Coral-limestone occurs in S:te Croix.

Recent coral-sand-stone occurs in most of the West-India Islands along the shores. It consists of small worn pieces of shells, corals and calcarious algæ bedded together to compact banks.

The surface of the limestone is often in the West-Indies very rough and contains numberless small pores.

Silicious limestone or perhaps more correctly *Silicious marl-stone* is a gray or greenish, hard and stratified rock, which often contains garnet or epidote. It frequently occurs interstratified with metamorphic rocks as micaslate, amphibolitic slate, clayslate, etc., and is very common in the cretaceous formation of the Virgin-Islands and also in the island of S:t Martin (probably of eocene date).

Marl. White chalk-like marl occurs in thick beds in the south-western part of S:te Croix. One specimen, taken near Mary's fancy, has been analyzed by Mr C. O. LUNDHOLM. It contains $\dot{C}a\,\ddot{C}$ 71,33; $\dot{M}g\,\ddot{C}$ 0,72; $\ddot{S}i$ 14,96; $\ddot{A}l$ 3,45; $\ddot{F}e$ 2,00; $\dot{K}$ 0,11; $\dot{N}a$ 0,06; $\dot{H}$ and loss 7,37. Sum. 100.

2. *Quartzite* in the form of veins is very common in the creataceous formation of the Virgin-Islands. Large masses of a kind of quartzite, probably metamorphic sandstone, is found on Virgin Gorda in the middle part of the island.

3. *Coal* of miocene date is said to occur in Puerto Rico and in Anguilla.

4. *Granite* occurs in two different forms in the cretaceous formation of the Virgin-Islands, viz: *Pegmatite* or granite occurring in veins and *Granular granite* occurring in dikes and probably of eruptive origin.

The pegmatite is always coarse and crystaline, composed of quartz, white oligoklase, reddish orthoklase and very little mica. It contains occasionally epidote, hornblend, prehnite and magnetic iron. This variety is found in veins in the anorthite-diorite of Beef-Island, at Belmont (Tortola) and in Great Thacht-Island.

Granular granite is a more or less fine-grained mixture of quartz, feldspar (oligoklase preponderating) and mica. The quartz is glassy, half transparent and commonly crystalized into pyramids, the feldspar occurs in rather small grains, often distinctly striated and of a whitish-gray or reddish colour. The mica is black or green and occurs in hexagonal leaves or needles. It is sometimes replaced by talc. It seems to graduate into felsite and always occurs in dikes. This rock occurs on Buck's-Island (near S:t Thomas) in dikes intersecting the diorite, and in the small Virgin-Islands as Peter's Island, Salt-Island and Cooper's Island, also intersecting the stratified metamorphic rocks. The small cays between Tortola and Virgin Gorda, George Dog etc. seem to consist of the same kind of rock or perhaps a crystaline variety of felsite. The rock in the cay of George's Dog consists of a mixture of reddish and whitish feldspar, some quartz, very little mica and greenish hornblend.

Granular granite from Buck's Island has the sp. gr. 2.72 and contains according to an analysis by Dr. TH. NORDSTRÖM.

Si 64,71; Al 15,09; Fe 2,56; Ca 4,51; Mg 1,16; K 1,38; Na 5,29 H 4,86. Sum. 99,56.

The rock from George's Dog sp. gr. 2,701 contains, according to an analysis by P. T. CLEVE.

Si 71,60; Al 13,63; Fe 3,03; Ca 3,37; Mg 0,94; Na 4,54; K 1,31 Ignition 0,63. Sum. 99,04.

The great quantities of lime and sodium indicate that a kind of oligoklase is here the preponderating feldspar.

5. *Felsite*, a mixture of feldspar and quartz, of which component parts the proportions are highly variable in different specimens, as is easily seen from the following analyses.

I. Felsite from »*Adlers villa*» *S:te Croix*, somewhat altered, compact, in small pieces half translucent. Sp. Gr. 2,702. Analysis by P. T. CLEVE.

II. Felsite from *Red-Point* (S:t Thomas). Dirty white, compact with small round spots of quartz. The structure of the rock is basaltic. Sp. Gr. 2,64. Analysis by P. T. CLEVE.

III. Felsite from the »*Sound*» (Virgin Gorda). Gray, micro-crystaline, with a small quantity of hornblend. Sp. Gr. 2,69. Analysis by Dr. TH. NORDSTRÖM.

IV. Felsite from *Regis Point* (S:t Thomas). Brownish gray, compact, and with small scattered reddish dots. Sp. Gr. 2,637. Analysis by P. T. CLEVE.

	I.	II.	III.	IV.
$\ddot{S}i$	63,89	80,79	69,33	73,97
$\ddot{A}l$	15,08	11,13	12,77	12,09
$\ddot{F}e$	4,63	0,35	2,19	2,90
$\dot{C}a$	9,00	0,21	7,23	—
$\dot{M}g$	1,06	—	1,03	1,03
$\dot{N}a$	1,00	4,22	4,75	3,38
$\dot{K}$	3,95	1,85	0,42	3,55
$\dot{H}$ (ignition)	1,45	1,26	1,47	1,54
Sum.	100,06	99,81	99,19	98,46

In the cretaceous formation felsite is a very important rock, and it occurs also in a great number of different forms. Sometimes the structure is compact, sometimes microcrystaline. In some varieties it is impossible to distinguish the component minerals, but in others quartz in small spots or pyramids may be seen distinctly, as at Cocolus Bay and Grass Cay (S:t Thomas), in which case the rock is quartz porphyry, or else the feldspar is seen in small crystals in a compact mass. In the latter case the rock may be called felsite-porphyry.

The rock occurs massive or in dikes and is consequently in all probability eruptive, but it occurs most often in stratified beds, and it is then an igneo-sedimentary rock.

The massive variety has sometimes an irregular angular cleavage, often its structure is parallelopipedic (as in Virgin Gorda) or basaltic, (as near Red Point, S:t Thomas).

Compact felsite interstratified with micaceous scales occurs in Dead-man's Chest.

In the form of breccia the felsite is very common. The breccia exhibits a great number of varieties, sometimes it has the coarseness of common sandstone, and sometimes the pieces in the breccia are some inches in diameter.

A peculiar variety of felsite occurs in the island of *S:te Croix* around the town of Christianstaed. Here it forms a kind of variolite, very distinct when the surface of the rock has been altered by atmospheric action.

A special variety of felsitic breccia is the »*bluebeache*», the most common rock in the Virgin-Islands. It is a breccia or conglomerate of felsite containing much hornblend commonly altered to a chlorite-like mineral, which gives the rock a dark-green and bluish colour. Further on in treating of the breccias, I shall give a more complete description of this rock.

The colour of the felsite is commonly light, whitish, grayish, or reddish. Through alteration it commonly gets the rose or bloodred colour, which is so characteristic in this rock on the southern coasts of S:t Thomas and S:t John. When the alteration is strong the rock graduates into kaolin. Sometimes the felsite contains some mica or talc and may then be called *protogine felsite*, and when the quantity of the latter ingredient increases the rock graduates into talc-slate. In many places in the eastern parts of *S:t John* such

gradual passages from felsite to a kind of fine-grained talc or mica-slate are to be found. In some places the felsite graduates into clay-slate as on the north side of S:t Thomas, near *Maho Bay*.

6. *Syenite-Porphyry* occurs in the eocene formation of *S:t Bartholomew* and probably also in *S:t Martin*, where I found loose boulders of this rock.

It appears to be a mixture of orthoklase, oligoklase and very little hornblend. It does not contain quartz in any quantity. The mass is gray or dirty greenish, compact and contains many small white crystals of feldspar or black shining needles of hornblend. The rock is evidently eruptive, it has a parallelopipedic or more commonly globular-concentric structure. It is very hard and is sometimes employed as building-stone in the town of S:t Bartholomew.

Its Sp. Gr. is 2,61, and one analysis by P. T. CLEVE has given:

$\ddot{S}i$ 66,28 $\ddot{A}l$ 16,23 $\ddot{F}e$ 2,71 $\dot{F}e$ 1,62 $\dot{C}a$ 4,03 $\dot{M}g$ 1,03 $\dot{N}a$ 3,36 $\dot{K}$ 1,60 $\dot{H}$ 2,65. Sum. 99,51.

7. *Diorite.* A crystaline granular mixture of oligoklase, hornblend and some mica. The rock occurs to a great extent in the cretaceous formation of the Virgin-Islands, and also in S:t Martin, which latter is probably of eocene formation. In Crab Island the diorite is the ruling rock; in S:te Croix also diorite is noticed near South-Gate and in the small rock called Green Cay, in which latter spot the rock is very coarse and contains some quartz. The little Buck-Island near S:t Thomas consists of diorite, penetrated by numerous trap-dikes. In the islands bordering the Francis Drake's Channel, and also in Virgin-Gorda and S:t John, the diorite occurs, and it is very probable, that the channel has been excavated in this rock of comparatively easy decomposition, which has originally formed an enormous large mass here situated in the synclinal axis of dipping metamorphic and stratified rocks.

The diorite of the Virgin-Islands has a great resemblance to syenite, being of a whitish colour from feldspar preponderating.

The feldspar is a variety of oligoklase containing much lime (Hafnefjordit). The analysis of that mineral has been given previously.

Hornblend occurs in a smaller quantity. It has a greenish black colour.

Greenish or bronze-coloured mica is to be regarded as an almost constant component and the rock may consequently be classed as Mica-diorite.

The diorite contains a little magnetic iron, however only a very small percentage. Among accessorial minerals found in the diorite I may mention *epidote* in crystaline masses or uncrystalized compact concretions (Brown's Bay, S:t John); *titanite* in small almost microscopical honey-coloured crystals; *garnet* of brownish colour and small quantities of copper-minerals. In fissures in the diorite *desmine*, *carbonate of iron* and white *quartz* are sometimes found. The rock is often penetrated by numerous dikes with diabase or granular granite.

The following analysis will show the chemical composition of the diorite:

1. Diorite from *Mary's Point* in S:t John, Sp. Gr. 2,801. contains only traces of magnetic iron. The analysis of the feldspar is given above. Analysis by P. T. CLEVE.

S̈i 59,24 Ä̇l 18,16 F̈e 3,26 Ḟe 3,56; Ċa 6,31 Ṁg 2,84 Ṅa 4,00 K̇ 1,31 ignition 0,87 Sum. 99,55.

2. Diorite from Beef-Island Sp. Gr. 2,860 contains 1,27 percent magnetic iron. Analysis by P. T. CLEVE.

S̈i 61,35 Ä̇l 15,39 F̈e 4,41 Ḟe 3,40 Ċa 6,60 Ṁg 3,32 Ṅa 3,87 K̇ 0,95 Ḣ 0,58. Sum. 99,87.

3. Diorite from *Ginger Id.* Analysis by P. T. CLEVE. The rock is more fine grained and darker coloured than 1 and 2 and occurs in *strata* imbedded in unstratified diorite. It may be termed stratified diorite.

S̈i 53,85 Ä̇l 17,15 F̈e 4,08 Ḟe 6,95 Ċa 8,99 Ṁg 5,29 Ṅa 3,01 K̇ 0,24 Ḣ 0,58. Sum. 100,14.

4. Diorite from *S:t Martin* near the town of *Philipsburg*, eruptive and light-coloured Sp. Gr. 2,72. Analysis by P. T. CLEVE.

S̈i 65,61 Ä̇l 17,26 F̈e 2,47 Ċa 7,66 Ṁg 2,50 Ṅa 4,19 K̇ 1,09. Sum. 100,78.

One may conclude from the small quantity of silica that the rock contains no quartz, and from the little quantity of potash that orthoklase does not enter in the composition.

The diorite is in most places unstratified and in some cases I have distinctly seen that the rock has been injected in a liquid state into branching veins in the surrounding rock. Very fine specimens of diorite occurring in this manner, are exhibited at Brown's Bay in S:t John, also at S:t Martin in the seacliffs near Philipsburg. In other spots no traces whatever are to be found of a violent intrusion into the surrounding rocks at their contact with the diorite. Thus in several of the small islands south of Sir Fr. Drake's Channel one may find diorite alternating in regular strata with amphibolitic schists and also gradual passages from those schists to massive diorite without any traces of stratification. It will not be easy to account for these differences as the diorite evidently belongs to the same mass. I think that the contradiction may be explained by supposing that the diorite is only a strongly metamorphosed clay slate and that the heat has given rise to the change and been increased also, through the same metamorphic action and in some parts of the mass even been strong enough with the aid of water and a powerful pressure to reduce the rock to a molten state. The gradual passages from diorite to amphibolitic schists and from them to clayslate make the hypothesis very probable. and the heat necessary to melt the rock with the aid of water and pressure, need not necessarily have been very high. It is also of interest to remark the fact, that the stratified rocks on both sides of the strait between S:t John and Tortola, where the mass of diorite is not very thick, dip in an opposite direction to the axis of the strait, when at some distance north and south of Sir Francis Drake's Channel, where the diorite has evidently been of an enormous thickness, the strata dip to the south as well in Tortola as in the small Virgin-Islands. The strata of the latter islands may be regarded as the continuation of the stratified rocks on the northern part of S:t Thomas and S:t John, where the dip is to the north. The change of dip is probably due to an inerease in the volume of the rock by its change to diorite.

I believe, consequently, that the diorite-mass is a volcanic hearth in fossil state, and I cannot participate in the common spinion, that the volcanic rocks are emanations from

a common molten igneous mass in the interior of the earth. The great variety in the chemical composition of the volcanic rocks, even in those from the same volcano, does not well harmonize with the hypothesis of an igneous molten mass in the interior of the earth. The heat produced by metamorphosis of mountain masses of many miles in extent may also be immense if it cannot escape, and may under favourable circumstances, give rise to volcanic phenomena.

The diorite of the Virgin-Islands has generally a very fine concentric-globular structure. It encloses in a more easily decomposed mass rounded concretions of concentric layers. These concretions are sometimes of an enormous size, being often as large as small houses, and the altered surface of the diorite is mostly covered by numerous blocks having the appearance of erratic blocks, which they are not by any means.

8. *Diabase* is a solid greenish-black fine-grained rock, in which one can scarcely distinguish the constituting minerals. In some varieties crystals of augite are scattered through the mass and by the chemical analysis one may take it as most probable that the feldspathic mineral is labradore, or perhaps also oligoklase. The black colour seems to be due to a chlorite-like mineral produced by alteration of the augite.

The diabase is very common in the formation of the Virgin-Islands, where, in the form of dikes, it penetrates bluebeache, diorite, felsite and sometimes, as in Whisling Cay near S:t John, stratified rocks. Generally the dikes with diabase are very narrow but larger masses also occur, as in the Hans Lollik islets north of S:t Thomas.

The colour of the diabase is mostly dark-green or black and it is commonly fine-grained, but in *Mariebluff* in S:t John it has an amygdaloidal structure. Augite often occurs in distinct crystals in the mass, as in *Buck's-Island*, *Coki Point* and *Hans Lollik, (S:t Thomas)*, giving rise to augitic porphyry. As an accessorial mineral in the diabase I have found epidote. Sometimes the diabase encloses fragments of the surrounding rock, and the dikes are generally most fine-grained near the surrounding rock and more crystaline in the middle, facts proving the eruptive nature of the rock.

The chemical composition of the diabase of the West-Indies may be seen from the following analyses.

I. *Buck's-Island* (S:t Thomas); black with crystals of augite. Sp. Gr. 2,854. Analysis by P. T Cleve.

II. *Coki-Point* (S:t Thomas); black with crystals of augite. Sp. Gr. 2,902. Analysis by E. Eklund.

III. *Whisling Cay* (S:t John); grayish-black, fine-grained. Sp. Gr. 2,895. Analysis by P. T. Cleve.

IV. *Coral-Bay* (S:t John); distinctly crystaline. Sp. Gr. 2,960. Analysis by P. T. Cleve.

V. *Red Point* (S:t Thomas); dike in felsite. Sp. Gr. 2,905. Analysis by P. T. Cleve.

	I.	II.	III.	IV.	V.
Si	48,12	48,42	54,07	49,84	52,55
Al	18,60	17,49	16,30	18,32	14,20
Fe	4,00	6,79	5,75	4,16	9,43

Ḟe	6,30	4,34	5,84	5,21	6,50
Ċa	7,36	9,83	7,63	12,31	6,68
Ṁg	6,16	5,35	3,41	3,93	4,03
Ṅa	4,11	3,98	4,00	3,24	4,51
Ḳ	1,09	0,55	0,90	—	0,20
Ḣ	3,63	2,68	1,35	2,05	1,62
	Sum. 99,37	99,43	99,26	100,06	99,72

9. *Labrador-Porphyry*, in chemical composition closely related to the diabase, is in the West-Indies such a distinct kind of rock that I may treat of it here as a separate species. It is found only on Culebra, which island seems to be entirely formed of that rock. The Labrador-porphyry is a dark-brown or grayish black and fine-grained rock, and contains numerous whitish crystals of feldspar, which, judging from the chemical composition of the rock, are labrador. Those crystals are commonly arranged in star-like groups or crossing one another. Also occur in the mass small needles of green augite.

The Sp. Gr. of the rock is 2,87, and the chemical composition, according to an analysis by Dr. Th. Nordström, the following:

S̈i 52,55; Ä̇l 14,96; F̈e 5,80; Ḟe 6,19; Ċa 7,05; Ṁg 3,22; Ṅa 5,37; Ḳ 2,83; ignition 2,48. Sum. 100,45.

The Labrador-porphyry is a massive rock, in general with a fine parallelopipedic or polygonal structure. It encloses numerous veins with rock-crystals, red iron-silex, green quartz or calcarious spar, sometimes, also, epidote or a chlorite-like mineral.

10. *Anorthite-Diorite*, is a crystaline mixture of anorthite (analysis of that mineral is given above), hornblend, and titaniferous magnetic iron. The rock is seen only in Beef-Island and occurs perhaps also in Virgin-Gorda. In the former island it form a mass enclosed in diorite.

Its Sp. Gr. is 3,059, and the composition according to an analysis by Mr. Patr. Peterson:

S̈i 44,60; Ä̇l 15,28; F̈e 8,50; Ḟe 8,03; Ċa 14,50; Ṁg 6,82; Ṅa 0,33; Ḳ 0,01; T̈i 0,92; Ḣ 0,56. Sum. 99,65.

With the magnet I was able to extract 7,5 percent of magnetic iron.

The anorthite is grayish white, half-transparent and sometimes it shows a fine twin-striation.

The hornblend forms black, shining crystals, sometimes of a large size. The magnetic iron occurs in small grains penetrating the rock.

The anorthite-diorite has a polyhedric or spheric structure and contains veins with quartz or pegmatite-granite.

As accessorial minerals in the rock I have found epidote and some traces of copper-minerals.

11. *Trachyte* is the ruling rock in the volcanic islands as Saba, S:t Eustatius, S:t Kitts, Montserrat etc. The rock of Saba is composed of a dirty-red porous mass in which

are imbedded numerous white crystals of glassy feldspar (easily melted by the blow-pipes) some needles of hornblend and also very few small greenish crystals of augite.

The Sp. Gr. is 2,71.

The rock of Saba has been analysed by Dr. TH. NORDSTRÖM.

Si 60,80 Äl 16,34 Fe 0,68 Fe 5,14 Ca 6,92 Mg 1,47 Na 6,71, K 1,12 H 0,37. Sum. 99,55.

The small quantity of potash as well as the presence of much lime and sodium prove that the rock is chiefly composed of oligoklase (andesine?) or microtinite, and as the low quantity of silica indicates the absence of quartz, this trachyte may be classed as microtinite without quartz.

Near the sulphur-mines of Saba the trachyte is changed to a kind of alum-stone. Such an altered trachyte has been analysed by Mr. TH. FIEBELKORN who has found it to contain:

Si 34,10 S 32,00 Äl 17,82; Al_2 Cl_3 5,47 K Cl 0,10 H 12,00. Sum. 101,49.

Thus by action of vapours containing sulphuretted hydrogen the rock has been deprived of its iron, lime, sodium, and a part of the silica, the former having been transformed to soluble sulphates and swept away.

12. *Mica Schists* are found in subordinate strata in the small Virgin-Islands as Salt Id, Peter's Id and in the northern part of S:t John. The mica always occurs in small dark scales. Schists of grayish or reddish colour and composed of very small scales of talc or mica occur near Caroline Estate in S:t John. It graduates into felsite, from which rock it seems to have originated by metamorphosis. In other places the mica schists seem originally to have been clay-slate as in the small islets between S:t John and S:t Thomas, and in Whisling Cay near S:t John.

13. *Clay-slate.* Black clay-slate, containing no fossils and in appearance resembling silurian clay-slate, is in the island of *S:te Croix* an important rock, constituting several high hill or mountains. It is also found in the northern part of S:t Thomas and S:t John. In Tortola I found the rock near Coxheat.

By metamorphosis the clay-slate is transformed in some places (as in S:t Croix, near Goathill, and at a spot near Christianstæd) to lydian stone or to a kind of hard gray chert or quartzite.

In other places may be seen gradual passages from clay-slate to mica slate, hornblend-slate and diorite. The smaller islands south of Sir. Fr. Drake's Channel, as also the north of S:t Thomas and S:t John, afford a very good opportunity for the study of those rocks.

14. *Chert-breccia* (Hornsteins-breccia). As such I consider a yellowish-white alveolar rock, probably originating from metamorphosis of volcanic breccias. It occurs in *S:t Bartholomew* in great extent near Grand fond.

15. *Limestone-breccia*, a rock composed of angular pieces of yellowish-white limestone cemented by a fine-grained red matter, occurs in fissures in the miocene formation of Anguilla. It contains bones of extinct mammals and shells of still living air-breathing mollusca. In the composition of the rock there is also some phosphate of lime.

16. *Magnetic-Iron-sand* occurs in a small quantity on Beef-Island near Tortola, where it has been washed down from the anorthite-diorite.

17. *Felsitic breccia.* Of that rock I have already treated in the article on Felsite.

18. *Bluebeache,* a rock thus named by the inhabitants, is a kind of felsitic trap conglomerate or breccia, varying very much in appearance. It has generally a dark bluish or greenish colour, sometimes also brown. It consists of angular pieces of felsite, porphyry, rounded scoriæ etc., of various sizes, imbedded in a darkgreen mass and occasionally containing hornblend or chlorite. Often its structure of conglomerate is so obliterated, that one may consider the rock to be a kind of trap or porphyry. In fine-grained varieties of this sort, the rock often has a fine spheroidal-structure. Sometimes the hornblend increases to such a degree that the rock may be mistaken for diorite. It is very likely that the clay-slate of the Virgin-Islands is only an exceedingly fine-grained variety of bluebeache.

Near Virgin-Gorda, in the small island of Prickly Pear occurs a remarkable variety in the form of an argillaceous, bluish-gray very fine-grained mass.

The bluebeache belongs to the cretaceous formation of the Virgin-Islands, S:te Croix and Puerto Rico.

19. *Porphyritic-breccia, conglomerate* and *tufa,* very much resembling bluebeache, are igneo-sedimentary rocks of the eocene formation of *S:t Bartholomew* and *S:t Martin.* The rock, varying in an extraordinary degree, is very difficult to describe or characterize. It is often stratified and alternates in *S:t Bartholomew* with strata of fossiliferous limestone. It is composed of larger and smaller fragments of different kinds of rocks, as volcanic scoriæ, small pieces of an altered rock, probably clay-slate, and of porphyry, etc. In different places the rock is more or less coarse or fine-grained, sometimes resembling claystone or clay-slate of a light colour.

The more fine-grained varieties frequently contain smaller crystals of feldspar, and are thus a kind of porphyry. It has sometimes a fine variolitic structure.

It contains very often fossils or nodules of fossiliferous limestone which proves it to be evidently of submarine origine.

By metamorphosis the rock is sometimes much altered. Thus chert-breccia and quartzite occur in S:t Bartholomew which have obviously been breccia in former times.

20. *Trachytic tufas,* composed of small quantities of feldspathic and often pumiceous ashes, occur in the volcanic islands, as in Saba, S:t Eustatius, S:t Kitts, etc.

VI. Notes on the geology of the other West-India Islands.

Cuba. The geology of this large island is very little known. In the history of Cuba by *Ramon de la Sagra* a chapter is devoted to the geology of the island*). The greatest part of the island is covered by a large and thick limestone formation, which, to judge from the fossils, seems to be of the same geological age as the limestone of Jamaica, S:t Domingo and Puerto Rico etc., or the miocene age. The fossils, of which

*) Histoire physique, politique et naturelle de l'ile de Cuba T. I. p. 107 Paris 1842.

d'Orbigny has published some illustrations belong partly to still living species and partly to extinct forms, found also in the miocene rocks of Anguilla and Puerto Rico. In the island of Cuba, too, an elder formation occurs, containing syenite associated with serpentine, basaltic rocks and brown saccharoid lime-stone. That formation is remarkable for the occurrence of very rich metalliferous veins*) and bituminous coal. The age of this formation, in which no fossils are found, is unknown.

*Jamaica***). The geology of this large island is far better known than the geology of the other West-India islands. We are especially indebted for our knowledge of the island to Mr. BARRETT, whose early decease was unfortunately a great loss to science.

The oldest fossiliferous rocks of Jamaica belong to the cretaceous formation. They are visible in the eastern part, near *Bath*, as well as in the interior of the island in the *Clarendon* district. The fossiliferous rocks rest upon igneous conglomerates and porphyries. They are very disturbed strata, sometimes almost vertical, sometimes raised at an angle of 40°—50°. The strata consist of compact limestones, shales etc. Among the fossils are *Nerinæa*, *Acteonella lævis* d'Orb, *Orbitoides* and *Rudistes (Barettia Monilifera* Woodw). The formation is believed to be an equivalent to the European »Turonien». To judge from the description, the petrographical character of the rocks seems to have a great resemblance to that of the rocks of the Virgin-Islands. The eocene formation of Jamaica is well developed and it forms beds of 1,000 meters in thickness. The rocks of the lower part of the eocene formation are porphyritic conglomerates, and in the upper part shaly and sandy beds occur. Some fossils are found in the upper part, and among them some corals, known from the eocene beds of the old world. It seems probable, that the eocene formation of Jamaica dates from the more ancient part of that time.

The greatest portion of the surface of Jamaica is covered by a hard and white limestone-rock, at least 600 meters thick. It contains only few fossils and rests in some parts unconformably and in others conformably upon strata of about 200 meters in thickness. The latter beds consist of sand, marls or various calcarious rocks and contain a

*) Descriptions of these veins are given by Mr ANSTED Quart Journ. Geol. Soc. Vol. 12, 1856 p. 144.

**) Papers published on the geology of Jamaica and of which I am cognizant, are:

1827 H. DE LA BECHE. Remarks on the geology of Jamaica Transact, Geol. Soc. of Lond. II Ser Vol. II, part II, p. 143—195.

1856 A. S. ORSTED. Skildring af naturen paa Jamaica (Tidskrift for populære framstillingar of naturvidenskaben p. 80).

1860 BARRETT. On some cretaceous rocks in the south eastern portion of Jamaica. Quart. Journ. Geol. Soc. Vol. 16 p. 324.

1862 SAWKINS. On the association of granite with Tertiary strata near Kingston, Jamaica. Quart. Journ. Geol. Vol. 19 p. 35.

1863 CARRICK MOORE. On some Tertiary Shells from Jamaica with a note on the corals by P. MARTIN DUNCAN and a note on some nummulinæ and orbitoides by R. JONES. Quart. Journ. Geol. Soc. Vol. 19 p. 510.

1864 DUNCAN and WALL. »A notice of the Geology of Jamaica etc.» Quart. Journ. Geol. Soc. Vol. 21 p. I.

1866 GUPPY on the tertiary mollusca of Jamaica. Quart. Journ. Geol. Soc. Vol. 22 p. 281.

large number of well preserved shells and corals. Some of the shells belong to species still living in the surrounding sea and some are extinct. The extinct species, as well as the corals, belong to types, in our time living in the Australian sea and the East-Indies. Some of the fossils also are known from the miocene beds of Malta, Vienna, Turin and Faluns. Consequently the formation is certainly of miocene date.

The most recent formation of Jamaica consists of alluvial beds around Kingston, Rio-Minho etc.

San Domingo. The greatest part of this large island is very little known to geologists. Only the northern part around the river *Yaqui,* is known from an able description by Colonel *Heneken**). The oldest formation consists of metamorphic and crystaline rocks and occurs in the *Cibao Mns.* They are covered by unfossiliferous rocks as greenstones, crystaline marble and micaceous schists, sometimes containing bituminous deposits. These rocks form the cordilleras of *Monte Christo.*

The younger formation begins with a red unfossiliferous sandstone, in horizontal or inclined beds, sometimes about 200 meters in thickness. Above the sandstone blue and green fossiliferous shales, argillaceous shales, and shingle-beds occur. They are called *Nivaje shale* and are about 200 meters thick. They are covered by tufaceous lime-stone in beds of about 100 meters in thickness. According to the paleontological researches of *Duncan, Sowerby* and *Moore* the Nivaje shale belongs to the miocene formation. In the southern part of San Domingo tertiary beds with large quantities of rock-salt have recently been found.

The Bahamas consist of a very large group of islands and cays, stretching from N. W. to S. E. between the West-Indies and Florida, north of Cuba and S:n Domingo. They are all very low and flat and probably of a very recent geological date**). They seem to have a very close resemblance to the island of Anegada, previously described.

Barbuda is a low and flat island north of Antigua. My only acquaintance with the geology of this island is derived from the following short description given by *Guppy****).

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*) Litterature concerning the geology of S:n Domingo:

1843 Th. Haupt. Geognostische und bergmännische Bemerkungen über S:t Domingo. Karsten und Dechen. Archiv für Mineral. Geogn. Bergbau und Hüttenkunde. Band XVII, p. 536—672.

1850 Carrick Moore. On some Tertiary beds in the island of S:n Domingo from notes by T. S. Heneken with remarks on the Fossils. Quart. Journ. Geol. Soc. VI p. 39.

1853 T. S. Heneken. On some Tertiary Deposits on S:n Domingo with notes on the fossil shells by J. C. Moore and on the fossil corals by L. Lonsdale. Quart. Journ. Geol. Soc. IX p. 115.

1863 Duncan P. Mart. On the fossil Corals of the West-Indian Islands P:t I. Quart. Journ. Geol. Soc. Vol. XIX p. 406.

1864 Duncan P. Mart. On the fossil Corals of the West-Indian Islands Part II. Quart. Journ. Geol. Soc. XX p. 20.

1868 Hatch. On a saliferous Deposit in S:t Domingo. Quart. Journ. Geol. Soc. XXIV p. 335.

1869 Ruschhaupt. On the salt-mines of S:t Domingo. Quart. Journ. Geol. Soc. Vol. XXV p. 256,

**) See Capt. R. J. Nelson. On the Geology of the Bahamas. Quart. Journ. Geol. Soc. Vol. IX p. 200 1853.

***) Guppy. On the relation of the tertiary formations of the West-Indies. Quart. Journ. Geol. Soc. Vol. XXII p. 578. 1866.

»Barbuda contains a formation resembling the coral-limestone of Barbados. It consists of a white calcarious deposit full of shells, all of which are, as far as I have examined, of existing species. The existence of a miocene formation in that island seems, nevertheless, to be indicated by the corals described by Dr. DUNCAN.»

As all the fossil shells of Barbuda appear to belong to still existing species and the miocene formation of the West-Indies contains comparatively few still living species, it may be found most probable that the formation of Barbuda is of a later date than the miocene time, unless miocene beds also occur in the island together with more recent strata.

*Antigua**). The island is composed of different kinds of rocks belonging to different geological ages. The oldest formation of Antigua is visible in the south-western corner where it forms a mountainous land with peaks, of which the highest rises about 406 meters above the sea-level.

This formation is composed of basalt of a globular structure and breccias, greenstone and porphyry. In that part of the island veins, containing heavy spar, are found.

Above this formation a series of stratified feldspatic clays of green or yellow colour occur. The strata dip generally 15°—20° to the north. Porphyry, greenstone and amygdaloid are found in this formation, which forms a band stretching from the *Five Island* division in *Dickinson Bay* to *English Harbour* and *Willough Bay*. Its highest point is Monkey-Hill. Near *Drews Hill* impressions of leaves, as also fossil wood and some shells and corals are found. A bed of hard, opake, white lime-stone rests *unconformably* upon this formation. It contains much chert, a great number of shells belonging to the genus *Cerithium* or *Melania*, silicified wood, and corals. The chert-formation occurs, according to DUNCAN, in the exact position of a fringing reef. The greatest part of the island is a hilly land, consisting of white and yellow marls and of more or less compact limestone etc. This formation contains a large number of fossil corals and shells, among which are also some terrestrial, but no fossil wood is found here. According to DUNCAN the fossil coral-fauna has no connection with the extant Caribbean, but it has a great affinity with the miocene fauna of Europe, as well as with what now exists in the Pacific Ocean. The fossil corals prove that the formation is of miocene date (DUNCAN), and according to Hovey about 70 percent of the fossil shells belong to still living species.

*Nevis***) is a high, conical and entirely volcanic island, south of S:t Kitts. It has hot springs, sulphur deposits, and also still working fumarols.

Redonda is a small and also volcanic island. (De Jonnés L'Hist. des Ant. Franc. pag. 79).

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*) Litterature on the geology of Antigua:

1821 NUGENT. Description of Antigua. Transact. of Lond. Geol. Soc. 1 Ser. Vol. V pag. 459.

1839 HOWEY. Geology of Antigua. Sillim. Am. Journ. Vol. XXXV p. 75.

1863 DUNCAN P. M. On the fossil corals of the West-Indian Islands. Quart. Journ. Geol. Soc. Vol. XIX pag. 408.

I have not had an opportunity to read the paper by NUGENT.

**) MACLURE. Journal of the Acad. of Nat. Sc. of Philadelphia. Vol. I Part. I p. 145.

Montserrat is volcanic. The rocks are trachytic and consist of white sanidine intermixed with black hornblend. It is employed in the West-Indies as »fire-stone». The volcanic action still continues in form of souffrières, exhaling sulphuretted hydrogen (NUGENT Trans. Geol. Soc. Vol. I pag. 185. 1811).

*Guadeloupe**) consists of the two islands of Basse Terre and Grande Terre, separated by a narrow channel. The latter, or eastern of these islands, constitutes a flat, hilly land while *Basse Terre*, or the western, is an entirely volcanic and very high and mountainous island.

The oldest formation of Grande Terre comprises rocks, called by *de Jonnés* and *Duchaissaing* »*Pierre à ravets*», and »sables volcaniques remaniés par la mer». The formation contains in the lower part a yellow tufa with but few fossils, although above that stratum grayish black, loose volcanic sands with numerous fossils occur. On these beds is superimposed a hard, sonorous and fine-grained limestone, containing fossil *Terebratulæ*. *Duchaissaing* enumerates among the fossils, found in the sandy beds, *Arca umbonata*, *Pectunculus pulvinatus* Lamk and *Cyathina Guadeloupensis*. The *Pectunculus* is a well known species of the European Eocene formation and, to judge from the description, the series of strata greatly resemble the eocene beds of *S:t Bartholomew*. The surface-formation of Grande Terre consists of a white, tolerably hard, calcarious tufa, containing foraminifera and numerous fossils, most of which, according to *Duchaissaing*, belong to still living species. Among the fossil echinoderms several extinct species are recorded. Also the *Lunulites umbellatus* is said to have been found in these beds. It seems to me to be most probable that this formation is of miocene age, as, to judge from the descriptions, there are several points of resemblance to the formation of Anguilla. Mr. *Duchaissaing* considers the formation to be the »older pliocene».

The third formation, or the newer pliocene of *Duchaissaing*, consists of 1. *madrepore-formation*, along the coasts, only elevated 2—3 meters above the sea, of 2. *alluvium*, containing shells of the large *Succinea patula* Brug., and 3. »*terrain à galibis*», which is of a very recent date, and contains human skeletons or anthropolites mixed with terrestrial or beach-shells, corals and fragments of crabs.

The neighbouring islands of *Desirade* and *Marie Galante* consist according to MACLURE of horizontal strata of coralline limestone.

Basseterre is still an active volcano with four volcanic centers (according to de Jonnès). One of these called the »soufrière» made eruptions in 1778 and 1797. In Basse-

*) Treatises on Guadeloupe:

1817 MACLURE. Journ. of the Acad. of Nat. Scien. of Philadelphia. Vol. I. Part. I p. 134.
1822, DE JONNÈS, ALEX. MOREAU. Histoire physique des Antilles francaises. Paris.
1847, DUCHAISSAING, PIERRE. Bullet. de la Soc. Géol. de France 2:me Sér. Tome IV. Part. II p. 1093.
1855, » » Bullet. de la Soc. Géol. de France 2:me Sér. Tome XII p. 753.
1860, DAMOUR. Comptes Rend. Tome LI p. 559.
1863, PAYEN. Bullet. de la Soc. Géol. de France 2:me Sér. Vol. XX p. 475.
1866, GUPPY. Quart. Journ. Geol. Soc. Vol. XXII p. 577.

Mr. CH. STE CLAIRE DEVILLE has published a work: Voyage Géologique aux Antilles, but I had no opportunity to see this work complete.

terre some fossiliferous deposits have been found by Mr. PAYEN. They contain shells of species still living in the Caribbean Sea except one *Terebratula*, which, according to Mr. DESHAYES, seems to be new. One of these deposits occurs at the hight of 40 meters, about 50 m. from the shore, and the other, which rests upon horizontal beds of volcanic rocks reaches the hight of 100 meters and is 200 meters from the sea. They seem to belong to the same geological time as Brimstone Hill in S:t Kitts.

*Dominica**) is separated from Guadeloupe by a strait, in which about 8 small volcanic islands »*Les saintes*», occur. The island is built by tufas, cinders, or lavas, and has two volcanic centers, one at the north, »La montagne du diable», and one at the south, »La soufrière». The island has hot springs, crater seas, and soufrières with alum stone and sulphur. A bed of coral lime-stone at an elevation of about 60—100 meters above the sea is found near *Rousseau*, resting horizontally upon and covered by beds of cinders.

*Martinique***). This large and mountainous island, extending N. W. to S. E., is entirely volcanic, and has according to DE JONNÈS six volcanic centers. The most northerly is *La montagne Pelée* of the height of 1,349 meters above the sea, (according to the survey by MONNIER 1824—25). Another volcanic center is *Piton de Carbet* which rises to the hight of 1,207 meters. Near another volcanic mountain, *le Volcan de Marin*, a bank of limestone is found, resting upon and covered by volcanic rocks.

S:ta Lucia is, geologically, very little known, but seems nevertheless to be entirely volcanic, as having hot springs and soufrières.

S:t Vincent is also a volcanic island, on which tremendous volcanic eruptions in the years of 1718 and 1812 are recorded, (see DE JONNÈS Hist. Phys. des Ant. Franc. p. 67.

The Grenadines form a group of about ten volcanic islets, having lava rocks of columnar structure, (see MACLURE L. c. p. 139 and DE JONNÈS L. c. p. 67).

Grenada is a volcanic island with several regular craters. According to DE JONNÈS (L. c. p. 66.) the island has two volcanic centers, one of which has formed the hill of *S:t Simon* and the other, to the south, had its crater in the pond surrounded by the hills of *S:t Sinai*, *S:t George* and *Beau Sejour*.

Tobago. According to DE JONNÈS (L. c. p. 120) the center of this island is volcanic and surrounded by large limestone beds.

*Barbados****). In the eastern, mountainous part of the island, called *Scotland*, the oldest formation of Barbados is found. It consists of a series of stratified slates, limestone and conglomerates etc, in strata, which dip to the N. E. and strike N. W.—S. E. The formation contains bituminous matter and also the well known silicious beds with remains of polycistinæ and diatoms. In this formation three species of fossil shells were

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*) 1817 MACLURE. Journ. of the Ac. of Nat. Hist. of Phil. Vol. I. Part. I p. 143.
1822 DE JONNÈS, A. MOREAU. Hist. Phys. des Ant. Franc.

**) 1817 MACLURE L. c. p. 142.
1822 DE JONNÈS. Hist. Phys. des Ant.

***) *Litterature:*
1816 SKAY. Trans. of the Geol. Soc. of Lond. Vol. III, p. 236.
1817 MACLURE. Journ. of the Acad. of Nat. Scien. of Philad. Vol. I. Part. I, p. 135.
1848 SCHOMBURGK. The History of Barbados London, 8:o.

found by SCHOMBURGK and described by FORBES, namely: *Scalaria Ehrenbergii, Nucula Schomburgkii* and *Nucula Pacheri*. The geological age of this formation is not known but it seems most likely that it is of the eocene or cretaceous period.

Of a newer time is the large formation of white and almost horizontal strata of limestone with corals and shells, by which the southern, western and northern parts of the island are covered, and which ascends from the sea in the form of four or five terraces. This formation contains a large number of shells, of which a list is given by SCHOMBURGK. Most of them belong to species still living in the surrounding sea. Mr. HOVEY*) remarks that, out of 41, species of fossil shells collected by him, he could not find more than three which he was unable to identify with living species, for which reason the formation appears probably to belong to the latest pliocene time.

That under this formation miocene beds occur is very likely as Mr DUNCAN**) describes a fossil coral, the *Astræa Barbadensis*, as having been found in a well sunk 40 feet in the coral marl. This coral is also found in the miocene formation of Antigua.

*Trinidad****). In geological respect this island is a continuation of the geological formations on the northern coast of South America. In the northern part of Trinidad metamorphic rocks without fossils and of unknown age occur. They consist of micaceous slates, sandstones and shales with bands of white or blue crystaline limestone. This series of rocks is called by the British surveyors The »*Caribbean*». In the middle of Trinidad a range of indurated sandstone with dark micaceous shales in exposed, and is believed to belong to the lower cretaceous formation (Neocomian). This series is called the »*Older Parian*». The space between the Caribbean and theolder Parian is filled with crystaline limestones and calcarious sands containing fossils and called the *Tamana series*, which is overlaid ty the *Caroni series* of sand, shale, clay and calcarious sand, with lignite. Near the crystaline rocks these beds are covered by a mass of detritus from the Caribbean rocks, which is termed the *Detrital series*. South of the older Parian are the *S:n Fernando* beds, consisting of marl and indurated limestone, and to the south of the latter series occurs the *Moruga* series. The S:n Fernando beds and the Tamana series constitute together the lower, and the Caroni and Moruga series the upper part of the *Newer Parian*, in the latter of which the mud-volcanos and the asphalt lake occur. The newer Parian is supposed to belong to the miocene formation, but, judging from its fossils, it seems more probable that the lower part belongs to the eocene and only the upper part to the miocene formation.

The fossils found in the San Fernando beds are: three species of *Terebratula*, several species of *Orbitoides, Lucina, Cardita, Pinna, Arca* etc., and beside these also the *Echinolampas ovum serpentis* GUPPY and *Ranina porifera* Wood, the former and also a species of

*) Sill. Am. Journ. Vol. XXXV, pag. 79. 1839.

**) Quart. Journ. Geol. Soc. Vol. XIX, p. 452.

***) Litterature known by the author.

1811 NUGENT. Trans. of the Geol. Soc. L. Vol. I, p. 63.

1856 BOWEN. Quart. Journ. Geol. Soc. Vol. XII, p. 389.

1860 WALL, G. P. Om the geology of a part of Venezuela and of Trinidad. Quart. Journ. Geol. Soc. Vol. XVI, p. 460.

1866 GUPPY. Quart. Journ. Geol. Soc. Vol. XVII, p. 570.

Ranina found by me in the eocene beds of S:t Bartholomew. According to GUPPY the general affinities of the fossils appear to be *nummulitic.* The lower part of the newer Parian is evidently of the miocene time, there being found in it several fossil species, also occurring in the miocene beds of Anguilla, Jamaica and S:n Domingo. Below the detrital series and exposed near the coast at *Matura* a newer formation, probably of pliocene date, was discovered by Mr. GUPPY, who has given a list of the fossil shells found there*). A great number of the shells belong to still living species, and are remarkable for their small size. According to Mr. GUPPY it is probable that the deposit belongs to about the same time as the glacial epoch.

VII. Summary of the geology of the West-Indies.

From the account given above it is seen that the oldest rocks of the West-Indies do not contain fossils and are, on that account, of an unknown geological age. They occur in Trinidad and are called the *Caribbean* series. They extend farther to the west in the northern part of South America. It seems very uncertain whether this series occurs in the other West-India islands.

The oldest fossiliferous rocks of the West-Indian Archipelago belong to the *cretaceous formation.*

The cretaceous formation is observed in Trinidad, Jamaica and in the Virgin-Islands, and it is not improbable that the conglomerates, and the metamorphic and igneous rocks of the large islands of Puerto Rico, S:n Domingo and Cuba may also be found to belong partly to that formation.

In Trinidad the cretaceous formation seems to be of an older date than the same formation in Jamaica and the Virgin-Islands. One *Trigonia* resembling T. *Boussignaultii* is found in the »older Parian» and this circumstance seems to indicate that the time for the deposit of those beds is about the neocomian period.

The cretaceous beds of Jamaica may be classed as a West-Indian equivalent to the European Hippurite lime or to the »Turonien» and Gosau deposit.

The fact of the rocks in the West-Indian cretaceous formation being mostly igneous or igneo-sedimentary, evidently proves them to have been heaped up in a time of powerful volcanic activity, and, as the miocene formation in several places covers the highly disturbed and metamorphosed cretaceous rocks, in almost horizontal and undisturbed beds, one may conclude that, before the miocene time, the cretaceous rocks were raised to a mountain-chain, having a common direction from east to west and running parallel with the northern coastline of South America.

Fossiliferous beds belonging to the *eocene* formation are found in Jamaica, in Trinidad (the *S:n Fernando beds),* as also in S:t Bartholomew. It may be regarded, too, as very probable that the same formation occurs in S:t Martin, Antigua, Guadeloupe (the »pierre à ravets»), Barbados (Scotland), and possibly also in Cuba, San Domingo and Puerto Rico. The eocene rocks of the West-Indies may be classed as equivalents to the lower or middle eocene formation of Europe (the lower »calcaire grossier» of Paris and »Bracklesham beds» in England).

*) Geolog. Magazine Vol. II (1865) p. 256.

The eocene formation contains to a great extent igneous or metamorphic rocks, which indicates the activity of the volcanic power also during the eocene time.

The *miocene* formation consists mostly of limestones or marls, and is enormously developed in the West-Indies. Limestone strata belonging to the miocene formation cover large spaces in Cuba, S:n Domingo, Jamaica, and Puerto Rico. They are also found in Anguilla, Antigua, Barbados and Trinidad. In S:te Croix the white marl also seems to belong to the miocene time. The miocene formation is continued in the northern part of South America and in Panama*). From the laborious paleontological researches made by Mrss. MOORE, DUNCAN, SOWERBY and GUPPY, before quoted in several places, it appears that the fossil fauna has a great resemblance with the miocene fauna of Europe (as in Malta and at Bordeaux etc.), and also that it shows a close affinity with the still living fauna of the Pacific Ocean and the East Indies. Among the fossil species of the miocene beds of the West-Indies, some are still living in the Caribbean Sea.

These facts have led to the supposition that in the miocene time an open channel existed over Panama to the Pacific Ocean, and also that a connection with Europe existed in form of an Archipelago extending from Europe across the ocean to the West-Indies. This theory, indicated and developed by Mrss. DUNCAN, SOWERBY, GUPPY and MOORE, seems very plausible and it coincides with the hypothesis which *Oswald Heer* proposed to explain the close affinities between the European miocene and the still existing subtropical North American flora.

The miocene fauna of the West-Indies does not, however, offer any close affinities with the miocene fauna of North America.

The thickness of the miocene strata of the West-Indies as well as their generally undisturbed position and the absence of volcanic rocks indicate that the miocene time was, in the West-Indies, a long period of calm, undisturbed by volcanic phenomena.

A farther exploration of the miocene rocks in the West-Indies may make it necessary to divide this formation into several subdivisions.

The Pliocene beds of the West-Indies occur in Trinidad (the Matura beds) and in Barbados. To the newest pliocene or post-pliocene formation, the lime deposits of Brimstone Hill in S:t Kitts, and of Basse-Terre (Guadeloupe) ought, most probably, to be referred. As these deposits occur among rocks, ejected from still active volcanos, it may be concluded that the latter take their origin from the pliocene or the post pliocene time. The Bahama Islands, the island of Anegada and a part of Barbuda belong to a very recent time.

From the facts exposed above it may consequently be inferred, that of the two prevailing lines of elevation in the West-Indies the one running from west to east originated before the miocene time, and that the other from N. W. to S. E., commencing with the Bahamas and continuing in the same direction down to Trinidad, was formed after the miocene time.

*) Quart. Journ Geol. Soc. Vol. IX 1853 p. 132.

65° 64° 63° 62°

19° 18° 17° 16°

Anegada

Sombrero

Virgin Gorda

Tortola

St Thomas

St John

Puerto Rico

Culebra

Crab Island (Viéques)

Anguilla

St Martin

St Bartholomew

St Croix

Saba

Barbuda

St Eustatius

Brimstone Hill

St Christopher (St Kitts)

Basse Terre

Nevis

Antigua

Redonda

Montserrat

Guadeloupe

Grande Terre

Geological Map

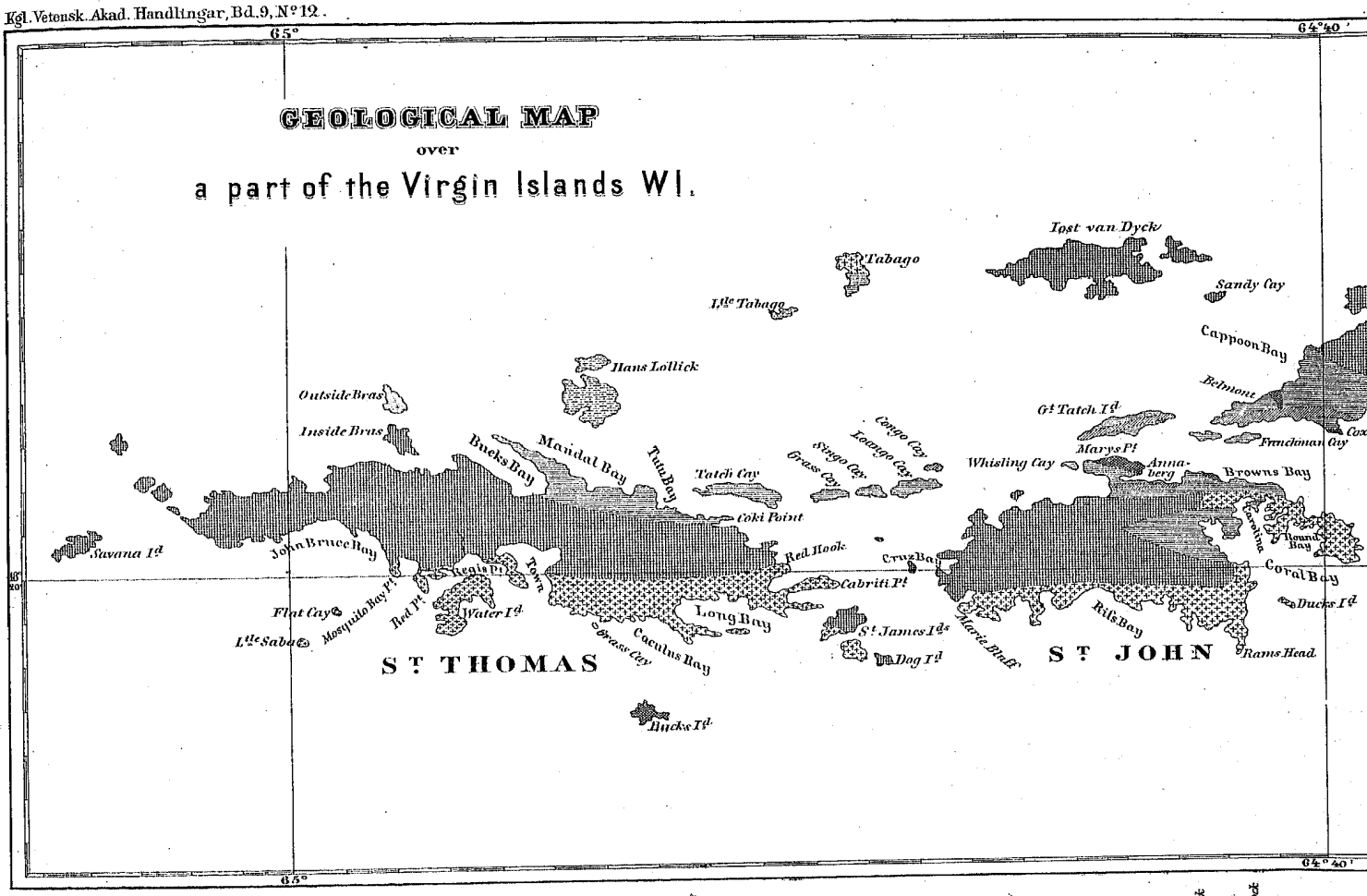
over

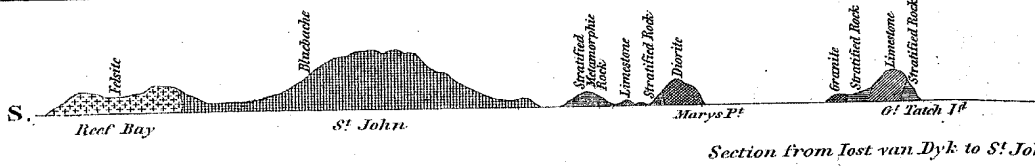
the North Eastern West India Islands

Scale: $\frac{1}{1,751,000}$.

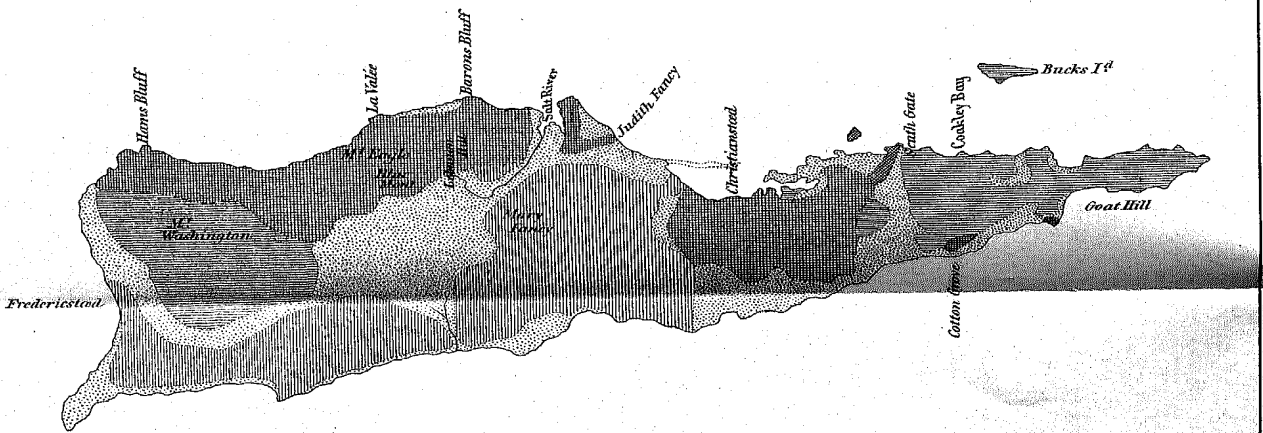
- Cretaceous (Igneous or Igneosedimentary Rocks Schists, Metamorphic, Stratified Rocks.)
- Eocene (Igneous or Igneosedimentary Rocks, Limestone, Stratified Metamorphic Rocks.)
- Miocene (Limestones and Marls.)
- Post Pliocene or Pliocene (Limestones.)
- Newer Volcanic Rocks.

GEOLOGICAL MAP
over
a part of the Virgin Islands WI.



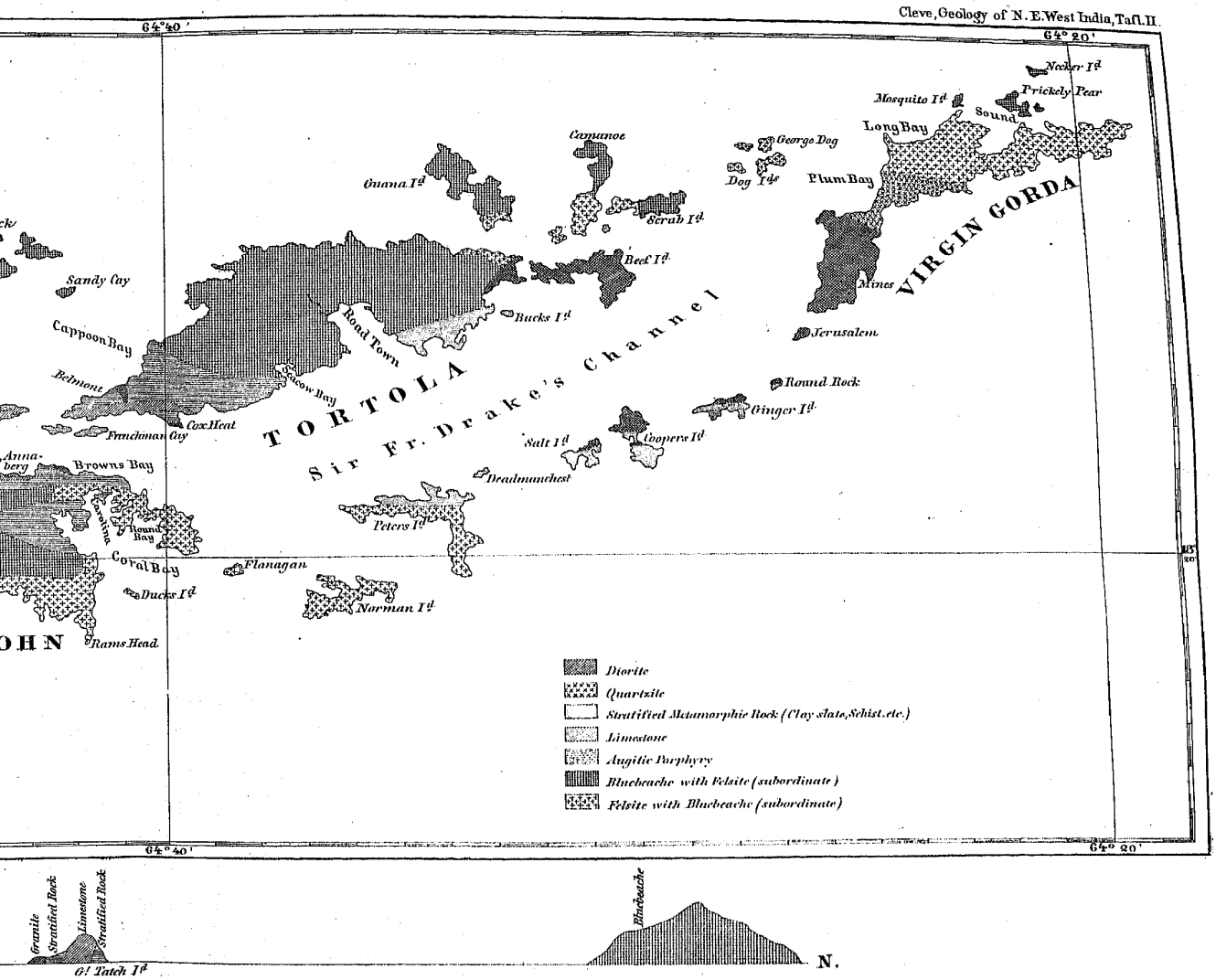


Section from Lost van Dyk to St Jo



Geological Map
over
STE CROIX.
Scale 1/232,000.

- Slate
- Conglomerate and felsite } Cretaceous ?
- Diorite
- White Marl. Miocene ?
- Recent Detritus and Shellsand.



rom Iost van Dyk to St John.