

ART. III.—*Geology of St. Croix*; by Prof. S. HOVEY, late of the Faculty of Yale College, Ct., and Amherst College, Mass.

DURING two winters which I passed at St. Croix for the recovery of my health, I found great relief from *ennui*, the well-known natural enemy of invalids in such circumstances, in examining the physical features of the island; and, had my observations been more complete, the record of them might have been a valuable contribution to science. Limited, however, and imperfect as they were, I am unwilling entirely to suppress them; especially, as they relate to a quarter of the world highly interesting, and but little known. Should they be productive of no other benefit, I hope they may lead some more competent individual, who may, perhaps, be driven, as I was, to seek refuge from the rigors of a New England winter, in the balmy climate of the tropics, to continue the examination, and to present to the public the more ample results of his investigations. My object in this article is to give a brief outline of the geology of St. Croix. Should time

and health permit, I may, perhaps, on a future occasion, extend my remarks to one or two other islands, and touch on some other topics.

I am not aware that more than two or three of the West India islands have attracted the attention of any geological observer. Indeed, the tropical countries in both hemispheres must yet be regarded, so far as geology is concerned, as nearly a *terra incognita*. Still, they will no doubt furnish highly important results in this interesting science. Here some of its most specious theories will be tested; and here, too, will be found entombed new races of organized beings, brought into existence and advanced to maturity, and finally destroyed, in circumstances differing from any present or past in other parts of the globe. If the axis of the earth has been changed, as some philosophers maintain, here we shall find the evidence of it, in a change of organic remains, corresponding with that in the northern regions, but in a reverse order. On the other hand, if the extraordinary size and character of fossil relics, in the high latitudes, are owing to a secular refrigeration of the earth, it will be interesting to know what were the types of animal and vegetable life, during the same geological periods, in the equatorial regions. If past periods in the tropics were as much more favorable than the present to the gigantic development of organic existences, as they certainly were in ours, the imagination can scarcely paint the monsters, which careful research may bring to light. I must confess, however, I saw nothing in the West Indies to countenance such suppositions. No animals or saurians, to my knowledge, contemporaneous with those imbedded in the secondary and tertiary formations of Europe and America, have yet been detected; nor, if we except the island of Trinidad, do I know of any indications of the existence of extensive subterranean deposits of vegetable matter. The pitch-lake of that island, and the petroleum which oozes from the rocks on the coast, are probably due to a vegetable origin; but if similar indications of carbon in a fossil state exist in other islands, they are yet to be discovered.

Most of the islands in the West Indies, as is well known, exhibit marks of volcanic action. Though not lying within the range of that great line of volcanoes which extends along the western coast of South America, and reaches to Mexico, they have often been subject to destructive earthquakes; and two of

them, St. Vincent's and Guadaloupe, are at present the seats of active volcanoes. By inspecting a map of the West Indies, it will be seen, that St. Croix is near the northern termination of the crescent of islands, which, commencing with Trinidad on the south, and ending with St. Thomas on the north, constitutes the eastern boundary of the Caribbean Sea. These islands extend through more than eight degrees of latitude; and yet, it is impossible to look at their relative position, without suspecting that they were elevated by a common force, and have been subject to similar geological revolutions. This, so far as my own observation and the information otherwise obtained extend, I believe to be true. Many of the islands contain several formations, dissimilar in age and geological constitution; but they all bear, if I may use the expression, a striking family likeness. The prevailing formations in the West Indies are, in the first place, recent igneous rocks, comprising the products of active volcanoes and different varieties of trap; in the second, tertiary groups, consisting of marl, calcareous sandstone, and shell limestone; and in the third, a stratified deposit, which, without at present intending to intimate its place in the geological series of rocks, I shall call *indurated clay*. As I have already suggested, some of the islands present all these formations, indications of which are seen upon the first approach to them. St. Croix contains only the two latter, which divide the superficial area of the island about equally.

This island is in north lat.  $17^{\circ} 45' 28''$ , and west long.  $67^{\circ} 12' 40''$ . It is about 26 miles in length, and, on an average, not more than four or five in breadth. Its shape is irregular. The northern and southeastern parts comprise the clay formation, and the central and southern are calcareous. There is a striking contrast in the elevation of the two portions of the island. The clay formation is a pile of mountains, separated, however, by gorges and valleys, which run in every direction, and give to it a beautifully diversified aspect. The highest point is Mount Eagle, which is estimated to be about 1200 feet above the level of the sea. The calcareous formation is much lower and less broken, but undulating. The greatest elevation in this part of the island, is about 600 feet. It is that on which stands Bulow's Mindo, the elegant country-seat of the governor, so named in memory of his friend, Gen. Bulow.

The most striking feature of the mountains of the clay formation, is their high state of cultivation, even when they are so steep that they cannot be ascended except in mule paths, which wind up their sides in zigzag lines. All bear the marks of great violence in their elevation. The strata were much broken by the unequal application of the uplifting forces, and formed into many distinct and grotesque summits; some of which, however, have since been rounded by the hand of time. Nothing can exceed the beauty of these mountains and the intervening valleys, when covered by a luxuriant growth of the sugar-cane, interspersed with plantations and orange groves, and seen from a summit, which, at the same time, commands a view of several vistas to the ocean. Some of the mountains, however, are too precipitous for cultivation, and the rocks are too hard to be readily broken down into an arable soil. Such is most of the eastern section of the group on the north, and the extreme portion of the south-eastern range. In favorable seasons, the cultivated tracts yield good crops of cane, but they are peculiarly susceptible to the drought.

As a mass, this formation is distinctly stratified. The strata vary in thickness from six inches to three feet; and, in many places, are exceedingly regular and well defined. A good section of this description may be seen on the coast, below the Mount Washington estate. In others, they are schistose, and much contorted, as near Punch, in ascending from Little La Grange, and at a quarry contiguous to Jolly Hill garden. In some cases, no stratification is visible—the whole mass breaking up into small angular fragments, or being consolidated into columnar blocks, with a structure and cleavage resembling trap. Localities, however, of the last description, are not common; and the angular fragments of the other beds are generally soft and easily decomposed.

The strata are highly inclined. The lowest angle I observed was near Capt. Sempill's house, at Butler's Bay, which was about  $45^{\circ}$ . The inclination varies in different places, from this to  $90^{\circ}$ . It is generally from  $70^{\circ}$  to  $80^{\circ}$ . The direction of the dip is pretty uniform, and is nearly north. The composition and general aspect of the strata in different localities, and even in juxtaposition, are often various. In some cases, they are decidedly aluminous; in others, silex predominates. They also vary much in hardness, the more aluminous being generally soft and inclined

to crumble, and the silicious requiring a smart blow of the hammer to break them. The grain is uniformly fine. I did not see, in this mass of rock, any thing like a pudding-stone. The formation seems to have been deposited in quiet waters, though there are frequent contortions in the strata, which may be due in part to the troubled state of the element from which they were deposited; but probably more to the force by which they were uplifted. There are beds in the ravine near Mount Victory, as we ascend on the road from Sprat Hall, which strongly resemble argillaceous slate. The color of the strata, in other places, passes through all the varieties of brown to that of clay. They are frequently colored red by the oxide of iron.

This is particularly true in the region of Annesley. In such cases, however, the oxide does not appear to have penetrated the substance of the rock, but to have been infiltrated through the seams and crevices. The soil is also impregnated with this substance.

Thin layers of quartz, from one fourth to half an inch in thickness, are often interstratified with this rock, and sometimes cut the regular strata, and also each other, diagonally. Mingled with schistose formations, I often found small beds of marl and calcareous spar. In some instances, the marl had been introduced from above, in the form of a deposit; in others, it was obviously interstratified with the rocks when they were formed. The streams, also, which ran down from the mountains over the hardest rocks, were more or less impregnated with lime.

I have already intimated, that the strata are often intersected by diagonal cleavage planes. This appeared to me a striking peculiarity of the formation. These planes were from one to three inches apart, sometimes parallel, but generally more or less inclined to each other. They were often crossed by others; so that the rocks naturally broke into angular, columnar, or rhomboidal fragments. It was often difficult to distinguish these cleavage planes from the true lines of stratification. In this respect, I was much struck with the similarity between these rocks and the greywacke formation of Wales, as described by Mr. Murchison.

The valleys and ravines of this formation, as I have already said, run in all directions, but more generally in that of the anticlinal lines of the strata. Such, for example, are those which extend from the coast road, at the west end of the island, towards Jolly Hill, Mount Victory, and New Caledonia.

Sometimes these valleys and the impending mountains are wild and picturesque in the extreme; in other cases, they are highly cultivated. The contrast is owing principally to the different degrees of hardness in the rocks.

One is at first surprised, that any portion of soil can be retained on the cultivated parts of the mountains, as they are so steep that, in ordinary cases, it would all be washed away. It would be in this, but for the fact, that the cane is planted in deep trenches, dug horizontally along the sides of the mountains, which prevent in a great measure the flowing of water; and also, that the rocks are continually decomposing and forming a new soil. Indeed this process of decomposition may every where be seen at present going on, in sections of roads cut through the rocks, where the passage from the solid, unchanged strata beneath, to the cultivated soil on the surface, is so gradual, that no distinct line of separation can be drawn.

A similar explanation is applicable to the different states in which the talus is found at the foot of the mountains. In some places, it is many feet deep, but thoroughly pulverized; in others, it remains in the state of broken fragments, covered with so little soil, as not to be susceptible of cultivation. This is strikingly seen at Ham's Bluff, which presents a stratum of undecomposed detritus twenty-five or thirty feet in depth.

The thickness of this formation is at least several hundred feet. On the west coast, north of Sprat Hall, the strata are seen standing side by side, in uninterrupted succession, for several rods; and, were it not for the gorges which break, occasionally, their continuity, the thickness might appear much greater.

As to its age, I am not prepared to express a decided opinion. On the one hand, it cannot be so low down as the older slates or the *metamorphic* rocks of Lyell; and, on the other, its composition, structure, and high inclination, bear a striking resemblance to those of greywacke. I did not observe it associated with older rocks, except in one place, near South Gate, where a bed of sienite occurs, thirty or forty rods in extent. As to organic remains, though I made diligent search, I found none; from which it must at least be inferred, that, if they exist at all, they are very uncommon. I ought, however, to mention, that, on the road from Little La Grange to Punch, I discovered in this formation, from two to three hundred feet above the level of the sea, a bed

of limestone, in which were imbedded the leaves and trunks of dicotyledonous plants. They were both converted into the substance of the rock, but were well preserved. The largest specimens of wood I obtained were about four inches in diameter; though, if I am not mistaken, I saw the impressions of those much larger. The cortical layers were very distinct, and, through the smaller pieces, were holes, which the pith of the plant once obviously occupied. The bed which contains them is of limited extent. It was clearly raised with the formation in which it is implicated; and, if they are both contemporaneous, the clay formation is obviously of recent origin. I am in doubt, however, whether this bed is not the remnant of a calcareous stratum, which may have covered the whole of this formation when it was raised, but has since been removed by meteoric agents. If this supposition is true, other beds will probably be found, from which farther light may be obtained. I may also add, that just before leaving the island, I received some specimens of limestone, containing casts of corals and marine shells, taken from a bed, which was said to be found in this formation near Judith's Fancy. I would especially recommend this locality to the attention of any one who may hereafter have an opportunity to examine the geology of the island.

It may not be improper to remark, that this formation is exceedingly well developed at St. Thomas, an island about forty miles north, which bears a strong resemblance in its geological character to that part of Santa Cruz which I have just described. The columnar and trappean forms of the rock, imperceptibly graduating into regular schistose strata, are, perhaps, more common. This island, also, contains extensive localities of trap and porphyry. On the west side of the harbor, they are seen protruded among and overlying stratified and altered rocks, where the peculiar globular concretions of the trap are very apparent in the decomposing surfaces of large insulated masses. The clay and the trap are the only two formations of this island. Of the corresponding groups of Antigua, I intend to speak at another time. I will only add here, that indurated clay constitutes a district of considerable extent on the island of Barbadoes. I saw it near Codrington College, where it is not fully developed, and cannot therefore speak of it with confidence. Here it was more aluminous and less indurated than the rocks of which I have

been speaking in St. Croix and St. Thomas. Indeed, at this place, the consolidated rocks were nearly covered by thick strata of clay mingled with sand, some of which were partially hardened into stone and dipped with the others at an angle of about ten degrees under the calcareous and tertiary formations, which constitute so striking and interesting a feature of that island. The greater portion of this district, consisting of strata highly inclined, is, I was informed, exceedingly wild, broken, and mountainous. Upon the whole, the entire class of rocks which I have been describing, though they may not be of precisely the same age, appear to me to have been formed in similar circumstances, and to owe their varieties principally to the different degrees of heat to which they have been subjected.

The general aspect of the calcareous part of the island, as I have before said, is undulating. With the exception of some estates on the south and southwest coasts, where the limestone rises to the surface of the ground, the soil is easily tilled and very fertile.

The strata incline at different angles and in different directions. Their prevailing position at the east end of the island, is a dip towards the west at an angle of about  $10^{\circ}$ . They crop out towards the east at Constitution Hill, and at King's Hill; but at an eminence near La Reine, towards the west, I saw them inclining in other directions, and, also, nearly horizontal, as at a quarry south of Mount Pleasant.

This formation presents considerable diversity also in composition. Perhaps it can best be described under three general divisions—the section which is now forming on the northwest coast—the marl and the calcareous sandstone, which occupy the central portion—and the limestone and coral crag, the former in most places overlying the latter, and together covering the south side of the island.

The first of these divisions is of limited extent. It is a narrow belt, from two to six rods wide, extending along the west, with few interruptions, from the bluff to Frederickstad. It consists of corals, shells, and comminuted detritus, thrown up by the waves upon the coast and agglutinated by a calcareous cement. Most of the shells are broken; the stronger ones, however, such as *Strombus gigas*, *Turbo pica*, *Tellina remies*, *Arca Noe*, are found entire, and even retain their natural colors. I observed a



few more delicate shells of the genera *Serpula*, *Lucina*, *Voluta*, *Bulla*, &c.; all these species still inhabit the surrounding seas. In addition to this fact, there are other circumstances which show the recent origin of this deposit. This part of the coast is liable to a strong surf, which is constantly drifting shells and other substances upon the shore, and dashing over them spray charged with calcareous matter. These generally unite and harden, especially near the surface, and form into a tolerably compact mass. I also found imbedded in these rocks iron utensils, which had been employed at no very remote period, in quarrying them. It contains many fragments and rounded pebbles of indurated clay, which as a general thing unfit it for the kiln.

Though it is obvious these rocks are still in the process of formation, they have been much abraded and broken by the surf. I doubted, indeed, for some time, whether they could have been formed in the face of such powerfully abrading agents; but the fact, that the windward coasts of coral islands are generally distinguished by the greatest accumulations of matter, removes the difficulty. I saw in one place a mass of rock containing about four hundred cubic feet, which had been detached from its bed, raised several feet, and thrown back upon the shore. This deposit every where rests upon the tilted strata of the indurated clay, which often form a precipitous bank, and generally rise within a short distance into high mountains. The shore is lined with tropical shrubs and trees, such as *Hippomane mancinella*, *Guilandina bonducella*, *Coccoloba uvifera*, *Lantana involucrata*, *Turnara ulmifolia*, *Mimosa spinosa*, &c.

The marl varies in composition, and hardens even within moderate distances. It often comprises extensive beds of lime nearly pure, and so soft that it may be dug with a hoe; in other places, it is mingled with sand, becomes harder, and forms a good building stone. In such cases, it is easily broken at first, but hardens by exposure to the atmosphere. In structure and general aspect I saw quarries much resembling those of the Paris basin, from which such ample materials for building are derived.

It is impossible to draw a dividing line between these beds and the purer lime deposits on the south and west. Both are no doubt contemporaneous, and owe their difference to peculiar circumstances in their deposition. The limestone sometimes occurs in a compact form; but the structure is generally loose and friable.

ble, especially at a little distance below the surface. It is often dug up for the purpose of deepening the soil, and left to decompose upon the surface. The lower beds, which rarely appear on the surface, are seen to good advantage along the southern coast, and consist principally of coral and shells converted into a ragged mass of nearly pure lime. The name *coral crag*, which I have applied to them, well describes their general appearance. The superficial beds, which are very imperfectly stratified, and have the appearance of a chemical deposit, vary in thickness on the coast from two to ten feet. The coral crag is not peculiar to St. Croix. I saw extensive beds of it in Barbadoes and Jamaica, where it often rises to the surface of the ground.

The whole calcareous group, which I have now described, obviously belongs to the tertiary formation. The first and most recent division may be classed with the formation of Guadaloupe, in which human skeletons have been found; and the others I am inclined to think do not extend back beyond the newer Pliocene of Lyell. I do not speak with entire confidence, because nearly all the shells which are found occur in the form of casts, from which it is often difficult to decipher the genera and species.\*

Fossil coral, unaccompanied by marine shells, also occurs in many places; sometimes beautifully colored, and incrustated with calcareous depositions. Whatever may be the age of this formation, it is no doubt more recent than the indurated clay; for, in addition to other facts already suggested, we find imbedded in it great quantities of angular fragments and even large masses of rocks from that group. This circumstance may be explained on the supposition that the island has been elevated at two different periods; indications of which, if I mistake not, are found at several places, and especially at Jolly Hill, a distance of about a mile from the west coast, and near a hundred feet above its level. They consist of a calcareous deposit by the side of the road, near the mill, upon the uplifted strata of the indurated clay, resembling those which I have already described; and stratified banks of gravel contiguous to the garden, in which marine and lagoon shells are promiscuously imbedded. On the lower grounds be-

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\* The two best localities for shells are a quarry near Dr. Stedman's at the west end of the island, and one at the east end, from which building stone was obtained for the new prison.

tween this and the sea, there are at present two lagoons, and also extensive beds of unstratified gravel, which have obviously been washed down from the mountains, and contain large quantities of shells belonging to the genera *Helix*, *Caracolla*, *Bulimus*, and *Pupa*, which are now extinct upon this island, but are found upon others in the neighborhood. I might adduce other evidence bearing on the same point, but the limits of this article will not allow.

The beds of the ocean are lined with coral on every side of the island, and, in many places, the reefs rise near the surface of the water. This is particularly true on the south coast, and at the harbor of Christianstad; which is, indeed, with the exception of a narrow break that affords a passage for vessels, completely enclosed by a coralline bank.

St. Croix contains but few minerals. Calcareous spar and arragonite are the only two varieties which I saw. The latter occurs in the form of small, parallel, combined columns, and of six-sided prisms with re-entering angles on the sides. Both kinds are well developed.

Though the soil of the island was originally very productive, it has been much impoverished by a long course of unvaried cultivation. The elements however of an admirable soil still remain; and all that is necessary is to bring them into a suitable combination. Many parts of the island might be exceedingly improved by an artificial admixture of the marl and clay; and all need a fresh supply of the nutritive principle of a vegetable compost. The island of Barbadoes, which much resembles St. Croix, both in the geological formations and in the worn state of the soil, has been wonderfully revived by improved agricultural processes, and especially by compost manures and a more frequent alternation of crops. I do not doubt that the productive powers of St. Croix might be doubled in a few years by similar methods; an object certainly deserving the attention of the landed proprietors.