ART. LI.—*On the Geology and Petrography of Conanicut Island, R. I.;* by L. V. PIRSSON.

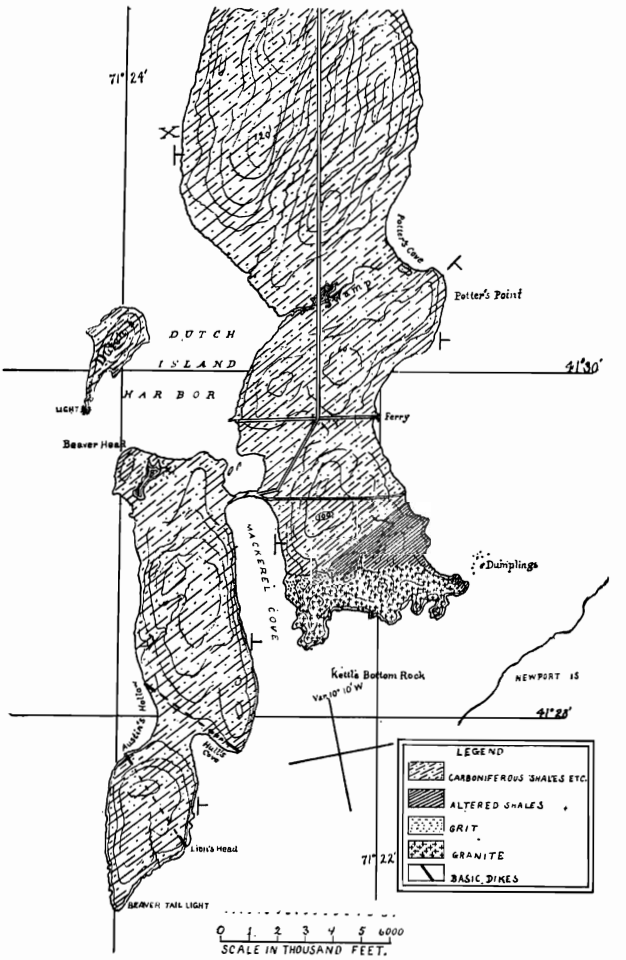
CONANICUT Island, lying in Narragansett Bay in Rhode Island and crossed by the meridian 71° 23′ of west longitude and the parallel 41° 30′ of north latitude, is about nine miles long in its greatest extent and nowhere much over a mile in breadth. As will be seen by reference to the map of fig. 1 it consists in reality of two portions, one large, the other much smaller, connected by a curving sand beach about an eighth of a mile long and nowhere much above a hundred yards in breadth.

The island consists in the main of extremely fissile soft shales, which weathering easily have determined the topography and given rise to smoothly rounded slopes and low hills. The highest point is about 135 feet above sea level. These smooth and undulating surfaces afford therefore no exposures of the underlying rocks and it is only along the shores where the constant gnawing of the waves has cut into the soft shales, making in places rugged shore lines, that

* Indeed the rate of the alternator may be so rapid that a large condenser in the circuit can be made to appear of small capacity. And under these conditions the condenser will not serve to annul self induction. The time of the residual charges must also be taken into account. The charging of a condenser, therefore, by means of an alternator is far from a simple phenomenon.

the rocks can be studied. To this general character, however, the extreme southern end of the main portion affords a notable exception: at this point a stock of intruded granite and tough hornstone rocks resulting from the metamorphism of the shales afford by their superior resisting properties a group of low, rugged and rocky hills, precipitous water fronts and

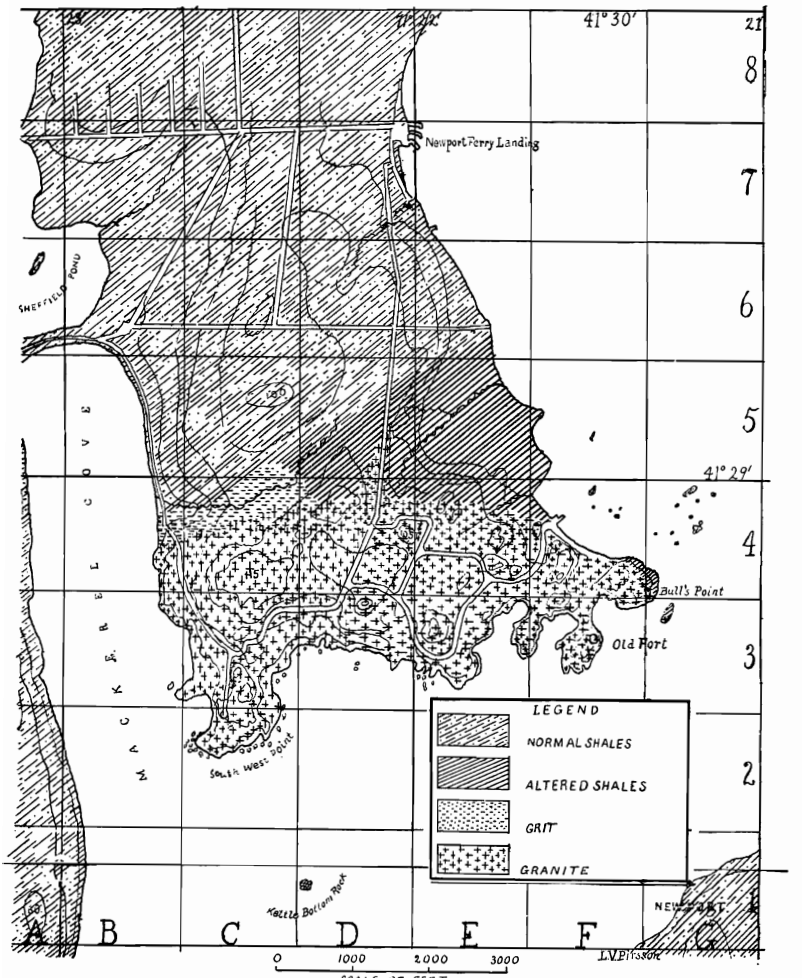
Fig. 1.



outlying islets, which are known under the name of the Dumplings. This portion of the island has become a well known seaside resort and the hills are dotted with summer villas. A map of it is shown in fig. 2.

Everywhere on the island occur bowlders of the glacial drift, among which by far the most common rock is a coarse conglomerate containing rounded granitic and quartzose pebbles; furthermore this conglomerate is seen in the bowlders not only in normal condition but also at times evincing the fact that before removal it had suffered dynamic pressures resulting in a gneis-

Fig. 2.



soid condition. Masses of it from six to eight feet in diameter occur at times. Granite, gneiss and slates occur also as bowlders and pebbles in the drift. The island is covered with a fertile soil but is too narrow to give rise to any but inconsiderable drainages.

Historical.—We are indebted, so far as I have been able to discover, to Jackson* for the first map and geological description of Conanicut. He regards the shales forming the main portion of the island as of Carboniferous age and the granite as intrusive in nature and describes very clearly and correctly the metamorphoses suffered by sedimentaries by the intrusion of an igneous rock. He also gives a few dips and strikes that are in the main correct. The same views were also held by President Hitchcock.† It is to be noted that these observers correlated the granite and other rocks with the granite and rocks on Newport Neck adjacent. They were substantially the views of C. H. Hitchcock‡ and also of T. Sterry Hunt§ except slight variations as to the age of a portion of the sedimentary beds at Newport. Various papers have been published by different authors also on the Narragansett basin as a whole, treating the subject from various points of view. Since, however, in so far as Conanicut is concerned, they do not appear to be based on personal observation and the island is not directly named, they are not given here. For a list of them the reader is referred to a paper by T. N. Dale.‖ This latter author in 1884¶ gives in a paper on the geology of the lower part of the basin, a pretty full account of Conanicut, based chiefly on a series of stratigraphical studies. He correlates the granite with that on Newport Neck and on stratigraphical grounds does not regard it as intrusive but as the lowest of his series and a metamorphic product. He describes the lithologic character of the various schists, shales, etc., and gives a large number of dips and strikes. Since, however, Dale, on Conanicut at least, mistook slaty cleavage for bedding, his conclusions, based as they are on largely mistaken stratigraphy, cannot be admitted. That this mistake was made, is evident, not alone from the given dips and strikes, but in the paper itself, where he several times mentions the shales as being "striped across the bedding." This striping is however the original bedding cut across by slaty cleavage; in many places on Conanicut the cleavage and bedding are parallel but generally not.

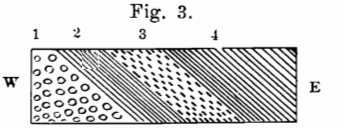
Geologically the sedimentary beds of Conanicut are of Carboniferous age, as is shown by their correlation with the coal-bearing strata of the region. Moreover on the most western point of the main portion at X, fig. 1, fossil plants are found of Carboniferous species according to Dr. A. E. Foerste. In general these sedimentaries are made up of an extremely fissile shale or phyllite, varying in color from grayish green or

* Geol. Surv. Rhode Island, 1840, pp. 89–92.
† E. Hitchcock, Geol. Mass., 1841, pp. 537–552.
‡ Geol. Is. Aquidneck. Proc. Am. Ass. Adv. Sci., 1860, pp. 119, 121, 126.
§ Proc. Bost. Soc Nat. Hist., vol. xiv, 1869.
‖ Proc. Bost. Soc. Nat. Hist., vol. xxii, p. 179, 1883.
¶ This Journal, vol. xxvii, 1884, pp. 217–226, 282–291.

silver-gray to varieties dark chocolate to black in tone. The light varieties are well exposed along the eastern shore as at Potter's Point where the dark varieties also occur in thin beds. The darker varieties occur also along the shores of Mackerel Cove. Frequently the two are interbedded in extremely thin layers but an inch or so in thickness, which cut across at an angle by the planes of cleavage gives a peculiar ribboned appearance to the outcrops, this being well shown along the east shore of Mackerel Cove in B 5, fig. 2. The dark shales sometimes contain small garnets in vast numbers and sometimes staurolite, while the green shales do not as they are deficient or wholly wanting in lime as shown by the analysis given later. There are also at X, fig. 1, a few outcrops of a pudding stone or rather coarse conglomerate and also of some micaceous sandstones.

When we attempt, however, to unravel the stratigraphy of these beds we are met by great difficulties; as before said, there are no outcrops except at the shores; here however, with few exceptions, they are either exposures of the planes of slaty cleavage on which the strike of the beds may be seen but from which their dip cannot be determined, or of such a nature that neither strike nor dip can be told. In general, so far as can be made out, the strike of the beds on Conanicut is north and south and the dip east. Along the shore from the ferry to Potter's Point, the strike is nearly north and south—the dip cannot be safely told; at Potter's Point the strike changes with a short radius and runs out under the water in a northeast direction. At this point a large number of small faults with small displacements can be seen. Along the Beaver-tail portion of the island the strike is about north and south, the dip which varies considerably to the east. The same is true along the east shore of Mackerel Cove the dip varying from 10°–30°; at a point nearly at the top of B 5 there is a small but excellent exposure which shows the beds bent into a half circle with radius of little more than a foot, the *convex* side to the *east;* this must have been an overfold and gives evidence of the great amount of distortion the beds have suffered. At X, fig. 1, an excellent exposure of the rocks is found. A section at this point from the water's edge to the bank under which the rocks disappear is given in fig. 3. The strike is north and south, the dip east. At this point along the shore the dip may be seen to have great variation. The cleavage is parallel to the bedding and the beds have

Fig. 3.



1 Conglomerate.
2 Black fissile shales.
3 Micaceous sandstone.
4 Shales.

somewhat curved outcrops; they wedge out in places along the strike and are filled with veins and large lenticular masses of secondary quartz. The conglomerate of the given section contains quite large rounded pebbles in a fine grained cement; where its outcrop can be traced along the shore it is seen in places to have suffered severely from dynamo-metamorphic processes, the pebbles are flattened, the cement becomes micaceous and transitions to gneiss or mica schist occur. It is strikingly similar in lithologic characters to the drift bowlders found over the lower part of the island and wholly different from the conglomeratic grit next to the granite on the east shore of Mackerel Cove in C 4.

The granite of Conanicut is coarse grained of a mixed grayish color on fresh exposures and it contains large often huge phenocrysts of orthoclase well distributed. These phenocrysts are of great importance in determining the relations of the granite and the grit in C 4. Petrographically the granite is described later. As will be seen by reference to the map, fig. 2, it forms the whole of the lower portion of the main part of the island. Its subaqueous limits can be pretty well defined by the sedimentaries on the west shore of Mackerel Cove; to the south by Kettlebottom Rock which is an outcrop of shale rising some eight feet above tide. Attempts were made to examine this rock closely but the heavy seas breaking on it prevented a landing; at a distance of some fifty yards it could be easily seen to be of shales and it is not probable that a drift mass could remain on a ledge in such an exposed position. On the Newport shore to the S.W. the shales recur again and the small island to the S.E. of Bull's Point in G 3 is composed as to its north part of altered sedimentaries and to the south of granite.

Evidences of intrusion.—That the granite is intrusive is best seen at Bull's Point where it is directly in contact with the sedimentary beds here altered to a dense hornstone-like rock. The granite is finer grained and more porphyritic; the contact between the two rocks is solid, specimens breaking across both as if one rock: it has sent out apophyses in the shape of dikes which cut into the sedimentary beds. Further to the eastward in E 4 the contact is buried, but at one point the granite and hornstone are but a few yards apart; here the granite is fine grained and aplitic in character, the hornstone extremely dense and tough. A short distance further westward between two little hills in E 4 there occurs an outcrop on the east side and near the bottom of the westward hill of a dark flinty rock, felsitic in appearance, characteristic of the contact facies of rapidly chilled highly siliceous magmas and which microscopically shows a crypto-crystalline groundmass

interspersed with quartz and feldspar often in micro-pegmatite intergrowth. This grows coarser in grain and a few yards to the south the granite outcrops again.

Also in D 5 occurs an apophysis which has been thrust out into the sedimentaries. Its outcrops occur along and in the road for a distance of some fifty feet or more and recent work on the road has thrown out some fresh material. This is a fine grained light reddish rock and microscopic examination shows it to be a most characteristic and typical micro-pegmatite. From this point farther to the westward there are no evidences of endomorphic contact in the granite; it is either covered or the rocks have suffered so from pressure and weathering that nothing certain can be deduced.

Exomorphic contact phenomena.—As will be seen by reference to the map, the region of the sedimentaries which has been chiefly affected by the intrusion of the granite is a roughly triangular mass lying in great part, in D 5 and E 5. It is not however the only place where exomorphic evidences of contact are shown. It may be said at this place that every transition can be found between unaltered shales and the most solid of hornstones in contact with the granite, but not however in any one place or exposure. Along the west shore of Mackerel Cove the shales although nearly normal are yet somewhat affected having a strongly knotted and speckled look, described by Dale* as containing "thickly disseminated minute nodules of siderite." They often do indeed contain carbonates but also at other times small nests of intertwined white mica leaves, secondary quartz, chlorite, etc. It would appear at times as if they might have been pseudomorphs of some former mineral and the whole phenomenon is indeed strongly suggestive of contact metamorphism. In C 4 in the gully cut by the little brook and just west of the new road, green shales or phyllites are found which are very near the normal, the only alteration noticeable being a slight loss of the fissile character together with a somewhat gnarled appearance and the formation of small knotted points. In the N.W. corner of D 5 just south of Mr. Green's barn occurs a long outcrop extending towards the south. At the north end the shales although still retaining a fissile character are very much gnarled and toughened and as one proceeds southward they pass within two or three rods into compact hornstones. From this exposure it may be seen that the loss of the shaly character and transition into hornstone occurs within a very short distance.

Along the east shore in E 6 the transition is covered and the first outcrop after leaving the shales is a dense slaty rock of a

* Loc. cit.

dark color and much jointed showing macroscopically only by color banding its sedimentary origin. Farther to the southward the rocks become more greenish or grayish green in color and more coarsely crystalline. In general it may be said that as we approach the granite the hornstones are more crystallized, harder, denser and break with a splintery fracture.

As previously noted the sedimentary beds are thin, vary in character and have a general N. and S. strike, consequently as one traverses the metamorphosed area in an E. and W. direction along the line of the granite there is considerable variation in the character and mineral constitution of the altered rocks as will be shown later. Another striking feature in the metamorphic character of these rocks is the presence of great quantities of fine veins of a yellowish color which traverse them in all directions, and which on microscopic examination are found to consist chiefly of tourmaline, of all minerals in the contact zone perhaps one of the most characteristic of the fumarole action of intrusive masses.

Grit.—Besides the conglomerate already mentioned as occurring at X and which is assumed as the lowest of the sedimentary series on the island there occurs another conglomerate rock or grit, exposed on the east shore of Mackerel Cove in close connection with the granite and evidently derived from it. It extends inland into C 4 as shown on the map: its outlines from a lack of good exposures are rather doubtful but probably as given. It differs widely from the first mentioned conglomerate in character in that it consists of fragmental granitic material; it is more of the nature of a grit consisting of quartz grains and fragments mixed with decayed feldspar material. Dale has characterized it as a "quartz clay aggregate." Its derivation chiefly from the granite both from its position and character of material seems quite clear. Moreover it contains fragments and even entire crystals of the large orthoclase phenocrysts which form so striking a character of the granite, their crystal form, broken or somewhat rounded. Its derivation from the granite would make it more recent than the adjoining sedimentaries and this is evinced by the fact that it contains *fragments of shales.* Some of these near the granite are slabs several feet in length whose long extension or strike is a little north of east and south of west, while they are standing nearly perpendicular, the strike of the shales to the north being N. and S. and the dip E. The granite adjoining though much weathered has evidently been strongly sheared and the whole appearance of this local mass of brecciated material is strongly suggestive of its being the result of pressure and shearing between the granite and the altered conglomerates, shales, etc., at this point.

Dikes.—The granite is cut through by aplite dikes in several places, an excellent example being a small one of but a few inches in width which cuts the exposed rock below and to the east of Mr. Clothier's house on Bull's Point, and which has been bent and faulted by later movements. Besides these which are in intimate connection with the granite there are two other dikes on the island, both on the Beavertail portion and cutting it and the strike of the beds transversely; see fig. 1. They are not large, the one at Hull's Cove is the larger and at this exposure from eight to ten feet wide. Its outcrop can be traced for some distance in a series of nearly buried bowlders.

The second one, a little south of the point known as Lion's Head is still narrower. Its western outcrop occurs on the south point of Austin's Hollow.

These dikes are of the lamprophyre rock known as minette or mica trap as will be shown later. They stand in close petrological relation to the granite and must be considered as of contemporaneous origin.

They have altered the adjacent shales, the one at Hull's Cove in particular having produced a rock similar in appearance to some of those formed in the contact zone of the granite as previously described.

Orographic movements.—Besides the original folding of the Carboniferous series the island has suffered great dynamic pressures subsequent to the intrusion of the igneous rocks. The thrust has been in a general north and south direction. The granite has been crushed and dynamo-metamorphosed in places; planes of fracture extend through it generally in an E. and W. direction, often highly slickensided as in an excellent exposure at the gate to the grounds of Mr. J. Wharton in C 3. The aplite dikes in it have been bent and broken. The minette dikes on Beavertail have also been bent and folded and highly pressed; in places they have become quite schistose as at the south point of Austin's Hollow and the schistosity is perpendicular to the thrust. The sedimentaries have also suffered from these forces, steps in the shales running E. and W. being of frequent occurrence and the beds in other places have been fractured and bowed up as at X, the fractures and hollows from bending being now filled with veins and lenticular masses of secondary quartz.

General summary.—From the foregoing facts the following general statement may be deduced for the geology of Conanicut Island. That it is in the main made up of a series of Carboniferous strata thinly bedded with a conglomerate as the oldest member, which has been folded so that the beds have a general north and south strike and dip mostly to the eastward.

That there has been a later intrusion of granite which has necessarily metamorphosed the sedimentary strata and which has been accompanied by the injection of dikes petrologically related to the granite, and lastly the whole mass has suffered from dynamic forces acting in a general north and south direction, the result of orographic movement and which has also produced by shearing a mass of local grit.

Note.—The author desires at this point to express his thanks to Dr. A. E. Foerste who some years since made a brief study of the island and has kindly given the writer a short abstract of his notes made at that time. His outlining of the areas and of the dikes is essentially the same as that here given. From the presence of feldspar in the hornstones at one point he is inclined to regard them as composed partly of altered older basic eruptives, and the grit at Mackerel Cove he prefers to correlate with the basal conglomerate of the basin, though he regards it as derived from the granite. In other respects the views of the writer are believed to be in agreement with those expressed by Dr. Foerste.

Petrography.

Granite.—The Conanicut granite is a rather coarse grained rock, on fresh surfaces of a light reddish color due to the iron oxide developed in the feldspar. As remarked before it carries nearly everywhere huge phenocrysts of orthoclase, examples 5^{cm} by 3^{cm} in width and thickness being a very common size. It is therefore, strictly speaking, a granite porphyry, only on a much larger scale of size of phenocryst and grain of groundmass than usual. All of the main constituents may be determined by the eye, magnetite, titanite, oligoclase, orthoclase and quartz, also dark masses of chlorite which are the representatives of a former ferro-magnesian mineral.

Under the microscope are found in addition zircon, apatite, white mica and epidote, and it is seen that the rock even in the freshest examples has suffered severely from dynamic pressures; the quartzes show undulatory extinction, the feldspars are broken and filled with sericite. The large phenocrysts have also suffered in this way and the cracks are filled with secondary quartz and calcite. The ferro-magnesian mineral is no longer recognizable, its place is entirely taken by chlorite, often mixed with epidote. It is possible that hornblende as well as biotite was originally present, the epidote as an alteration product and the association with titanite rather favoring the idea.

With regard to the order of crystallization of the various components, the rock has in general been subjected to too much alteration of various kinds that obscure the structure to

draw safe conclusions: in regard to the large phenocrysts, since they contain apatite, titanite, etc., it may be said that they are not the first products of crystallization while their more or less idiomorphic outlines indicate that they are older than the groundmass in which they lie. It is a striking fact that the rock never contains any phenocrysts of quartz and in this is unlike most peripheral facies, dike forms, etc., of granite porphyry. And it is probably true that while granites with large feldspar phenocrysts are not uncommon they rarely or never contain corresponding phenocrysts of quartz as might be expected from analogy with effusive forms—an indication that they have been formed under different conditions. The analysis of this granite yielded the results here presented.

SiO_2	71·23
TiO_2	·21
Al_2O_3	13·64
Fe_2O_3	1·70
FeO	1·00
MnO	·05
MgO	0·75
CaO	2·31
Na_2O	3·55
K_2O	3·79
H_2O	1·72
Total	99·95
Sp. G.	2·690

It is that of a typical granite in all respects and needs no special comment. The water is of course from alteration. It may be remarked here that in this as in the following analyses the water was actually weighed as such during the process of the analytical investigation. This analysis was made from a specimen taken from an outcrop on a little hill in the N.W. corner of D 4, the freshest and best exposure found. From here as one goes southwest and south the granite becomes more and more dynamo-metamorphosed, and one of the most striking examples and best exposures of this is found in a recently worked outcrop just inside of Mr. J. Wharton's gate in the middle of C 3. Here the rock has been much fractured, it is full of slickensides and other evidences of shearing and pressure. Under the microscope all the components are seen to be broken and crushed; they lie in a mass of broken material which cemented together by secondary silica renders the rock extremely similar to a metamorphosed grit It is indeed similar to a grit only mechanically made. Epidote and other secondary minerals abound. In other places as along the shore of Mackerel Cove the rock exposures have suffered so much

in addition from weathering that it would be difficult if not impossible to distinguish former granite from the conglomeratic grit occurring there if it were not for the large feldspar phenocrysts with *crystallographic outlines* which serve to differentiate it (additional to the included shales in the grit).

Aplite.—This presents the usual panidiomorphic mixture of orthoclase and quartz with a very little plagioclase, a little iron ore and the ferro-magnesian minerals almost wholly wanting. It has suffered greatly from pressure. Remains of micropegmatite structures can be detected at times.

Micro-pegmatite which occurs as mentioned in the central apophysis is very typical and comparatively fresh. It does not appear to have suffered so much from dynamic forces as the foregoing rocks.

Minette.—As before mentioned there are two dikes of this lamprophyre rock on the lower portion of the island as shown on map No. 1. The best and most unaltered exposure is found at Hull's Cove. The rock here is of a dark reddish rusty color on exposed surfaces, stained by iron oxide. On a fresh break it is of a dark gray, and fine grained, in which phenocrysts of biotite, at times several mm. in diameter, may be seen. Small fragments of the shales through which it has broken up may at times be found in it altered to a siliceous hornstone. Owing to the dynamic pressure the rock has received it breaks with a somewhat schistose fracture at times. The exposure of the second and southern dike at Lion's Head is similar only as the dike is smaller it has suffered more severely from squeezing and has a more pronounced schistose structure and the biotite phenocrysts are more rarely seen. The other exposure of this dike at the south point of Austin's Hollow shows these points in a still higher degree, the rock is completely schistose and is recognized only as a dike by its cutting across the strike of the shales, by its same reddish weathering color and by its strike being such that it must be the continuation of the Lion's Head outcrop. These points of identification are confirmed by the microscopical examination. The outcrop of the northern dike on Austin's Hollow was not visited by the writer but is given on the authority of Dr. Foerste. Under the microscope the freshest and best example of these rocks, from Hull's Cove is seen to be composed chiefly of orthoclase and biotite, the latter in two generations. Apatite, zircon, pyrite in well formed idiomorphic crystals and pretty abundant in amount; plagioclase and calcite are also largely present. Some secondary quartz occurs. The structure where it has not been destroyed is panidomorphic or allotriomorphic granular.

The rock is in that first stage of alteration of a lamprophyre which may be called the carbonate stage; it effervesces when placed in acids, but the second stage of alteration in which these rocks lose their carbonates and pass into masses of impure clay, and which may be termed the kaolin stage, was nowhere observed in either dike. The chemical composition is given

SiO_2	46·11
TiO_2	·84
X	·97
Al_2O_3	14·75
Fe_2O_3	2·20
FeO	4·51
MnO	tr.
MgO	5·73
CaO	7·82
Na_2O	1·29
K_2O	3·84
H_2O	2·90
CO_2	7·32
S	1·37
Total	99·65
O = S	·33
	99·32
Sp. G.	2·904

in the above analysis. The amount of CO_2 shows the considerable amount of carbonates present and the sulphur that of the pyrite. The symbol X refers to the oxides of those earths which after fusion with $HKSO_4$ do not dissolve in cold water. It is probably more or less impure with zirconia, titanic oxide, etc. No attempt was made to determine it.* A comparison of the chemical composition of this rock with that of minettes from other parts of the world shows a striking agreement with some of them as given in Roth's Tabellen.

The same rock in other portions of the dike exhibits the effects of pressure. The mica leaves are bent and curved, they begin to disappear and their place is taken by a cloudy decomposition product which shows perfectly the form and cleavage of the original biotite crystal. All grades of transitions may be traced from the unaltered crystals to those completely changed. On examining this cloudy alteration product with the highest powers it is found to be full of minute rutile needles and prisms. While other effects of pressure are clearly visible, this is one of the most noticeable in this dike

* Conf. Williams' Igneous Rocks of Arkansas, Ark. Geol. Surv. Ann. Rep., 1889, vol. ii, p. 226, who gives full literature, etc.

rock. The Lion's Head dike is precisely similar, only as it has been more highly pressed it shows this change in a higher degree and this reaches its highest development in the outcrop on S. point of Austin's Hollow. Here the rock is strongly folded in the strata and as already mentioned it has a pronounced schistosity. Also under the microscope it shows a schistose structure and contains considerable white mica and chlorite along with the broken material of the original rock, and were it not that all grades of transition from the nearly normal rock at Hull's Cove down to these forms can be traced, it would be impossible to recognize its original composition.

Phyllite.—It would be impossible to give here a minute description of all phases of the unaltered sedimentary rocks existing on the island. A pale greenish or grayish phyllite of extremely fissile character, however, is by far the most common rock, and it was selected for analysis. Thin sections of it from various places showed pretty nearly the same general character. Between crossed nicols with a moderate power the slice presents a dark gray "pepper and salt" appearance interspersed with fine points of brighter polarizing mineral fragments. This is due to its excessively fine grain. Under very high powers this is resolved into a mixture of sericite, chlorite, occasional fragments of feldspar (orthoclase and perhaps albite), specks of hematite, scales of graphite and pieces of quartz. Occasionally very minute but idiomorphic crystals of tourmaline occur. The chlorite and mica, interwoven into a fine mesh and strung out along the planes of schistosity, are with the quartz the chief components. This is everywhere penetrated

SiO_2	56·36
TiO_2	0·97
Al_2O_3	22·78
Fe_2O_3	1·04
FeO	6·25
MnO	0·15
MgO	2·40
CaO	none
Na_2O	1·48
K_2O	3·91
H_2O	5·01
Total	100·35

by swarms and clouds of the most minute rutile crystals. Muscovite occurs at times in tabular crystals which in their orientation bear no reference to the planes of schistosity. The

chemical composition of a specimen from Potter's Point is given in the above analysis. Lime was carefully tested for but not even a trace precipitated. It seems to be a very pure and typical phyllite. Even in the clearest and most uniform examples the original bedding shows in slight changes of a color banding across the cleavage planes.

Contact metamorphic rocks.—From what has already been said in the foregoing it is evident that no safe petrographical conclusions can be drawn concerning the nature of the metamorphism which has been effected in the sedimentaries by the intrusion of the granite. For the original strata varied rapidly in thickness and in character; their exact stratigraphical position in relation to the granite can no longer be made out, they have suffered from dynamic forces and from weathering as well, each bringing its own series of changes. The original character therefore is strongly masked and can only at times be suspected. Their geological relations are indeed far better seen and studied in the field than with the microscope though the latter reveals some interesting facts.

The first stage of alteration, where the shales assume a knotted appearance, has been sufficiently described, what follows relates to the harder and tougher hornstones. The dark solid slate-like rock occurring on the shore in a recent cutting in the lower part of E 6 shows an extremely fine grain consisting of quartz, white mica, specks of graphitic matter and iron ore with groups composed of masses of fine crystals that appear to be epidote and zoisite. These are strung along in a schistose structure. All through it appear places with less highly doubly refracting material that between crossed nicols show idiomorphic outlines and seem like pseudomorphs or phantom shapes of some former mineral that appeared in porphyritic crystals.

A very common form of the hornstone rocks is one composed chiefly of quartz and chlorite together with white mica, iron ore, etc., in allotriomorphic structure. This is assumed to be a rock which was formerly composed chiefly of quartz and biotite. It generally occurs pretty near the granite and composes largely the outcrops of E 4, lower E 5 and to the west of the road in D 5. It occurs also in direct contact with the granite in F 4 on Bull's Point.

Another form is that which occurs in the outcrop south of Mr. Green's barn in D 5 and east of the road. This as remarked before begins with a rock which has not entirely lost its shaly character. The rock consists essentially of quartz, white mica, fragments of feldspar, chlorite, bits of graphite and iron ore being freely sprinkled through it. Sections cut from the rock to the south of this show in addition a development

of hornblende crystals in stringy forms mixed with masses of fine crystal particles of very low double refraction and high single refraction and which appear like masses of zoisite. Still farther southward this character of the rock together with the amount of hornblende increases. A somewhat similar form is found on Bull's Point and in addition some triclinic feldspar is present. It is indeed possible, as suggested by Dr. Foerste, that some former basic eruptive rock was present and included in the metamorphism produced by the granite, although in this case it could have formed but a relatively small proportion of the triangular altered area and its characters are now too much obscured for recognition. On the other hand the presence of feldspar as a result of contact metamorphism is well known especially in such rocks as contain a considerable amount of alkalies as suggested by Harker.*

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