ART. XLIX.—*Geological Relations and Genesis of the Specular Iron-Ores of Santiago de Cuba;* by JAMES P. KIMBALL.

FOR a distance of at least some 20 miles east of the longitude of the bay of Santiago de Cuba, the Sierra Maestra, or coast-range, maintains a height of about 4240 feet, as barometrically measured by Mr. Emile Sarlabous, vice French Consul, at the point on its crest well known as Gran Piedra. On local maps of the Province of Santiago, this point is laid down as 5·69 miles from the coast of the Caribbean Sea, which is generally parallel to the crest of the range. The great outlier or escarpment of Gran Piedra, according to the same authority, presents the same lithological features as its lower foot-hills, namely—a coarsely crystalline syenyte of eruptive origin. Wherever this has come under my own observation, within the expanse of the lower foot-hills, it is penetrated by very numerous dykes of dioryte.

From the overflow of similar dykes, the upper immediate flank of the Sierra Maestra and middle foot-hills are covered with a mantle of the same trappean rock. The maximum thickness of this mantle I estimate to be about 2000 feet, corresponding to an altitude of about 3800 feet.

The Sierra Maestra is the south (front or coastward) range, and last elevated, as well as the longest, of a series of successively elevated ranges, together forming the broad belt of mountain plateau, stretching nearly to the north coast, and running out to a point at Cape Maysi. West of the bay of Santiago, a lower range, of still subsequent elevation, forms the coast-range of the southern peninsula. This range is locally known as the Sierra de Cobre, although on general maps not distinguished from the Sierra Maestra.

Reference will presently be made to the more special lithological features of both ranges, within the limited scope of my observation. Occasion is here suggested to note as a significant fact in relation to the vulcanism of the Sierra Maestra, the family relation of the two types of eruptive rocks entering into the structure of at least the base and south flank of this range. The significance of this fact, in connection with others that will be noticed, appears to be that the overweighting of the syenyte mass along an inherent line of least resistance, corresponding to the margin of the sub-oceanic basin of the Caribbean Sea, has been followed first by depression, attended with re-melting of the base of the mass; and afterward by elevation. This elevation, it will be shown, has taken place by successive stages. The final, if not the concurrent, result of such oscillations of level has been to inject the molten magma in the form of dioryte through fissures incidental to elevation.

The diorytic mantle thins off toward the coast, in part by erosion, while the lower ranges of foot-hills are completely denuded of dioryte, if ever enveloped.

The immediate coast presents a remarkable development of coral rock, or coral limestone, in three terraces, of which the upper is about 350 feet above the sea. The second terrace is at an altitude of about 175 feet, and the present shore, a plateau of comparatively recent elevation, about 14 feet above tide. These terraces mark successive elevations of the Sierra Maestra range. These stages of elevation were in direct, but probably remote, succession with other elevations which I shall show to be indicated by traces of more ancient corallines (coral formations) about two miles still farther back from the present coast.

The last terrace, or that of the present shore, falls away vertically into deep water, soundings at the mouth of the Carpintero, 150 feet off shore, giving a depth of 165 feet. It retains to a remarkable degree the structure of solid reef, studded with distinct forms of coral, and is strewn with fragments of coral, rounded by the waves, but in good preservation, and numbering a large variety of species.

The two older terraces retain little or nothing of corallum structure, but are thoroughly consolidated, indurated and crystalline. As an effect of the action of the waves in former periods, they still present mural escarpments seaward, with a talus at the base of each from weathering, and from clefts produced by the wedging effect of roots of trees.

The upper terrace reposes directly on the syenyte, and east of the Carpintero river (Juraguacito) forms the immediate coast. The base of the two lower terraces is concealed.

The bay of Santiago corresponds to an original recession of the coast, the eastern limit of which was the mouth of the river just mentioned. This recession was once filled out with coral formation. Subsequent to the final elevation of the Sierra Maestra, the coralline was eroded into the present land-locked form of the bay with the preservation of a wide margin of this calcareous rock. Both shores have been excavated from corallines, of which those already noticed are the more recent and easily distinguished. These present a bold front to the bay. The old Morra fortress is on the second and third terraces, numbered in inverse order of succession. Earlier corallines are less easily identified with what study I have been able to give to the region. The elevation of the Sierra de Cobre, the eastern end of which range faces the bay, seems to have resulted in the final elevation of the coralline area. The succeeding excavation of the bay has been effected with but little aid from existing streams, the present drainage of the mountain plateau of the Sierra Maestra and back ranges being to the east and west of it.

The bay of Guantanamo, 51 miles east and about three times the area of the bay of Santiago, possesses so many obvious points of resemblance to the latter, including littoral, topographical and hydrographical relations, as to suggest in both cases also similar geological relations. Mr. Sarlabous informs me that the margin of the larger bay, like that of its twin, is of coral-rock.

In the vicinity of Guantanamo Bay and thence eastward, the dioryte mantle appears from the sea to envelop the crest and the whole southern flank of the Sierra down to the coast. Place is given to this remote observation, confirmed as it is by Mr. Sarlabous.

The Juragua Hills, so-called, are the culmination of the middle ranges of foot-hills of the Sierra, about half way between the bays of Santiago and Guantanamo, or, more closely defined, between the mountain streams, the Carpintero (Juraguacito) and the Daiquri.

Along with a study of some very remarkable deposits of a specular ferric oxide, in course of development by the Juragua Iron Co. (Lim.), for consumption in Pennsylvania, these hills came under my observation in the months of June and July last.

As here distinguished, they consist of two parallel ranges of foot-hills distinct from the immediate south flank of the Sierra Maestra. The first or upper range reaches an elevation of about 2000 feet; the second or lower, of about 1100 feet.

Both ranges are the topographical result of the erosion of the south slope of the Sierra Maestra, within the compass of the dioryte mantle down to the underlying syenyte, and in the case of the lower range, well into the syenyte. The syenyte base of the upper range is occupied by the bed of the Carpintero, and that of the lower range by the Juragua and its east fork—the Benevolencia.

The lower contact of the dioryte mantle with the syenyte base of the Sierra (according, first, to unequal elevation and, second, to subsequent unequal erosion), follows a convoluted line. This contact corresponds, as I believe, to parts of a former coast line, as shown by traces of ancient corallines. These traces are as follows:

1. Isolated bodies of marble without stratification, but with marked prismatic cleavage. These invariably occupy the elevated parts of the contact.

2. Isolated bosses and other bodies of specular and amorphous ferric oxide, only partially dehydrated, which I take to be replacements of ancient corallines. These occupy the lower parts of the contact.

Referring both occurrences to their original relations to the coast, they seem to be relics of bodies of coral rock and of coral reef reposing on the syenyte. These masses became implicated in the igneous overflow, one or more than one, from the north. This is shown by the approximately east and west direction of the longer axes of them all. The upper ones, or those now occurring as marble, were probably of the nature of emerged coralline, while those occurring as ferric oxide, lower in position and farther to the south, were probably of the nature of coral-reef when involved in the eruptive flood. These are found directly back of the lower contact, while the bodies of marble, in a similar relation to the contact, appear to be farther back of it.

The thinning of the dioryte mantle toward the sea is thus seen to have been not altogether the result of its flow, slackening as may be supposed inversely to its mass, but to have been promoted by the extinguishing effect of the sea. The sea seems also to have brought the flow to a stop.

No traces of ancient coral reefs have been observed between the contact, within the area of the still lower syenyte foot-hills, and the emerged corallines of the present coast margin. Yet such corallines may have once existed, and since disappeared by subaerial erosion.

Nor is proof afforded of any former extension of the dioryte mantle below or south of the contact. Diorytic dykes, nevertheless, in great number, penetrate the syenyte on every hand, their frequency becoming less toward the west, as distance increases from the culmination of the Juragua foot-hills. Beyond them, west of the Carpintero, but in line with the second range of foot-hills, or just back of the general course of the contact, the syenyte hills have been wholly denuded of dioryte, the hills themselves becoming gradually degraded toward the bay of Santiago, and exhibiting the extreme effects of weathering decay characteristic of highly crystalline feldspathic rocks in lower latitudes. Remnants of detritus, dioryte and hematite, upon the surface of these hills, attest the former extension of at least a thin development of the dioryte mantle. Unlike the lower syenyte hills of the Juragua group, these hills have not opposed to erosive agencies a great number of ribs or dykes of more enduring trappean rock.

In the absence of remnants of dioryte in place, the presence of specular ore-float in place is equally significant. For all recognized ore-bodies and marble-bodies are encompassed by dioryte, or by products of its weathering, though limited to its lower margin—the ancient littoral, and in part submarine, relations of which are argued as above.

The interesting question now arises whether the diorytic intrusions within what at the period of their vulcanism was a submarine syenitic area, below the level of the habitat of coral life—did not stop short of overflow. That such intrusions may have been limited in upward range by the submerged surface of the syenyte seems indeed probable on general grounds. Hence the erosion of the lower syenyte ranges of hills, three in number, of the Juragua group, may never have involved the disappearance of even a reduced thickness of the dioryte mantle, as compared with its medium (if not minimum) original development immediately back of the present contact. The proposition then is that the present syenyte contact, as far as indicated, was the actual lower limit of the dioryte mantle, as it is in fact at present. This I am inclined to believe.

The several terraces of recent coralline mark, as already indicated, successive, and in chronological order the later, uplifts of the Sierra, in vertical range not less than 500 feet. These, together with the series of corallines of the second line of foot-hills, as recognized by the bodies of hematite and marble, are proofs of a sum of uplifts of not less than 1300 feet.

Obscure traces upon the first range of foot-hills of still more ancient corallines, to which I shall again refer, point to a still more remote succession of uplifts whose vertical range—referred to the latest indicated level of coral formations, some 100 feet below the present shore—may be estimated as about 2300 feet. From the syenyte hills may have disappeared by subaerial erosion intervening corallines, between those of the present coast and the line of ancient, and now metamorphosed, corallines traced along the contact or southern margin of the dioryte mantle.

Dry beds of once powerful streams occupy deep defiles of the foot-hills, further attesting hydrographical changes of such a scope as may be believed to be commensurate to the degree of successive elevations of the Sierra. Such defiles are the arroyos Negro, Caridad, La Plata and Berraco. The dry and nearly filled up Laguna of Berraco, so-called, some fifteen miles east of Santiago Bay, and a few feet above tide, corresponds to a former indentation of the coast at the mouths of what appears to have once been two of the largest streams of the south slope of the coast range.

The syenyte of the lower foot-hills is weathered to a depth as far as yet penetrated by railway cuts. All fresh surfaces thus exposed exhibit its disintegration along divisional planes, with the result of an obliteration of its prismatic structure from jointing. The incomplete exfoliation of prismatic blocks between joints has resulted in the usual rounding of the undecomposed centers in the form of cores. At the surface, where freed from their interstitial products of decay, these appear as outlying bowlders. The weathering of the diorytic dykes which traverse the syenyte in directions of least resistance corresponding to its jointing, is indicated by the passage of their hornblende into epidote and chloritic residuums.

The dioryte also presents toward its lower margin marked phenomena of weathering decay or of metasomatic alteration. These will presently be described as subsidiary results of the process of epigenesis, or course of permutations, by which the calcareous material of implicated bodies of corallines has been replaced by ferric oxide.

The weathering of the upper parts of the dioryte mantle is less obvious. Yet, like all superficial masses of ancient (especially eruptive) basic rocks, it stands for a once more basic aggregate, from which protoxide bases have been largely eliminated in the form of sulphates and of alkaline bicarbonates. The epidotic character of much of the dioryte where least obviously weathered, is one of the proofs of the instability of the hornblende. Again, regarded as a feldspathic aggregate under conditions of extreme exposure to weathering action, all parts of the dioryte must be assumed to represent its effect, however unequal, and insusceptible of measurement without the partial preservation of the original type for comparison. This consideration is one of importance in the present case, because a large source of ferric oxide must be looked for to account for its accumulation, under favorable circumstances of drainage, in the form of the iron-ore bosses along the lower edge of the dioryte mantle, at its contact with the underlying syenyte.

Two series of circumstances have determined the *loci* of these iron-ore bosses, viz: (1) the *loci* on the ancient submarine slope of the syenyte on which coral-reef was reared, or on which coral sediments were piled up by the waves; and (2) subsequent favorable conditions for the supply of ferric oxide to replace lime carbonate as fast as it dissolved under the intermittent action of percolating acidulated waters and of alkaline bicarbonates.

1. Proof of the coralline parentage of the iron-ore bosses is the preservation in nearly all of them of fossil corals, or at least of casts of coral. Such casts are found toward the outer parts of ore-bodies, in what may be called their transition parts. These are in general siliceous from the segregation of silicates. While the lime carbonate of the casts referred to is replaced by ferric oxide, the cells of the corallum are filled out with segregated matter, more or less chloritic from secondary alteration.

The larger bosses, corresponding to coralline masses, exhibit a concentric structure characteristic of segregation by foliation or external deposition. The smaller ones, on the other hand, frequently present the peculiar warped surfaces characteristic of the coral rocks, and such as may be seen on every cliff or detached mass of coral rock in the terraces along the present coast.

The larger bosses may in a general way be described as lenticular bodies, any section of which is approximately elliptical. The smaller ore-bodies are of irregular shape and suggest a fragmentary relation to the larger ones, especially as they are always found near the larger, and invariably in such relations as would correspond to the superior surfaces of corallines referred to their original relations with their syenyte base.

The position of all the ore-bodies is on the inner or upper side of the syenyte contact, but laterally and terminally surrounded with altered diorytic rocks. This fact, together with the circumstance that their longer axes are approximately parallel to the crest of the Sierra as well as to the present coast, tends to show the parent corallines to have been involved in the igneous flood down the Sierra slope from the overflow of innumerable dykes. The implication of the corallines in the flood of eruptive, was probably attended by elevation of the whole range, including the coast. Subsequent elevations have raised them higher, and further withdrawn the coast. Some of the ore-bodies are penetrated by courses of dioryte, now sometimes represented by chloritic kaolin. These I am disposed to refer to ramifications of the eruptive material in the act of overflow and upheaval.

2. The ore-bodies, whose general position is thus to be defined, occupy the thinning edge of the dioryte mantle. How far its reduced thickness is due to erosion, and how far to its original development, or to the circumstances of its flow, is partially indicated by the degree of erosion which the ore-bodies themselves have undergone. All that have been discovered have been more or less truncated by erosion.

The relation of the marginal region of the dioryte mantle to the great body of the same basic formation back of it, and to the underlying syenyte, and the preservation under conditions of energetic weathering of the syenite in hills in front, are circumstances readily recognized as favorable to metasomatic action along this margin. Underground as well as superficial drainage of both formations must have been directly toward this margin, especially before the present minor topography was sculptured. That the present topography has been wrought subsequent to the formation of the iron-ore masses is clear from the fact of their erosion by the streams, which now follow in part the same marginal region of decayed and decaying rocks.

Unequal elevation or unequal erosion, or probably a combination of both conditions, has served to introduce a series of conditions unfavorable in certain cases to the radical alteration of coralline masses. In such cases the coralline mass occurs in the form of white marble. In attitude and general relations both with the syenyte and dioryte such masses have only certain features in common with the ore-bosses. They have already been described as devoid of stratification, and as strongly characterized by a prismatic cleavage. They all occupy positions in the Juragua Hills toward the summits of the second range, at the base of which the ore-bodies are distributed. Under such circumstance all drainage both from the dioryte and the syenyte is and always has been away from them, and *pari passu* toward the iron-ore bodies. The encasing dioryte exhibits no marked phenomena of weathering. The argument for the limited degree of weathering sustained by this rock under such conditions, it will be noted, is by induction. Replacement of calcareous matter has gone on only at the surface of such bodies as shown by the prevalence of float of ferric oxide remarkably pure, but evidently from small plates or segregations on their sides. Garnetiferous aggregates with considerable proportions of specular and magnetic oxides of iron are the most common products of metasomatism met with on the dioryte summits.

The marble ledges have, however, so many relations in common with the iron-ore bodies, the coralline parentage of which seems to me demonstrated, that they likewise must be referred to a similar primary origin. Their metamorphism or crystallization is due to igneous contact. Their preservation in the metamorphic state without metasomatic alteration, is explained as above by their obvious exclusion from the conditions which have governed the alteration into ferric oxide of other corallines, whose more favorable environment with reference to such an alteration, I now proceed to describe.

Toward the continuous base of the second range of hills the dioryte margin, just back of the contact, has passed into miscellaneous aggregates of a chloritic type. Such are the rocks which immediately encase the ore-bodies. They are soft, rotten and bleached. In color they are of various light shades of green. By further oxidation of ferrous silicates, this coloration has locally given way to darker complexions of red and brown, especially in such as exhibit a notable proportion of free silica, and a dense amorphous consistency. Aggregates of clear crystalline quartz in admixture with magnetic oxide of iron likewise occur, apparently as residual forms of the alteration under local circumstances of basic material originally containing a notable proportion of this oxide.

The syenyte conspicuously outcrops in contact with ore-bodies only in a single instance. This is the south ore-body of East Mine Hill. Here one side and both ends of the ore-boss abut upon the syenyte, which thus forms a *cul-de-sac.* The contact upon the exposed side is occupied by two courses of rotten, aluminous and bleached chlorite in a kaolinized state. These are succeeded by a plate of amorphous siliceous and highly ferriferous material, 3 feet in thickness, within the compass of the ore-body and forming its outer wall. Irregular courses of chloritic and distinctly aluminous material correspond to outer shell-like divisions of the ore-body, due, as I suppose, to the exfoliation of siliceous (insoluble) matter in the process of molecular rearrangement of the mass in the process of segregation and concentration of ferric oxide, attending its replacement of lime carbonate. A part of the siliceous matter thus exfoliated probably represents detrital contents of coralline masses; another part the alteration *in situ* of ramifications or tongues of diorytic eruptive material intruded into fractures of the original coralline mass when overwhelmed and lifted.

Courses of chloritic material of the above description encase the lower ends, at least, of all the ore-bosses wherever terminal parts have been uncovered by excavations. These conform to the general lenticular outline already referred to, and hence are to be referred, as above, to exfoliated insoluble residuums. They are similar in type to the intrusions of siliceous material within the compass of the ore-bodies. The decomposition of dyke-like ramifications *in situ* is seen to result in a product indistinguishable from the residuums instanced from diorytic detritus in the parent coralline. This may be supposed to follow from the qualitative identity of such detritus with the dioryte from which it was mainly derived.

The terminal parts of only the lower and more accessible ends of the ore-bodies have thus far been exposed by excavations at the base of the hills, and just back of the contact, where, in the course of its convolutions, this conforms to the southerly course of streams. The longer axes of the ore-bodies are therefore transverse to such parts of the beds of streams as have been eroded along the contact. Only where assuming a longitudinal direction has the contact, for obvious reasons, presented to erosion the line of least resistance.

The chloritic courses immediately encasing the ore-bosses, and which have been described as exfoliated residuums, alternate with divisions of siliceous ferric oxide. Incomplete quaquaversal or rounded dips are thus observed at the lower terminal parts of ore-bodies. The concentric structure, of which they are the outer manifestation, prevails as far as can be seen within the interior of the less eroded ore-bosses where penetrated by drifts. Hence a divisional structure resembling that of an onion, and easily mistaken for bedding. The shell-like divisions, elsewhere described as transition parts of ore-bosses, give way inside to massive ore divisionally arranged as above instanced. The conditions of the central and nether parts of the larger ore-bosses have not yet been brought to light. The center of the south ore-boss of East Mine Hill appears to be not far away from its eroded surface. The ore is there presented in massive form and of extraordinary purity.

The larger ore-bodies present all the numerous physical types of specular oxide, besides a variety of phases from unequal distribution of pyrite and of magnetic and manganic oxides, and from an unequal degree of hydration. Earthy admixtures are of a chloritic and epidotic type, and thus essentially basic, differing in this respect from Huronian speculars whose earthy tendency is decidedly acid from segregations of quartz or from intercalations of jasper. As returned by numerous average proximate analyses from commercial samplings, exclusive of my own, moisture, in part hygroscopic, is constantly present in percentages of 0·24 to 0·81; silica and insoluble 5 to 10½; phosphorus 0·009 to 0·065; sulphur 0·045 to 0·248; and iron 61 to 68½.

It is needless here to follow out what may be termed the circular processes of the epigenesis of ferric oxide from basic rocks through the mediation of meteoric waters charged with organic, sulphuric and carbonic acids, and of its preservation under favorable conditions. The replacement of soluble lime carbonate by comparatively insoluble ferric hydrate in the act of peroxidation from ferrous carbonate and from ferrous sulphate, and its concentration under favorable conditions by segregation or as a sediment as the case may be, are common and well known phenomena.

The Clinton so-called fossil-ores of the Upper Silurian areas of the United States afford a familiar example of the replacement of limestone by ferric oxide. The Archean specular ores of the James River of Virginia are an example of the segregation of ferric oxide from metamorphic schists *in situ*. Eruptive porphyries of Leadville, Colorado, have given origin to similar segregations. The gossans of almost every mineral vein further illustrate the familiar phenomena of epigenesis of ferric oxide. The Cuban iron-ores, above described, differ from the Archean schistose deposits of Michigan and Wisconsin, and from the bedded parts of the deposits of Pilot Knob and Iron Mountain of Missouri, in the following particulars: (1) They have had their immediate source in eruptive rocks rich in protoxide bases instead of metamorphic rocks comparatively poor in proto-silicates. (2) Their ferric oxide has been concentrated without ever reaching hydrographical channels of drainage, and therefore preserved almost *in situ* without the mediation of basins. (3) The basic character of their siliceous impurities, occurring as residuums, characterizes them still further from both classes of Archean ores, especially from the schistose, whose accessory admixtures are not only acid but of the nature of segregations, intercalations and mechanical sediments. These in point of sizable development and, cursorily regarded, in general lithological appearance are, however, their nearest familiar analogue.

Besides the iron-ore bodies above described as *replacements*, another class of deposits of ferric oxide remains to be described. These may be distinguished as *concentrations*. These are partially altered diorytic masses characterized by a notable but unequal concentration of ferric oxide *in situ*. The outcropping portions of such masses are often no less rich in specular oxide than the ferric replacements of coralline, from which, however, they are readily distinguished by their superior hardness and density, and by their sharp metallic sound when struck with a hammer, as well as by the circumstances of their metasomatic association with unaltered or incompletely altered dioryte.

What has determined the localization of such deposits within the dioryte mantle has not been made clear. Certain indicated circumstances rather than well ascertained facts, seem to bear upon this question. (1) The location of such deposits, as far as recognized, is near the contact, but not uniformly immediately back of it, as in the case of the ore-bodies of coralline parentage. Some relation between the two classes of deposits may be suspected from the fact that an occurrence of this kind is recognized alongside, and probably in contact with, the developed lenticular north ore-body of West Mine Hill; while alongside a similar trappean concentration in Dry Arroyo, further up the same hill, the presence of lenticular ore-bodies of the nature of replacements is indicated.

Ferriferous parts of the dioryte referred to are usually beneath the detritus, and may be considered as representing a state of weathering intermediate between the normal dioryte and its bleached and obviously weathered products. Such occurrences are a conspicuous feature of the first range of foot-hills. On the Yuca Mine location, what appears to be garnetiferous casts of corallum have been found in juxtaposition with an ore-deposit of this description. This is the only relic, if such it be, of the former existence of corallines discovered by me so far back as this range of foot-hills.

The question therefore arises whether obscure and in some places obliterated corallines may not under such circumstances have given way to available replacements of which ferric oxide was but a minor part, and have determined the *loci* of such metasomatic activity or chemical permutations as to have resulted in the exchange of acids and bases in the basic and pyritiferous eruptive, followed by concentration of ferric oxide. The peroxidation of ferrous oxide *in situ* is easily conceived to have been a result from the tardy circulation, in so dense an aggregate, of chalybeate, or of solutions of the vitriolized products of iron and copper pyrites, especially under the further condition of an adjoining body of limestone. Calcic carbonate has also been at hand from decomposing silicates.

As a corroboration of the general induction, such occurrences may be held to attest an originally more basic constitution of the dioryte, and especially a once larger proportion of ferrous oxide, and accordingly of proto-silicates. Minor exhibitions of the same general class, but clearly without the mediation of limestone, are outcropping surfaces of diorytic dykes, the identity of some of which seems to have been preserved within the compass of their general overflow, or, as above distinguished, the dioryte mantle. The concentration of ferric and magnetic oxides upon such surfaces, presents outliers popularly regarded as outcrops of ore-bodies of great richness. A few blasts are generally sufficient to prove their superficial character. Cupreous stains of green carbonate from the epigenesis of a sulphide of copper, are found within the ore-bosses of coralline origin as well as in the interior of ferriferous parts of the dioryte.

The copper deposits of the Sierra de Cobre west of the Bay of Santiago, exhibit to a remarkable degree still active metasomatism of the diorytic porphyry in which they occur. Not only is the overflow of mine-water from the abandoned mines a present source of cement-copper, but exfoliations more or less cupreous are observed on all weathered surfaces of wall-rock left standing by the old English companies. Even individual fragments of dioryte detritus in the old burrows have become completely coated with exfoliated mineral matter. Ferric, as well as miscellaneous cupreous products thus occur, along with a variety of silicates and other insoluble compounds. Even the old slags show zeolitic and other drusy segregations. Secular phenomena of this kind may be considered as in part an effect of the humidity and high mean average temperature of the climate.

Under the same favorable climatic conditions secular weathering, or metasomatism of eruptive basic rocks, has gone on to a remarkable degree throughout the whole region above briefly described. Permutations of this kind tend to produce from the eruptive, now represented by dioryte, a series of rocks resembling in lithological character metamorphic chloritic, garnetiferous and ferriferous schists. The basic character of the prevailing admixtures of the latter, occurring in association with the ferric replacements of corallines, is their most obvious lithological point of difference from the prevailing type of Huronian specular schists, which as above remarked are essentially acid. Thus, they more closely resemble certain Laurentian magnetite-schists whose earthy admixtures are generally basic. Yet quarztiferous aggregates are not wanting among the great variety of ferriferous admixtures here referred to.

The ferro-garnetiferous aggregates are characterized by a subcrystalline groundmass of wine-colored garnet, probably magnesian, with druses of magnetite, and a minor proportion of the same oxide irregularly scattered throughout the mass. Narrow ledges of this rare material in West Mine Hill are remarkably continuous. Their occurrence is under such circumstances in general as to indicate their relation to the single series of dykes, the individuality of some of which has been preserved within the compass of their collective overflow. So considered, they may be taken as a special metasomatic transformation, governed by obscure local conditions, of certain dykes belonging to the same series as chloritic, epidotic and ferriferous outcrops, as well as distinct diorytic courses, readily differentiated as dykes, within the more porphyritic mantle. The latter, it is conceived, represent, under limited dynamical conditions (whence their extreme density of grain amounting in places to almost aphanitic aggregation), the least advanced state of weathering of the original eruptive. Among the numerous pseudomorphic relations of garnets, may be recognized some corresponding in kind to the metasomatic relations which may be supposed to exist between massive garnet rock and basic eruptives, along with the altered alumino-magnesian silicates whose transformation has also been wholly or in part by loss of certain ingredients.

Labradorite-dioryte more or less chloritic and of metamorphic origin, as well as metamorphic representatives of a long series of intrusive species of rocks, have been described by Prof. Dana and the late Mr. Hawes. "The fact," as remarked by Mr. Hawes, "that metamorphic action can produce rocks exactly like the igneous in external aspect and chemical constituents is of great interest in the study of rocks."* It seems almost certain that ancient eruptives afford few if any standards for such comparison where permutations of the nature of metasomatism have not led to their resemblance to related metamorphics. This may be assumed especially in the case of chloritic and epidotic rocks.

The chloritic products from alteration of the Sierra Maestra epidotic dioryte closely resemble, as above remarked, metamorphic occurrences of chloritic schists. Such resemblances tend to indicate, indeed, a middle ground where meet products lithologically identical, proceeding on the one hand from basic eruptive rocks by metasomatism, and on the other hand from sedimentary rocks by metamorphism. Resemblance between essentially chloritic aggregates of both types hardly needs the confirmation of analyses.

The dioryte of the Sierra Maestra, though not without traces of orthoclase, is essentially plagioclastic. The syenyte is mainly orthoclastic with occasional crystals of triclinic feldspars. The basalts indicated by Ansted in 1856 would now be classed as dioryte.†

* This Journal, 1876, xi, 126. † Proc. Geol. Soc., xii, 144.

Lehigh University, Bethlehem, Pa., Oct. 10, 1884.