SCIENCE

FRIDAY, JULY 20, 1900.

CONTENTS:

MSS. intended for publication and books, etc., intended for review should be sent to the responsible editor, Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

*PRE-CAMBRIAN SEDIMENTS IN THE ADIRONDACKS.**

CONTENTS.

Introduction, the rise of stratigraphical geology.
  Its gradual application to the pre-Cambrian strata.
The Adirondacks outlined, geographically and geologically.
  Work of C. H. Smyth, Jr., H. P. Cushing and the writer.
The Varieties of Sedimentary Rocks.
  The Limestones.
  The Quartzites.
  Minor Associates of the Limestones.
  The Sedimentary Gneisses.
General Distribution of the Metamorphosed Sediments.
  The Northwest.
  The Eastern Side.
  Resumé.
Typical Stratigraphical Cross-sections.
  Catamount Mountain.
  The Western Spur of Whiteface.
  The Lewis Section of Quartzite.
  Limekiln Mountain.
  Styles Brook Section in Southern Jay.
The Significance of Graphite.
Conclusion.

Stratigraphical geology had its rise in those old mining regions of Germany, the

* Address of the Vice-President and Chairman of Section E of the American Association for the Advancement of Science, given at the New York meeting, June, 1900.

The field work on which the above paper is based was done under both the U. S. Geological Survey and the New York State Geological Survey. All the data under the authority of the latter and here drawn upon have been printed. For permission to use much unpublished matter belonging to the former acknowledgments are here respectfully made to the Hon. Charles D. Walcott, Director.

Hartz, the Erzgebirge and Thuringia; and speaking as I do, in a lecture room of our oldest American School of Mines, it is a special pleasure to note this connection and to render to the ancient art of mining—the real mother of geological science—her just due. There is no doubt in my mind that the keen observation of miners had convinced them that there was some regular succession in the rocks, long before this principle found accurate, scientific expression in printed form; but, so far as we know, it was first formally stated by Johannes Gottlob Lehmann in connection with some profiles or cross-sections of the Hartz and the Erzgebirge, which he prepared about the middle of the last century. Lehmann, who was a mining official under the Prussian government, had observed that flat and undisturbed beds rested upon earlier tilted beds and upon crystalline rocks, both of which latter he assumed as his original base but with whose relations he did not concern himself. A few years later in Thuringia, George Christian Fuchsel dealt in a tectonic way with the Coal Measures, the Permian and the later systems, but as we all know it was not until the close of the eighteenth century that William Smith made known the use of type fossils in English geology, nor was it until 1808 that Cuvier and Brogniart, working upon the extremely regular deposits of the Paris basin, established for France if not for the world the use of fossils on a large scale. They brought out a definite system, which anticipated by a few years the issue of William Smith's famous map of England.

It was natural that these results should be attained in regions of simple and easily deciphered stratigraphy, and of relatively modern beds. Taught and inspired by this pioneer work, the geologists of the quarter century that followed interpreted the Tertiary and Mesozoic strata, wherever fairly flat and undisturbed. Even the Coal Measures were studied and placed in their true position, but except in New York, where the older series are likewise flat and undisturbed, the lower lying Paleozoic remained a sealed book. It even seemed a rash and foolhardy undertaking when the two English geologists, Sedgwick and Murchison attacked the hills and mountains of Wales and Devonshire some 75 years ago. The structural problems which this region presented were esteemed too complex and too difficult to justify the expenditure of effort upon them. Sedgwick and Murchison, however, found the clues and by careful work finally classified the strata and despite faults, folds and moderate metamorphism, placed them in their true position. These observations opened up for investigation the whole Paleozoic and set the pace as well as laid out the course for stratigraphical geologists until a decade or two since. So much has now been accomplished, however, that even in regions of very violent change, the problems of the Paleozoic may now be considered to be in a high degree solved, and the range of work upon its series and stages has become chiefly faunal and biological.

But the course of geological investigation has tended ever downward to lower and lower horizons. It may be said that in recent years the chief problems of stratigraphic interest have involved that tempting yet elusive series of sediments that lies below the limits of well-preserved and recognizable fossils. The remains and organisms, which are so abundant and useful in the Paleozoic, disappear in the most remarkable way as we go below the Cambrian, and yet there are few geologists who do not confidently believe that in some corner of the world, not yet fully explored, they will be found in satisfactory abundance. Traces are of course already known. Walcott, in the West; Matthew, in the maritime provinces; and Barrois, in Britany, have met with encouragement, but the great discoveries remain for the future, because as yet the evidence is meagre and amounts to little more than a stimulus for later work.

And yet despite the lack of organisms, the elucidation of the genetic and structural problems supplied by these ancient sediments is of the highest interest and importance. They carry us ever farther and farther back toward the primeval conditions on our planet, and year by year the circle of the recognized Algonkian closes in on the admissible Archean, and year by year the ancient gneissic areas yield up the secrets of their pedigrees.

Not all the sedimentary rocks, once regarded as pre-Cambrian, have proved to be such on investigation. In many localities metamorphic schists, once supposed to be very ancient, have been safely lodged in the Paleozoic fold, but many more remain and there will be no lack of material for the next generation of geologists to work upon. In all the advances, methods of observation and interpretation have been developed, and the results gained in one locality have been of the greatest service in another. In the Highlands of Scotland, under the guidance of Peach and Horne, we have learned the part that overthrust faults may play and have realized the complex, although not quite hopeless, aggregate of tangled strata which may result. In the Lake Superior region, Irving and Van Hise and their co-laborers have developed the methods applicable in a region, folded in a complicated way and more or less metamorphosed, although not faulted. In the Green Mountains, Pumpelly, Dale and others have dealt with folds, metamorphism and faults, all three. In New Jersey, Nason and Wolff have attacked the old gneisses, worse subjects for stratigraphical elucidation than any yet cited, except the Scotch, and Wolff has appealed with much if not conclusive success to inconspicuous, although fairly persistent bands of peculiar rocks to indicate traces of a sedimentary succession. Adams, in the crystalline areas of Quebec and Ontario has dealt with problems more like those which we are to pass in review to-day than are any of the localities mentioned above. They involve the most ancient gneisses, the crystalline limestones, the vast intrusions of plutonic eruptives, and the same dynamic metamorphism; but there is one important factor in the Canadian area which we probably lack in the Adirondacks, and that is the most ancient gneiss, there called the Ottawa. At least we doubt if its equivalent occurs anywhere south of the international boundary. With the crystalline limestones and their associates in the Grenville and with the Norian intrusives, however, we have much in common.

Outline of the Adirondacks.—The Adirondacks—under which term I include the crystalline rocks of northern New York—cover about 12,500 square miles. In outline the area is somewhat like a circle, that has been flattened on the East along Lake Champlain, and pulled out to a cusp on the West toward the Thousand Islands. The diameter is very nearly 125 miles. The surface consists almost entirely of crystalline rocks, for, although a few outliers of Upper Cambrian and Ordovician beds are known as much as 40 miles from their parent masses, they are an insignificant fraction of the whole. In the area of the crystallines, metamorphosed representatives of both sedimentary and igneous originals are present. All except the small trap dikes have suffered severely from dynamic processes, sometimes to an extraordinary degree, and in instances the sediments are to be hardly if at all recognized as such. Sufficiently numerous examples, however, remain which can with certainty be referred to their originals, and great probability for the same derivation can be established for others. While deeply buried, the sediments have been invaded by an enormous mass of plutonic eruptives, of whose nature and succession we now have much evidence. So extensively has this been true on the East, that the sediments are broken up into small and often isolated areas, whose relations are difficult to decipher. On the west as shown by C. H. Smyth, Jr., they are more extensive although everywhere pierced by eruptives. After the intrusions dynamic metamorphism of a pronounced type crushed, sheared and mixed them up with the igneous intrusions; upheaval and faulting disguised the relations; and erosion removed or obscured the evidence, so that a problem is afforded, that is much the same as if the Basement Complex of the Marquette region had invaded the Huronian sediments and had split them up into small areas after which faulting had ensued. And yet in the eastern Adirondacks it does not appear that close folding has very largely if at all taken place. On the contrary, despite the dynamic metamorphism, the decipherable dips in the ancient sediments and the contacts between limestones and neighboring gneisses are often flat, and low folds if any seem to be the rule. Nevertheless crushing and granulation are very wide-spread and have often produced mashing in the rocks of all sorts, except the latest trap dikes. The mashing cannot be due to the larger intrusions, because they exhibit it as much as the sediments, and it must have followed their entrance. It preceded the Potsdam and it must have taken place under a considerable load, else there would have been more severe folding. From this brief general statement it will be seen that the problems possess their own individual characters and in a measure seem to differ from those of other regions unless it be Quebec and Ontario.

Recent Geological Work.—I pass over all mention of earlier workers in the region, because their contributions have already been reviewed elsewhere by me, and because they were not serious in a stratigraphical way. Detailed fieldwork has been required and this has only been attempted by C. H. Smyth, Jr., H. P. Cushing, myself and our assistants. Smyth has worked in the western counties; St. Lawrence, Jefferson, Herkimer and western Hamilton. Cushing has studied Clinton and Franklin Counties on the north; and I have been busied with Essex, Warren, Washington, eastern Hamilton, Saratoga and Fulton. We have however kept in close sympathetic touch in all our work. In Cushing's area less of the undoubted sediments occur, as only two small exposures of limestone have thus far been discovered. In Smyth's area the limestones are most extensive and furnish the best large exhibitions, whereas in the region covered by myself, they are most numerous, although of smaller individual extent, but they have associated with them certain other forms of metamorphosed sediments, which are not yet recorded in such large amounts elsewhere, which are of special interest; and which throw light on the nature of the series. Smyth has suggested the name Oswegatchie series for the limestones and their associates on the West, and while the equivalency of the rocks with the previously named Grenville series of Canada seems probable in a general way, we all have agreed to use this term. Any term must however be considered more or less provisional because as will later appear there is a great gap in outcrops between the original exposures of the Oswegatchie, along the river of the same name, and the near neighbors to it, on the one hand, and the next exposures to the southeast on the other.

VARIETIES OF SEDIMENTARY ROCKS.

Before discussing the general distribution of the exposures, it will be well to give a brief resumé of the kinds of rocks with which we have especially to deal. Right in this particular, appears the great difficulty of a metamorphic problem. In sedimentary or unaltered igneous rocks we are never at a loss to understand their nature and method of origin, but in excessively metamorphosed varieties the great difficulties arise in describing these questions at the very outset, and if we were only sure of many of these puzzling gneisses, the battle would be more than half won.

The Limestones.—The most easily recognized is a coarsely crystallized, white limestone and it is at the same time the widest in occurrence and the most significant evidence of the presence of the old sediments. While at times of considerable purity, as at the marble quarries at Gouverneur, it is generally more or less richly impregnated with graphite, apatite, quartz, pyroxene, horneblende, phlogopite, biotite, scapolite, chondrodite, garnet and feldspars. The silicates tend to be aggregated into streaks and bunches, that owe their shape in large part to the shearing and stretching effects of dynamic metamorphism. In the larger bunches, less common minerals, such as titanite, pyrrhotite and tourmaline are met. Most of the minerals cited above are without doubt produced by the regional metamorphism of more or less siliceous limestones. Such are quartz, pyroxene, hornblende, biotite, graphite, apatite and feldspar. But others, such as tourmaline, chondrodite, scapolite, titanite and to some degree apatite are the results of contact metamorphism, as Smyth has so well shown for the west side of the area.

A variation which is met in several localities, appears when the marbles become charged with serpentinous alteration products, from pyroxenic originals? This is true, most prominently, in Moriah township, Essex county; and in Thurman township, Warren county, although the same rock is met in less amount in a number of other places.

Regarding the development of these limestones it may be only said here, that they are beyond question calcareous and magnesian sediments which involved siliceous, ferruginous and aluminous admixtures, in some cases very richly. During metamorphism the latter elements supplied the materials necessary for the production of various silicates. The limestones appear to be less pure and consequently more charged with silicates on the east than on the west, and to present smaller cross-sections, but from this statement we must omit the contact zones of St. Lawrence county. In judging of the impurity of the limestones we must also make exception of the included masses of rocks, composed of silicates, which in the dynamic metamorphism, have been torn off from the wall rocks or from pegmatite or more basic dikes that had penetrated the limestones before the disturbances. I also reserve graphite for special consideration further on. The limestones exhibit many interesting proofs of having yielded to pressure like viscous substance. They have flowed around the harder inclusions and bordering rocks, have moulded themselves into their irregularities, and have behaved in all respects like a plastic material. This property on their part has made the determination of accurate dips and strikes a matter of difficulty and has added to the obscurity of the problem.

The Quartzites.—But little has yet been stated in print regarding the rocks of this type and they are indeed far less abundant than the limestones. In former papers reference has been made to thin sulphur-yellow beds which accompany the limestones near Port Henry. They are friable quartzites and contain much sillimanite, graphite and pyrite. At Hague, a town on

Lake George, and at a point five miles west from the lake shore, the interesting graphite mines have been opened, which show undoubted fragmental sediments. A bed some 6 to 15 feet thick has been faulted once so as to be exposed in two places. It dips to the west at an angle of 10 degrees and contains abundant flakes of graphite, all of which show a rubbed and streaked appearance from much mashing and shearing. The rock contains little else than quartz and graphite and cannot reasonably be interpreted otherwise than as sandstone, which has been richly charged with some carbonaceous matter, either originally organic or subsequently introduced as some hydrocarbon. Walcott has significantly remarked that the openings look exactly like a coal mine in pre-Cambrian strata. Beneath and above the graphitic quartzite is a garnetiferous gneiss, richly charged with sillimanite. Above the upper sillimanite gneiss is still more quartzite and all rest on a granite gneiss. I interpret the succession as one which involved a sandstone, porous enough to admit the carbonaceous matter now represented by the graphite, and interstratified in a somewhat calcareous, sandy shale now changed to the garnetiferous, sillimanite gneiss. Whether the lower granitic gneiss is an intrusive, which has developed these minerals by contact metamorphism or not ; or whether it was the old foundation on which the sediments were laid down is an obscure question, which I am unable at present to positively decide. The minerals involved are produced both by regional and contact metamorphism. At one point near the mines some small amount of limestone has been revealed by an exploring drill hole, at a shallow depth (30 feet) and on the whole I have been more inclined from the evidence in hand to consider the granitic gneiss as the foundation on which the sediments were deposited.

The largest exposure of quartzite yet recorded is in the town of Lewis, about three miles north of Elizabethtown, in Essex county. Ledges occur more or less charged with graphite and so metamorphosed as to resemble vein quartz, but stratigraphically they have a good dip and strike and they run under gneisses of which I shall later speak. The dip of the quartzite is about 10 degrees and the thickness across the stratification is about 100 feet. The general relations leave little doubt that we are dealing with an old sandstone, somewhat bituminous, and now thoroughly recrystallized. All around are great intrusions of gabbros, anorthosites and syenitic eruptives so that the quartzite remains practically as a little island in the midst of an eruptive area.

In a considerable number of other places these quartzites have been noted and as a rule they have shown a pronounced banded, if not bedded, structure and have almost always exhibited graphite. They likewise very commonly contain dark, rounded discs of a mineral that proves when examined in thin section, to be monoclinic pyroxene. It is irregular in outline and pale green in color. The rocks are therefore aggregates of quartz in excess and pyroxene in considerable amount and are to be interpreted as old quartz sandstones, that contained some calcareous and magnesian admixture, which, during metamorphism, yielded the pyroxene. A little iron oxide also entered into the result. In several instances we have found small masses of the quartzites in the anorthosites, forming inclusions which have been torn off during the intrusion of the igneous rock, and which have been surrounded by small zones or reaction rims, due to contact metamorphism.

Minor Associates of the Limestones.—Another peculiar and characteristic rock that is associated with the limestones in many places in minor amounts consists of quartz and milk-white plagioclase, with occasional titanites scattered through the aggregate. It seems to be a metamorphic product from the transition sediments between the limestones and the associated clastics.

Likewise associated with the limestones in several localities, but more especially at Port Henry and Fort Ann, there are hornblende schists, of dark black color. They are often involved with the former in a most intricate way, running in as tongues and stringers, penetrating as dikes, which may be broken up into several scattered masses, or appearing as single boulder-like inclusions. In all cases where the rocks are prominently developed, there is easily recognized, intrusive gabbro in the vicinity and the burden of probability would seem to favor an igneous origin for them. At the same time calcareous, magnesian shales might be responsible for similar mineral aggregates, when exposed to excessive metamorphism, as Professor Emerson has shown for the Chester region of central Massachusetts, and in localities of compression and mashing they might become involved in a complex way with softer beds such as limestones; but still I think the Adirondack evidence favors irruptive contacts for them and the mashing and involution of dikes.

An almost invariable associate of the limestones, but in comparatively small amount is a rock consisting of a granular aggregate of dark green pyroxene. Some little calcite may often be detected in the interstices between the pyroxene, but as a rule the coarsely crystalline bits of the former make up practically the entire mass. The rock has manifestly resulted from the metamorphism of siliceous transition deposits from the limestones to the clastics.

Garnet Pyroxene Rock.—At two localities, one in Keene valley, on the west bank of the Ausable river and about a mile above Keene Center, and the other in northwestern Lewis, extensive ledges of a peculiar rock have been met that seems to belong to the limestone series. It is quite massive and gives no trace of dip or strike. It is a coarsely crystalline aggregate of deep red garnet, and green monoclinic pyroxene. In each case the ledges are associated with hornblendic gneisses and they may be a peculiarly altered, calcareous sediment, but the mineralogy strongly suggests contact metamorphism upon limestones, although in neither case was it possible to establish the presence of eruptives in the immediate vicinity. In the Keene locality anorthosites are in masses of mountain size, within half a mile, but gneisses intervene. In the latter case no eruptives of the gabbro family are near enough to be reasonably considered causes in the effect.

The Sedimentary Gneisses.—In intimate relations with the limestones in many localities and in quite extended outcrops, without them in other places, are gneissoid rocks that are quite certainly altered sediments. They are characterized by a very pronounced and persistent banding and the banding is regular and runs for very considerable distances. The transitions from dark bands, consisting of prevailing bisilicates to lighter ones containing quartz and feldspar are abrupt and can only be accounted for by changes in sedimentation. They differ entirely from the short lenticles which are produced by the stretching of the minerals of an eruptive rock. The layers are at times quite pure quartz and again suggest the mineralogy of pegmatites. Graphite is a very common mineral and is one of much significance.

On account of fragmentary exposures and the ever present drift or forest growth it is difficult to determine the actual thickness of these rocks. In southwestern Jay township, Essex county, I have paced carefully over a series of continuous exposures of very regular and flat dipping beds that were at least 75 feet thick and then became concealed under drift. A mile away they again appeared on a mountain side with very nearly the same strike and dip and there is no doubt that a very considerable thickness is present. Gabbros in one direction and anorthosites in another cut them out, and on the strike they were traced into exposures which contained limestones. Graphite was abundant both in limestones and gneisses.

In many other localities these same rocks have been met but mostly as isolated exposures in the midst of the heavy forest growth and too few in number to enable us to work out their thickness or their accurate relationships, but there is no doubt that they represent sediments that must have been originally of the nature of sandy shales, which at times had more richly calcareous layers and which, in this way, yielded the variable metamorphic results, now accessible to us. As a rule the dips of these gneisses are low, although high dips are met.

Besides the gneisses just described, which exhibit the marked regularity in their banding there are others that are more massive and uniform, and yet that from their general relations and associations give strong evidence of belonging in the sedimentary series with the limestones. They are almost always rusty on their outcrops as distinguished from the certain eruptives and whenever this character is observed we commonly look with success for the near presence of limestones. Although apparently quite basic the microscope reveals in most cases quartz and microperthite as the light-colored minerals in the midst of the prevailing hornblende and less augite. Plagioclase is not lacking, but is decidedly subordinate. Graphite has been occasionally detected in them.

These rocks have proved exceedingly puzzling members to deal with in the field, because one would be inclined at first sight and from microscopic examination to regard them as gneissoid gabbros or diorites, but the microscope gives the results just specified and the structural relations which will be shortly taken up lead to the conclusion that they are altered sediments, and that they probably represent large and fairly uniform bodies of shale.

Professor Cushing has noted in the eastern part of Franklin county considerable outcrops of a very coarsely crystalline and slightly rusty rock, which I have likewise had the privilege of studying in the field with him. It consists of almost nothing else than lenticles of quartz, half an inch or more wide, an eighth or more thick, and an inch or two long, which are set in a matrix of microperthite. Practically no dark silicates appear. I have also occasionally observed the same rock further south and I do not know how to account for it otherwise than as a recrystallized and squeezed conglomerate, whose pebbles have been stretched and rolled out to the lenticles and whose interstitial filling has yielded the microperthite. If this view be correct, we have all the ordinary members of a sedimentary series represented among these metamorphic rocks and a much more probable association for an important and extended member of the geological column, than would any one or two of the above cited members be alone. It is quite possible that others of the more massive gneisses are altered sediments rather than sheared eruptives, but in the absence of positive proofs I hesitate to take even a tentative position regarding them, although I am free to admit that beginning with prepossessions in favor of the igneous origin of many of the gneisses, I have become more and more convinced that altered sediments play a very prominent rôle.

GENERAL DISTRIBUTION OF THE METAMORPHOSED SEDIMENTS.

The Northwest. — The crystalline limestones furnish the most widely distributed, indubitable form of pre-Cambrian sediment with which we can deal in a general sketch, but as already indicated it is fully within the bounds of probability that other kinds of rocks will be recognized to possess this same character, as time goes on and observations accumulate. The limestones are in much the largest amount of all the Adirondack localities in the northwest, where they have been investigated by Professor C. H. Smyth, Jr. St. Lawrence county chiefly contains them and they are also found in important areas in the neighboring counties of Jefferson and Lewis. They are not all accurately mapped as yet. They constitute large northeast and southwest belts as well as minor exposures, but to what extent additional ones are buried beneath the Potsdam, the Drift and the forest growth we have no means of knowing. Smyth has already mentioned four principal belts. The northwestern one is called the Macomb. It extends from Theresa township, in Jefferson county, across the county line and through Rossie, Macomb and De Kalb into De Peyster, St. Lawrence county. This makes a distance of about 25 miles and the belt may be 2 miles across. The next one to the southeast is the Gouverneur belt, the largest of all. It begins in Antwerp, Jefferson county, and runs for 35 miles through Rossie, Gouverneur, and De Kalb, terminating in Canton. It varies from 2 to 6 miles across but is somewhat divided as regards outcrops by overlying Potsdam and by gneiss. The next belt to the southeast runs from Fowler township through Edwards and terminates in Russell; and the last of the four extends from Wilna, Jefferson county, through Diana in the same county, to and into Pitcairn, St. Lawrence county. All lovers of minerals will recognize at once in these names classic localities of many species, which more than any other one product have served to make this region known, the world over.

There are other small areas in Pierrepont, Parishville and Potsdam further north, which have been located by Professor Cushing upon his published map of the boundary of the Potsdam, executed for Professor James Hall, and if we may draw inferences from Professor Ebenezer Emmons' few notes in the early Survey of the Second District of New York, still other outcrops exist toward the Thousand Islands of which Professor Smyth will no doubt prepare descriptions in time. But when one passes to the southeast of the Diana belt, Smyth has stated that for 30 miles the gneisses extend without a break. Limestones are however known at the Fourth lake of the Fulton Chain, as recorded by Vanuxem and they have been found by Smyth in small amount amid gneisses near Bisby lake and on the South Branch of the Moose river at its junction with Limekiln brook. Emmons also mentions limestones as abundant around a lake that he calls Lake Janet and again Lake Genet, and describes as being at the head of the Marion river. Lake Janet is apparently the one now called Blue Mountain lake but although fairly detailed work has been done around it by my assistant D. H. Newland, no record of these rocks was made and there may be some mistake about the earlier note.

Despite these small areas last mentioned there still remains a vast extent of crystallines that form a broad area from northeast to southwest wherein no sediments are known. This is the greatest stretch of the whole Adirondack region that is devoid of them and as it forms a somewhat pronounced belt, parallel to the general structural trend of the country, it cannot well be without some special significance. Much of this stretch in Franklin County has been shown by Cushing to be anorthosite, but to the southwest it appears to be granitic gneiss, of greater uniformity than is usual elsewhere.

The Eastern Side.—Beginning on the northeast, but one exposure has been met in Clinton County and that is a stratum about 20 feet thick and 150 feet long at the foot of Catamount mountain. Dip and strike are very difficult to determine with accuracy. The bed apparently passes into the mountain at an angle of about 45–60 degrees. The relations will, however, be more fully commented on in taking up the stratigraphical features under a subsequent topic.

Just across the line in Franklin county, and near the village of Franklin Falls, there are two separated ledges of limestone. The dips are low and with the calcareous beds are rusty hornblendic gneisses and some graphitic quartzite, the latter being certainly sedimentary and the former probably the same. Intrusions of anorthosite have served to obscure the larger relations.

In Essex county, to the south, in St. Armand township, a double bed of white, crystalline limestone outcrops at the foot of the steep, westerly spur of Whiteface mountain. It lies embedded in feldspathic gneisses, but anorthosites outcrop further up the slope. In North Elba, the next township eastward, and on the western slopes of Sentinel mountain, in the Wilmington pass, a small ledge of limestone has been met, obscurely exposed in the bed of a little brook. Passing to Keene township, the next one east, there are a number of exposures in the northern portion that together constitute a pronounced belt. From a point a mile south of Keene Center for several miles to the north, until one passes into Jay, they may be located first on the west side of the valley and then on the east. Quartzites in small amount and a great thickness of dark, rusty hornblendic gneisses accompany them. Away from the central valley and well up into the bounding ranges of mountains, limestones have been, discovered both in the eastern and southeastern portions of Jay. Over the high divide in Chesterfield township, the next one to Jay on the east, two exposures have been met, each time involved with gneisses, but each time in a region where huge intrusions of anorthosite are likewise serious factors in the geology, although at some distance from the limestone. In Lewis township, next south, as well as in Elizabethtown which lies beyond, a long succession of limestones and quartzites in a general north and south belt, are met over a stretch of at least 15 miles, but they are much broken up by anorthosites and basic gabbros. In two or three instances, however, the ledges are of the greatest stratigraphical interest, as I shall shortly bring out.

In the valley of Lake Champlain a small exposure of limestone with much associated graphite forms the extreme point at the picturesque Split Rock, Essex township, a landmark to all travelers by steamer on the lake. While the amount of limestone is not great, the associated gneisses are in considerable development, before they are replaced by anorthosites, which make up the main part of the Split Rock range. No more limestones are then met until a point is reached in the hills in the extreme southwestern part of Westport, where again a small ledge has been located in the midst of an area consisting chiefly of the plutonic intrusives. In Moriah township, both on the lake near Port Henry and back in the upland valley which rises to the westward from the lake, the limestones are frequent and of considerable thickness. Next the lake they are the best exposed and thickest of any outcrops in the eastern part of the mountains. Details of the exposure have already been printed by me. In Crown Point and Ticonderoga, the next townships south along the lake, small ledges have been located in many places and relatively large areas of the associated gneisses, and if we pass right down into Washington county, on the south, we shall find in the high narrow ridge that lies between Lake Champlain and Lake George several small beds in Putnam and Dresden townships. In Whitehall and Fort Ann, however, the exposures become more serious and give greater promise of stratigraphical results. At Whitehall an attempt has been made by me to work them out, and in a report, that will shortly appear from the office of the State Geologist in Albany, a detailed map with cross-sections will be given which indicate a marked anticlinal character for them and the associated gneisses. Quartzose gneisses are also present that afford strong evidence of being metamorphosed sediments.

If now we return to the latitude of Crown point and Ticonderoga and pass westward into Schroon, we find a belt along a somewhat marked depression, ranging from western Crown Point, through the valley of Paradox lake to and along Schroon lake. There are likewise scattered outliers in the adjoining hills. Still further westward in Minerva and again to the north in Newcomb, right in the heart of the mountains and west of the highest peaks, very extended outcrops occur, as usual with the associated gneisses. They scarcely cross the line from Essex into Hamilton county to the west, but they run south through Warren county and appear in small and scattered areas in Johnsburgh, Chester, and Thurman. In eastern Hamilton county, two or three have been discovered in Wells and Lake Pleasant townships. But then they seem to end so far as our present information goes, and from these townships southward along the western border line of Hamilton county and in a sweep around to the westward along the southern rim of the crystallines, so far as known they fail. To the eastward in Warren county, we have located a number of small and scattered outcrops, amid the gneisses of Horicon and Bolton townships, while in Hague are the interesting quartzites already referred to. In the several townships that intervene on the south before the mantle of the Paleozoic conceals the crystallines, the limestone is lacking so far as known.

Resumé.—In a brief general survey of these various details, it is evident that the limestones are chiefly found along the northwest and southeast or eastern portion of the great crystalline area. In its northern portion they practically fail, and in the broad band running from northeast to southwest across it, they are unknown. They are likewise absent in the southern and southwestern border. On the northwest they are in extended and comparatively broad belts, but in the eastern portion they appear in many small and separated exposures, associated with some quartzites and much greater amounts of characteristic gneisses, but greatly broken up by igneous intrusions.

Broadly considered, it is inconceivable that we should have these numerous, thin exposures of limestones, undoubted sediments, over so wide an area, without corresponding and very much greater amounts of clastics. The comparatively few recognizable quartzites serve to corroborate the inference so far as they go, but it is still an inevitable conclusion that we must have the representatives of very much greater deposits, that have been shales or some similar materials, and that are represented now by the gneisses, because schists or slates are practically unknown.

It is also significant that so far as our present information goes the recognizable, fragmental sediments are most numerous on the east, where at the same time the limestones are thinnest and most scattered. While it is well appreciated by me, that much fuller knowledge awaits us as Professor Smyth's work progresses, yet the significance of this relation cannot be entirely overlooked, and it seems justifiable to believe that if the limestones on both sides of the mountains belong to the same geological series, the sedimentation involved more shales and sandstones on the east and more limestone on the west. To a certain degree the same relations hold good for the Trenton series to-day, its limestone being more massive on the southwest of the crystallines and more shaly on the eastern boundary. Nevertheless, for the pre-Cambrian formations, the assured, fragmental sediments are still, as emphasized above, comparatively thin and scarce, and the inferences just stated regarding the gneisses will arise. With a view of throwing light on this question a few typical sections will now be given in some detail, and in the mind of the observer or reader, the point of view should always be maintained as to whether it is possible to explain such relations by igneous contacts, or whether we must not logically refer them to a regular sedimentary succession.

TYPICAL STRATIGRAPHICAL CROSS-SECTIONS.

Catamount Mountain.—This is the most northerly of the eastern outcrops. Although the crystallines extend for miles beyond, there are no more limestones. At the foot of a steep mountain-side that looks away to the southeast and that rises from twelve to fifteen hundred feet above the valley, a ledge of limestone has been well-exposed by quarry operations. It is 20 feet thick and 150 feet long. It is a difficult matter to convince oneself of the dip and strike, but certainly the upper edge of the limestone runs along quite regularly and considered as a whole the rock seems to be a distinctly bedded mass in other rocks. The banding of the included minerals give a dip of from 45 to 60 degrees into the mountain. All exposures of rock are concealed both above and below the limestone so that its immediate associates cannot be made out, but out in the valley, in the road, a short distance to the south Cushing has noted an outcrop of a rusty friable gneiss consisting of nearly colorless monoclinic pyroxene and microperthite. With these are sillimanite, titanite, magnetite, pyrite and graphite. A band of basic hornblende plagioclase gneiss is also associated. These latter details I quote from Cushing with whom, however, I have been over the ground. In Wilmington mountain to the southeast, I have found further outcrops of graphitic rocks and of hornblendic gneisses and pyroxenic aggregates, such as are commonly associated with the limestone.

In passing up Catamount mountain above the ledge of limestone, no outcrops can be found for a distance which involves some hundreds of feet of cross-section, and then a dark gneiss appears with parallel strike and vertical dip. Under the microscope it exhibits plagioclase, green augite, less brown hornblende, garnet and magnetite, an assemblage that has strong affinities with gabbros. Near the top of the mountain this rock yields to a gneiss with abundant quartz. I forbear to attempt to interpret this poorly exposed succession at the present, merely citing it as an illustration of the relations met and of the difficulties of the problem.

The Western Spur of Whiteface.—From the northern end of Lake Placid a wild and narrow pass runs across a small divide, separating the Ausable drainage from that of the Saranac. At very nearly the crest of the water-shed and in the foot of the steep westerly spur of Whiteface mountain, a double bed of limestone has been discovered. The upper bench is 6 feet and the lower 12 with an interval of 25 feet occupied by gneisses. Up the steep slope with a somewhat flattening dip, hornblendic gneisses extend for 300 feet of section, then feldspathic gneisses for 300 feet more, until the peculiar type of anorthosite of the Whiteface massif appears. To the westward in scattered exposures hornblendic gneisses occur, until in the second row of hills anorthosites replace them. The exposures of limestone can only be traced a short distance on the strike, say 200 yards before they are concealed, but they have all the appearance of a regularly stratified, sedimentary rock, and their contacts give no evidence of igneous metamorphism. They dip into the mountain at about 40 degrees.

The Lewis Section of Quartzite.—About one mile west of Lewis post-office a ledge of graphitic quartzite arises out of the sandy terrace and, with a dip of 25 degrees to the west, extends for quite 100 yards without a break. It then dips under a series of graphitic gneisses, which may be found a little to the south across a narrow gulch. Still further westward and after an interval that is concealed, the anorthosites appear in a hillside. To the eastward of the quartzite ledge everything is concealed by a half mile of sand and then anorthosites again appear. The quartzites and their associated, graphitic gneisses present every character of a sedimentary series and while examining them one cannot resist the conviction that one is face to face with a fragment of an ancient series of clastics. Further south the anorthosites have been found outcropping within less than 50 feet of the sedimentary rocks and with abundant evidence of contact metamorphism.

The Two Exposures in Limekiln Mountain.—In the southwestern corner of Lewis and near its line with Elizabethtown, there arises a bunch of peaks, called Limekiln Mountain on the maps of the U. S. Geological Survey. The main summit is about 3000 feet above sea level. A number of valleys and gulches separate the mountain into several knobs. A gradual, drift-covered slope rises from the valley on the east to a height of about 1400 feet above tide, and then the shoulder of the mountain ascends quite abruptly. Just in the foot of this slope a ledge of limestone 20 to 30 feet thick has been opened up for quicklime. The dip is very flat, being almost horizontal. The exposures extend perhaps 50 yards and then are concealed by soil. The rock beneath the limestone is not shown, but excellent opportunities are afforded to run the section up the hill for a considerable distance. For 50 feet across the dip gneisses appear which are shown by the microscope to contain quartz, microperthite, some plagioclase, augite, and magnetite. After a concealed interval, rocks of a gabbroic character are met, consisting of labradorite, green augite, garnet and magnetite, but with no microperthite or quartz. If now we pass across the high ridge to the westward and down into the next valley evidences of limestones not well displayed may be discovered and then a quarter of a mile further and somewhat southwest from the first locality a beautifully exposed and regularly bedded stratum, 20 feet in thickness and dipping not more than ten degrees into the mountain is revealed in old workings for quicklime. Its general strike and dip are closely parallel with the one just mentioned, on the other side of the mountain but it has this advantage, that the gneisses are well shown beneath it, and one can climb the steep ledges of gneiss above it for more than a thousand feet of cross-section. They are the same quartzose, microperthitic gneisses mentioned a moment ago. The limestone itself forms a very flat and gentle roll and then disappears under the talus in each direction. Other small rolls can be traced out in the direction of the dip, before they disappear for good. In the bottoms of brooks in this same portion of the mountain, graphitic gneisses have been met, fairly remote from the limestone, but the forest growth is so thick and the exposures so fragmentary that connected structural details cannot well be worked out.

These two separated ledges of limestone

with their flat dips and close resemblance to the familiar sections in the Paleozoic or other well-defined sediments, have borne home to the writer with greater force than have any others observed in the eastern mountains the general conception of what the ancient sediments must once have been, before metamorphism, igneous intrusions and upheavals threw them out of their simple and regular relations. They show that despite the severity of the changes elsewhere displayed, two remnants remain, not appreciably mashed, and scarcely even tilted, and one can well picture to oneself a regular and widespread sedimentary series covering extended areas in this region.

The Styles Brook Section in Southern Jay.—One more section will suffice. It is located five miles from the last and beyond a group of mountains. It runs in a northeast and southwest line across a beautiful valley, about two miles wide. In the bottom of the valley, and fortunately cleared of a heavy mantle of overlying drift by a recent freshet, about 50 feet of graphitic quarzites and gneisses with a northerly dip of 35 degrees are exposed. To the northeast, within an eighth of a mile, a huge flow of basic gabbro cuts out the sediments. To the southwest, after three-quarters of a mile of drift, there are rusty hornblendic gneisses, which dip almost the same as the previously mentioned ledge of quartzite; then after another three-quarters of a mile of drift and forest-covered mountain-side, quartzite, charged with pyrite, constitutes the country rock. Anorthosites appear not far away along the mountain, but still, despite the fragmentary exposures, one must believe in the presence of a very considerable and not greatly disturbed series of sediments. Along the strike of the first mentioned quartzite in the valley abundant limestones are found within a mile.

Instances similar to the ones which have been cited could be greatly multiplied, for we have now recorded over fifty separate exposures of the limestones in the eastern mountains, but the range of phenomena is fairly well illustrated by the above. In most cases they are isolated fragments, too much broken up by eruptives to admit of working out extended structure, but as one passes into Warren county the larger manifestations of the undoubted eruptives decrease and encouraging opportunities are afforded to trace out folds or other structural features. In one or two cases this has been done by me, and the coming summer the matter will be carried further under the auspices of the State Geologist, but more detailed work is required than we have been able to attempt in the first reconnoissance.

For the greater areas of limestone on the northwest, Smyth has found evidence of a series of compressed folds, which pitch to the northeast, and which are overturned so as to dip on both flanks to the northwest, but his statements are as yet somewhat guarded.*

The Significance of Graphite.—Graphite has been tentatively referred to in many places as one of the criteria for determining the presence of sedimentary rocks, and for a moment its value in this respect deserves consideration. While I am well aware that it often appears in pegmatitic dikes or veins, and indeed that the old historic mines at Chilson Hill, Ticonderoga are based upon deposits of this character, yet it is true that the graphite is almost never met except in close connection with the limestones or their characteristic associates, or in areas where these form a prominent feature in the local geology. The commonest occurrence is immediately in the limestones and hardly an exposure of them or of the bunches of silicates in them has been discovered without the presence of the shining black scales.

* Report of the State Geologist of New York for 1893, I., 497.

When graphite appears in metamorphic rocks it has been generally considered in America and until recently abroad as well, to have been derived from organic matter originally in the sediments, but in more recent years investigations have been carried out which throw some doubt on these conceptions. Graphite, considered purely as a mineral has come in for a large share of attention and some writers have even distinguished three varieties, viz, graphite, graphitite and graphitoid, depending on differences of physical structure or behavior with oxidizing reagents. Weinschenk, of Munich, has however quite conclusively shown in a recent paper, that all are varieties of graphite proper, differing only in fineness of scales or perfection of crystalline form. All true graphite when warmed with fuming nitric acid and potassium chlorate changes into yellow, transparent crystals, possessing the same hexagonal form as the original and exhibiting while wet and fresh, the optical properties of a negative uniaxial crystal. These are called graphitic acid. They yield by analysis somewhat variable results but they are known to have assumed over 40 per cent. of oxygen and about 1.5 of hydrogen. Other dark amorphous forms of carbon dissolve in fuming nitric acid and potassium chlorate to a brown liquid.

So far as my observations go, all the occurrences on the east are true graphite. I have not noted any other form of carbonaceous matter, but in the marbles quarried at Gouverneur there are cloudy veinings, which may not be the mineral.

In a valuable paper on the graphite deposits along the border of Bavaria and Bohemia, usually referred to as the Passau district, Weinschenk* has shown that the graphite occurs in a much decomposed gneiss, in lenticular enrichments, the best of which are associated with crystalline limestone, and all of which follow the contact line of a huge granite intrusion and at small distances from it. When the contact is left the graphite deposits become leaner and leaner and finally die out. The graphite fills all manner of cracks in the minerals of the containing rock and the interstices between the minerals and may even amount to 60 or 70 per cent. of the mass. Weinschenk concludes that the graphite has not come from original deposits in the gneiss and limestone, but from gases emitted at moderate temperatures from the granite and which penetrated into all the small cavities of the gneiss and limestone. The most probable constituents of the gases are thought to be carbonic oxide, carbonates of iron and manganese, cyanides of titanium, carbonic acid and water. All contributions from the gneiss and limestone and all other forms of carbonaceous matter are specifically ruled out.

Into the abundant other literature of graphite, especially as concerns Ceylon or other productive regions, I do not go as the important point before us is to determine the significance of the graphite in the Adirondack rocks, and to decide whether its carbon has been introduced by the eruptives. Of eruptives there is no lack, if not always in immediate association with the graphitic rocks, at least within short distances.

In any conclusions the following conditions must be met:

1. The graphite is in all the crystalline limestones, sometimes richly.

2. It is most coarsely crystalline in the pegmatitic bunches of silicates, which of all sizes from that of the finest to that of many cubic yards, are so richly present in the limestones.

3. It is richly developed in the quartzite at Hague and appears in many others in less amount.

* Weinschenk, E., 1897. Vorkomnisse aus Graphitlagerstätten nordöstlich von Passau. *Zeit. f. Kryst. and Min.*, 1897, XXVII., 135.

4. It forms scattered scales in the rusty gneisses which are associated with the limestones, but here only in comparatively small amount.

5. It enters richly some pegmatite veins and forms pockets of considerable size as well as leaf-like individuals which wrap around the component minerals of the rock, penetrate their cracks and impregnate every fissure. In the Ticonderoga veins, which cut across the foliation of a gneiss, the graphite is associated with feldspar, quartz, pyroxene, calcite and apatite, all in very coarsely crystalline development.

6. It also forms veins by itself in gneisses, as at Split Rock, near Essex, where fissures an inch or more wide are lined with large leaflets, growing out from the walls and mingled with quartz in small amount. To what depth the veins extend cannot be stated, but they run for some yards on the surface in the little prospect where they are exposed.

7. Graphite has been discovered by me in one place in anorthosite, where the latter was in close association with rocks of the limestone series. One or two small scales were detected in the midst of the labradorite crystals. Dr. Hillebrand of the United States Geological Survey has also determined by analysis the presence of carbon not combined as carbonates to an amount of 0.05 per cent. in the igneous, titaniferous magnetites near Lincoln Pond, Elizabethtown and has obtained traces in samples from two other mines. Gneisses were located near these intrusions but no limestones have been discovered nearer than several miles.

From the above it is evident that in the cases of the pegmatite veins and included bunches of silicates in the limestones, the carbon of the graphite has been introduced into its present situation in some migratory and penetrating form and that it has permeated the crevices of the rocks. The interesting point is whether it has probably come from the intruded magmas, or whether under the metamorphic processes of a regional character as well as of a contact nature it has been produced from carbonaceous matter originally in the sediments. Despite the occurrence of very small amounts in the igneous rocks, my own opinion from the preponderating evidence is that it has been derived from the limestones, quartzites and gneisses and has only been worked over, caused to migrate and recrystallize by the metamorphosing agents. The practical limitation of the graphite in large amount to the limestones and gneisses seems to me to favor this decision, but I am free to admit that the other view has some points in its favor. There is no question that some conditions, analogous to those which favor the production of pegmatites have been necessary to yield the coarse leaves. Aside, however, from the question of origin, abundant experience has proved the value of graphite as an indicator of sediments even if it be not derived from them, and as a sort of 'type fossil' it is most useful.

Conclusion.—In conclusion the more important points of our recent work upon the Adirondack sediments may be summarized as follows. They have been shown to be much more widely distributed than we formerly appreciated, but they are absent from a wide central area, where only massive gneisses and eruptive rocks have thus far been met. That the sediments were extensive is apparent from the evidence and from the thinness of the limestones on the east as well as their association with demonstrable quartzites, we infer that the clastics were deposited in much greater amount than has been realized. Both the nature of many gneisses and also these general considerations lead us to infer that shales or related rocks have been likewise present. On the east at least we have not yet been able to prove that the sediments form synclines, pinched into underlying gneissoid rocks. On the contrary they seem to constitute low dipping faulted monoclines.

All the sediments are thoroughly recrystallized and metamorphosed and the associated igneous rocks are plutonic or deep-seated types. Both these facts indicate their former burial at very considerable depths, and the subsequent removal of some thousands of feet by erosion. The next later rocks, of whose geological age we are assured, are the Potsdam sandstones, which lie on the old crystallines with dips seldom if ever more than ten degrees and which are not seriously metamorphosed. The greatly metamorphosed sediments are certainly pre-Potsdam and the large tectonic relations of the Georgian strata in Vermont to the Potsdam and the crystallines preclude our considering the latter as of possible early Cambrian age. We are forced to conclude therefore that they are pre-Cambrian, and from the comparatively unmetamorphosed condition of the Cambrian beds, we infer that the pre-Cambrian strata suffered their metamorphism in pre-Cambrian time. They may be taxonomic equivalents of the Huronian, but we have no good grounds for correlation.

The evidence regarding the Cambrian as interpreted by Walcott in the Champlain valley, leads us to believe that the Cambrian sediments encroached from the eastward upon the area of the crystallines. The Georgian is only found in Vermont. The Potsdam alone appears on the western side of Lake Champlain. It was not therefore any load of Paleozoic sediments, which rendered possible the deep-seated metamorphism of the pre-Cambrian sediments and the plutonic textures of the intrusions, but a load of pre-Cambrian rocks which have since disappeared. What those rocks were is an interesting subject of speculation.

They may have been sediments, whose disappearance leaves us with a lost interval. If so there is a gap in the records, which would be more comprehensible if we had better evidence of tight folds in our pre-Cambrian sediments and not the comparatively flat beds of limestone so often seen.

They may have been fragmental ejectments and vast surface flows of lava from centers of eruption whose deep-seated roots alone remain to us in the anorthosites, gabbros and syenitic rocks and whose materials piled up in the not unreasonable thicknesses of some thousands of feet, have been in time removed to contribute to the Cambrian or still earlier but undiscovered strata. Certainly the period of erosion was long and the results pronounced.

Bearing these consideration in mind, sometimes while seated upon a lofty peak of the mountains and while reflecting on the scene spread out in every direction, I have allowed my fancy free play and have pictured again the cones and vents that probably made of the Adirondacks a volcanic center comparable with Lake Superior. Beginning with eruptions of medium composition, as we know from the oldest igneous rocks now present they passed to more acidic types and closed with the basic gabbros. The fires seem then to have cooled and long erosion ensued.

Meantime beneath the piles of igneous rock, metamorphism from the hot intrusions and from the general rise of the isogeotherms went steadily forward, and the ancient sediments, whether calcareous or clastic, were changed over to marbles, quartzites and gneisses. Their carbonaceous matter became destructively distilled and penetrated every available crevice. In time it was changed to graphite. It even wandered over to the neighboring, partly cooled, igneous rocks and took part in the formation of the pegmatites.

Gradually the early Cambrian sea crept

up on the flanks, first attacking them in Vermont. The Ordovician sea followed and its sediments reached points well into the crystalline area. Pursuing the thought further we may raise the query, were the crystallines then reduced to a base-level and did submergence gradually bury them, and did the Ordovician sea and the subsequent Silurian sea go all across from side to side with a continuous mantle of sediments? Or were the crystallines a great island during all this time and have they remained so with minor faultings and upheavals to the present? These are questions easy to ask and difficult to answer. The most that we shall say about them now is that they are another story.

J. F. KEMP.

COLUMBIA UNIVERSITY.

ON KATHODE RAYS AND SOME RELATED PHENOMENA.

II.

THE view here briefly formulated, although first suggested by Wiechert, owes its development chiefly to J. J. Thomson. The number of instances in which its consequences are at least qualitatively confirmed is already surprisingly large. Thus it has been known for some time that a wire or carbon filament, when heated to incandescence in vacuo, sends off negatively charged particles. Thomson * has recently shown that the ratio e/m for such particles is the same as for the kathode rays. Many metals also are capable of giving off negatively charged particles when illuminated by ultra-violet light; at sufficiently high vacua, rays may be produced in this way which possess all the essential properties of the ordinary kathode rays.† In this case also, the ratio e/m is found to be the same.‡ In these cases we have an indication that the corpuscles may be separated from the molecules of a substance by processes different from those which occur at the kathode. That intense heat, on account of the violent collisions between molecules, should make it easier for the corpuscles to escape, is quite natural. And that the rapid electrical vibrations set up by light, especially by that of short wave-lengths, should produce a similar effect, agrees equally well with the corpuscular hypothesis.

If the light radiated by a molecule of gas is due to the vibration or orbital motion of these charged corpuscles, a highly concrete and satisfactory explanation is at once obtained of the Zeeman effect. The theory has shown itself capable of accounting not only for the comparatively simple phenomena first observed, but also for the more complicated modifications of the spectral lines detected later. The ratio e/m as determined from the Zeeman effect is of the same order of magnitude as that determined from observations on the kathode rays.

Perhaps the strongest confirmation of Thomson's corpuscular hypothesis is that afforded by the recent investigations, of the Becquerel rays. In 1899 it was found that some of these rays, notably those produced by certain preparations of radium, were deflected in passing through a magnetic field.* More recently, it has been found that the rays are electrostatically deflected† and that they carry a negative charge. In fact, they behave in all respects like kathode rays. Within the last few months the ratio e/m has been determined by Becquerel‡ and found to have approximately the same value as in the case of the Zeeman effect and the kathode rays.

* *Phil. Mag.*, 48, p. 547, 1899.

† Merritt and Stewart, *Physikalische Zeitsch.*, 1, p. 338, 1900.

‡ Thomson, *Phil. Mag.*, 48, p. 547, 1899.

* Meyer and v. Schweidler, *Phys. Zeitsch.*, November 25 and December 2, 1899. Giesel, *Wied. Ann.*, 69, 834, 1899. Becquerel, *Comptes rendus*, 129, p. 996, 1899.

† Dorn, *Abhandlungen d. Naturforsch. Gesell.*, Halle, March 11, 1900.

‡ *Comptes rendus*, 130, p. 809, March 26, 1900.