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EDITORS

JAMES D. AND EDWARD S. DANA.

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[THIRD SERIES.]

ART. I.—*The History of a Doctrine;* Address by S. P. LANGLEY, retiring President of the American Association for the Advancement of Science.*

"Man, being the servant and interpreter of nature, can do and understand so much, and so much only, as he has observed, in fact or in thought, of the course of nature. Beyond this he neither knows anything nor can do anything."—BACON'S *Novum Organum*, aphorism 1.

IN these days, when a man can take but a very little portion of knowledge to be his province, it has become customary that your president's address shall deal with some limited topic, with which his own labors have made him familiar; and accordingly I have selected as my theme, the history of our present views about radiant energy, not only because of the intrinsic importance of the subject, but because the study of this energy in the form of radiant heat is one to which I have given special attention.

Just as the observing youth, who leaves his own household to look abroad for himself, comes back with the report that the world, after all, is very like his own family, so may the specialist, when he looks out from his own department, be surprised to find that, after all, the history of the narrowest specialty is strangely like that of scientific doctrine in general, and contains the same lessons for us. To find some of the most useful ones, it is important, however, to look with our own eyes at the very words of the masters themselves, and to

* This Address appears here complete with the notes that have not hitherto been published.—EDS.

take down the dusty copy of Newton, or Boyle, or Leslie, instead of a modern abstract; for, strange as it may seem, there is something of great moment in the original that has never yet been incorporated into any encyclopædia, something really essential in the words of the man himself which has not been indexed in any text-book, and never will be.

It is not for us, then, here to-day, to try

> "How index-learning turns no student pale,
> Yet holds the eel of science by the tail;"

but, on the contrary, to remark that from this index-learning, from these histories of science and summaries of its progress, we are apt to get wrong ideas of the very conditions on which this progress depends. We often hear it, for instance, likened to the march of an army towards some definite end; but this, it has seemed to me, is not the way science usually does move, but only the way it seems to move in the retrospective view of the compiler, who probably knows almost nothing of the real confusion, diversity, and retrograde motion of the individuals comprising the body, and only shows us such parts of it as he, looking backward from his present standpoint, now sees to have been in the right direction.

I believe this comparison of the progress of science to that of an army, which obeys an impulse from one head, has more error than truth in it; and, though all similes are more or less misleading, I would prefer to ask you to think rather of a moving crowd, where the direction of the whole comes somehow from the independent impulses of its individual members; not wholly unlike a pack of hounds, which, in the long-run, perhaps catches its game, but where, nevertheless, when at fault, each individual goes his own way, by scent not by sight, some running back and some forward; where the louder-voiced bring many to follow them, nearly as often in a wrong path as in a right one; where the entire pack even has been known to move off bodily on a false scent; for this, if a less dignified illustration, would be one which had the merit of having a truth in it, left out of sight by the writers of text-books.

At any rate, the actual movement has been tortuous, or often even retrograde, to a degree of which you will get no idea from the account in the text-book or encyclopædia, where, in the main, only the resultant of all these vacillating motions is given. With rare exceptions, the backward steps—that is, the errors and mistakes, which count in reality for nearly half, and sometimes for more than half, the whole—are left out of scientific history; and the reader, while he knows that mistakes have been made, has no just idea how intimately error and truth are mingled in a sort of chemical union, even in the work of the great discoverers, and how it is the test of time chiefly, which enables us to say which *is* progress, when the man himself could not. If this be a truism, it is one which is often forgotten, and which we shall do well to here keep before us.

This is not the occasion to review the vague speculations of the ancient natural philosophers from Aristotle to Zeno, or to give the opinion of the schoolmen on our subject. We take it up with the immediate predecessors of Newton, among whom we may have been prepared to expect some obscure recognition of heat as a mode of motion, but where it has been, to me at least, surprising, on consulting their original works, to find how general and how clear an anticipation of our modern doctrine may be fairly said to exist. Whether this early recognition be a legacy from the Lucretian philosophy, it is not necessary to here consider. The interesting fact, however it came about, is the extent to which seventeenth century thought is found to be occupied with views which we are apt to think very recent.

Descartes, in 1664, commences his "Le Monde" by a treatise on the propagation of light, and what we should now call radiant heat by vibrations, and further associates this view of heat as motion with the distinct additional conception, that in the cause of light and radiant heat we may expect to find something quite different from the sense of vision or of warmth;* and he expresses himself with the aid of the same simile of sound employed by Draper over two hundred years later. The writings of Boyle on the mechanical production of heat†

* "Me proposant de traiter ici de la lumière, la première chose dont je veux vous avertir est qu'il peut y avoir de la différence entre le sentiment que nous en avons, c'est-à-dire l'idée qui s'en forme en notre imagination par l'entremise de nos yeux, et ce qui est dans les objets qui produit en nous ce sentiment, c'est-à-dire ce qui est dans la flamme ou dans le soleil qui s'appelle du nom de lumiere: la plupart des philosophes assurent que le son n'est autre chose qu'un certain tremblement d'air qui vient frapper nos oreilles; en sorte que si le sens de l'ouïe rapportoit à notre pensée la vraie image de son objet, il faudroit, au lieu de nous faire concevoir le son, qu'il nous fît concevoir le mouvement des parties de l'air qui tremble pour lors contre nos oreilles. * * On passe doucement une plume sur les lèvres d'un enfant qui s'endort, et il sent qu'on le chatouille: pensez-vous que l'idée du chatouillement qu'il conçoit ressemble à quelque chose de ce qui est en cette plume?

† Detached passages from Bacon, Hobbes, and Locke, referring to the conception of heat, as a mode of motion, have been so often cited, that I will not repeat them here; but as these after all convey rather an impression of the acuteness of their authors, as men before their time, than the idea of a doctrine fully and clearly apprehended at the time, I prefer to offer the following much less known quotation, which I find in the works of Boyle, published *circa* 1670.

I beg the attention of the reader to the remarkable passages which follow, and which must have had, in Newton's day, all the currency which the eminent reputation of the author (a founder of the Royal Society) could give.

Extracts from the treatise on the "Mechanical Origin of Heat," by the Honorable Robert Boyle.—"Heat will appear the more likely to be mechanically producible, contain illustrations (like that of the hammer driving the nail, which grows hot in proportion as its bodily motion is arrested) which show a singularly complete apprehension of views we

if we consider the nature of it, which seems to consist mainly, if not only, in that mechanical affection of matter we call local motion mechanically modified, which modification, as far as I have observed, is made up of three conditions."

"The first of these is, that the agitation of the parts be vehement. Thus, in a heated iron, the vehement agitation of the parts may be easily inferred from the motion and hissing noise it imparts to drops of water, or spittle, that fall upon it. For it makes them hiss and boil, and quickly forces their particles to quit the form of a liquor, and fly into the air in the form of steams."

"The second is this, that the determinations be very various, some particles moving towards the right, some to the left hand, some directly upwards, some downwards, and some obliquely, etc. As a thoroughly ignited coal will appear every way red, and will melt wax, and kindle brimstone, whether the body be applied to the upper or to the lower, or to any other part of the burning coal. And congruously to this notion, though air and water be moved never so vehemently as in high winds and cataracts; yet we are not to expect that they should be manifestly hot, because the vehemency belongs to the progressive motion of the whole body."

"There is yet a third condition; namely, that the agitated particles, or at least the greatest number of them, be so minute, as to be singly insensible. For though a heap of sand, or dust itself, were vehemently and confusedly agitated by a whirlwind, the bulk of the grains or corpuscles would keep their agitation from being properly heat. If some attention be employed in considering the formerly proposed notion of the nature of heat, it may not be difficult to discern that the mechanical production of it may be divers ways affected. For by whatever ways the insensible parts of a body are put into a very confused and vehement agitation, by the same ways heat may be introduced into that body; agreeably to which doctrine, as there are several agents and operations by which this calorific motion (if I may so call it) may be excited, so there may be several ways of mechanically producing heat."

Boyle goes on to cite numerous experiments.

"Experiment VI. When, for example, a smith does hastily hammer a nail or such like piece of iron, the hammered metal will grow exceeding hot and yet there appears not anything to make it so, save the forcible motion of the hammer, which impresses a vehement and variously determined agitation of the small parts of the iron; which being a cold body before, by that superinduced commotion of its small parts becomes in divers senses hot. Again, if a somewhat large nail be driven by a hammer into a plank, or piece of wood, it will receive divers strokes on the head before it grow hot; but when it is driven to the head, so that it can go no further, a few strokes will suffice to give it a considerable heat; for whilst, at every blow of the hammer, the nail enters further and further into the wood, the motion that is produced is chiefly progressive, and is of the whole nail tending one way; whereas, when that motion is stopped, then the impulse given by the stroke, being unable either to drive the nail further on, or to destroy its entireness, must be spent in making a various vehement and intestine commotion of the parts among themselves, and in such an one we formerly observed the nature of heat to consist."

"Experiment VII. That I might also show that not only a sensible, but an intense degree of heat, may be produced in a piece of cold iron by local motion, I caused a bar of that metal to be nimbly hammered by two or three lusty men and these soon brought it to that degree of heat, that not only was it a great deal too hot to be safely touched, but probably would have kindled gun-powder."

Boyle goes on in the eighth experiment to illustrate the production of heat by friction by the use of a file, the whetting of a blade of a knife, the head of a piece of brass rubbed on the floor until it burns one's fingers, the heat of the axletree of a carriage by the friction of the wheel, and the common experiment of striking fire with a steel and flint, the latter as illustrating the instantaneity of the production of the heat.

are apt to think we have made our own; and it seems to me that any one who consults the originals will admit, that, though its full consequences have not been wrought out till our own time, yet the fundamental idea of heat as a mode of motion is so far from being a modern one, that it was announced in varying forms by Newton's immediate predecessors, by Descartes, by Bacon, by Hobbes, and in particular by Boyle, while Hooke and Huyghens merely continue their work, as at first does Newton himself.

If, however, Newton found the doctrine of vibrations already, so to speak, "in the air," we must, while recognizing that in the history of thought the new always has its root in the old, and that it is not given even to a Newton to create an absolutely new light, still admit that the full dawn of our subject properly begins with him, and admit, too, that it is a bright one, when we read in the "Optics" such passages as these:

"Do not all fixed bodies, when heated beyond a certain degree, emit light and shine, and is not this emission performed by the vibrating motions of their parts?" And again: "Do not several sorts of rays make vibrations of several bignesses?" And still again: "Is not the heat conveyed by the vibrations of a much subtler medium than air?"

Here is the undulatory theory; here is the connection of the ethereal vibrations with those of the material solid; here is "heat as a mode of motion;" here is the identity of radiant heat and light; here is the idea of wave-lengths. What a step forward this first one is! And the second?

The second is, as we know, backward. The second is the rejection of this, and the adoption of the corpuscular hypothesis, with which alone the name of Newton (a father of the undulatory theory) is, in the minds of most, associated to-day.

Do not let us forget, however, that it was on the balancing of arguments from the facts then known, that he decided, and that perhaps it was rather an evidence of his superiority to Huyghens, that apprehending equally clearly with the latter the undulatory theory, he recognized also more clearly that this theory, as then understood, utterly failed to account for several of the most important phenomena. With an equally judicial mind, Huyghens would perhaps have decided so too, in the face of difficulties, all of which have not been cleared up even to-day. These two great men, then, each looked around in the then darkness as far as his light carried him. All beyond that was chance to each; and fate willed that Newton, whose light shone farther than his rivals, found it extend just far enough to show the entrance to the wrong way. He reaches the conclusion that we all know; one not only wrong in regard to light, but which bears pernicious results on the whole theory of heat, since light being conceded to be material, radiant heat, if affiliated to light, must be regarded as material too, and Newton's influence is so permanent, that we shall see this strange conclusion drawn by the contemporaries of Herschel from his experiments made a hundred years later.

It would seem then that the result of this unhappy corpuscular theory was more far-reaching than we commonly suppose, and that it is hardly too much to say that the whole promising movement of that age toward the true doctrine of radiant energy is not only arrested by it, but turned the other way; so that in this respect the philosophy of fifty years later is actually farther from the truth than that of Newton's predecessors, and the immense repute of Newton as a leader, on the whole so rightly earned, here leads astray others than his conscious disciples, and, it seems to me, affects men's opinions on topics which appear at first far removed from those he discussed. The adoption of phlogiston was, as we may reasonably infer, facilitated by it, and remotely Newton is perhaps also responsible in part for the doctrine of caloric a hundred years later. After him, at any rate, there is a great backward movement. We have a distinct retrogression from the ideas of Bacon and Hobbes and Boyle. Night settles in again on our subject almost as thick as in the days of the schoolmen, and there seems to be hardly an important contribution to our knowledge, in the first part of the eighteenth century, due to a physicist.

"Physics, beware of metaphysics," said Newton,—words which physicists are apt so exclusively to quote, that it seems only due to candor to observe that the most important step, perhaps, in the fifty years which followed the "Optics," came from Berkeley, who, reasoning as a metaphysician, gave us during Newton's lifetime a conception wonderfully in advance of his age. Yet the "New Theory of Vision" was generally viewed by contemporary philosophers as only an amusing paradox, while "coxcombs vanquish[ed] Berkeley with a grin;" and this contribution to science,—an exceptional if not a unique instance of a great physical generalization reached by *a priori* reasoning,—though published in 1709, remains in advance of the popular knowledge even in these closing years of the nineteenth century.

In the meantime a new error had risen among men,—a new truth, as it seemed to them,—and a thing destined to have a strong reflex action on the doctrine of radiant energy. It began with the generalization of a large class of phenomena which we now associate with the action of oxygen, then of course unknown, a generalization useful in itself, and accompanied by an explanation which was not in its origin objectionable. Let us consider, in illustration, any familiar instance of oxidation, and try to look first for what was reasonable in the eighteenth-century views of the cause of such phenomena.

A piece of dry wood has in it the power of giving out heat and light when set on fire; but after it is consumed there is left of it only inert ashes, which can give neither. Something, then, has left the wood in process of becoming ashes; virtue has gone out of it, or, as we should say, its potential energy has gone.

This is, so far, an important observation, extending over a wide range of phenomena, and, if it had presented itself to the predecessors of Newton, it would probably have been allied to the vibratory theories, and become proportionately fruitful. But to his disciples, and to chemists and others, who, without being perhaps disciples, were like all then, more or less consciously influenced by the materiality of the corpuscular theory, it appeared that this virtue also was a material emanation;—that this energy was an actual ingredient of the wood,—a crudeness of conception which seems most strange to us, but is not perhaps unaccountable in view of the then current thought.

I have said that the progress of science is not so much that of an army as of a crowd of searchers, and that a call in a false direction may be responded to, not by one only, but by the whole body. In illustration, observe that during the greater part of the entire eighteenth century, this doctrine was adopted by almost every chemist and by many physicists. It had as general an acceptance among chemists then as the kinetic theory of gases, for instance, has among physicists now, and, so far as time is any test of truth, it was tested more severely than the kinetic theory has yet been; for it was not only the lamp and guide of chemists, and to a great extent of physicists also, but it remained the time-honored and highest generalization of chemical science for over half a century, and it was accepted not so much as a conditional hypothesis, as a final guide, and a conquest for truth which should endure always. And now where is it? Dissipated so utterly from men's minds, that, to the unprofessional part of even an educated audience like this, "phlogiston," once a name to conjure with, has become an unmeaning sound.

There is no need to insist on the application of the obvious moral to hypotheses of our own day.

I have tried to recall for a moment all that "phlogiston" meant a little more than a hundred years ago, partly because it seems to me, that, though a chemical conception, physics is not blameless for it, but chiefly because before it quitted the world it appears to have returned to physics the wrong in a multiplied form, by generating an offspring specially inimical to true ideas about radiant heat, and which is represented by a yet familiar term. I mean "caloric."

This word is still used loosely as a synonym for heat, but has quite ceased to be the very definite and technical term it once was. To me it has been new to find that this so familiar word "caloric," so far as my limited search has gone, was apparently coined only toward the last quarter of the last century. It is not to be found in the earliest edition of Johnston's dictionary, and, as far as I can learn, appears first in the corresponding French form in the works of Fourcroy. It expressed an idea which was the natural sequence of the phlogiston theory, and which is another illustration that the evil which such theories do lives after them.

"Caloric" first seemingly appears, then, as a word coined by the French chemists, and meant originally to signify the unknown cause of the sensation heat, without any implication as to its nature. But words, we know, though but wise men's counters, are the money of fools; and this one very soon came to commit its users to an idea which was more likely to have had its origin in the mind of a chemist at that time than of any other,—the idea of the cause of heat as a material ingredient of the hot body; something not, it is true, having weight, but which it would have been only a slight extension of the conception, to think might one day be isolated by a higher chemical art, and exhibited in a tangible form.

We may desire to recognize the perverted truth which usually underlies error and gives it currency, and be willing to believe that even "caloric" may have had some justification for its existence; but this error certainly seems to have been almost altogether pernicious for nearly the next eighty years, and down even to our own time. With this conception as a guide to the philosophers of the last years of the eighteenth century, it is not, at any rate, surprising if we find that at the end of a hundred years from Newton the crowd seems to be still going constantly farther and farther away from its true goal.

The doctrine of caloric is, however, always recognized as an hypothesis more acceptable to chemists than to physicists, some of whom still stand out for the theories of Newton's predecessors, even through the darkest years; so that the old idea of heat, as a mode of motion, has by no means so utterly died that it does not appear here and there during the last century, and indeed, not only among philosophers, but even in a popular form.

In an old English translation of Father Regnault's compilation on physics, dated about 1730, I find, for instance, the most explicit statement of the doctrine of heat as a mode of motion. Here heat is defined (with the aid of a simile due, I believe, to Boyle) as "any Agitation whatever of the insensible parts. Thus a Nail which is drove into the Wood by the stroke of a Hammer does not appear to be hot, because its immediate parts have but one common Movement. But should the Nail cease to drive, it would acquire a sensible Heat, because its insensible Parts which receive the Motion of the Hammer now acquire an agitation every way rapid." We certainly must admit that the user of this illustration had just and clear ideas; and the interesting point here appears to be, that as Father Regnault's was not an original work, but a mere compendium or popular scientific treatise of the period, we see, if only from this instance, that the doctrine of heat as a mode of motion was not confined to the great men of an earlier or a later time, but formed a part of the common pabulum during the eighteenth century to an extent that has been forgotten.

Although Prevost gave us his most material contribution about 1790, we have, it seems to me, on the whole, little to interest us during that barren time in the history of radiant energy called the eighteenth century,—a century in which science wore the pedant's cap and gown, and her students read the poem of Creation like grammarians, for its syntax;—a century whose latter years are given up, till near its very close, to bad *a priori* theories in our subject, except in the work of two Americans; for in the general dearth at this time of experiments in radiant heat, it is a pleasure to fancy Benjamin Franklin sitting down before the fire, with a white stocking on one leg and a black one on the other, to see which leg would burn first, and to recall again how Benjamin Thompson (Count Rumford) not only weighed "caloric" literally in the balance and found it wanting, but made that memorable experiment in the Munich founderies which showed that heat was perpetually and without limit created from motion.

It was in the last years of the century, too, that he provided for the medal called by his name, and which, though to be given for researches in heat and light, has, I believe, been allotted in nearly every instance to men, who, like Leslie, Malus, Davy, Brewster, Fresnel, Melloni, Faraday, Arago, Stokes, Maxwell, and Tyndall, have contributed toward the subject of radiant energy in particular.

We observe that before this time the scientific literature of the century scarcely considers the idea even of radiant heat, still less of radiant energy; so that we have been obliged here to discuss the views of its physicists about heat in general, heat and light in most minds being then distinct entities; all the ways for pilgrims to this special shrine of truth being barred, like those in Bunyan's Pilgrim's Progress, by the two unfriendly giants who are here called Phlogiston and Caloric, so that there are few scientific pilgrims who do not pay them toll.

The last years of this century were destined to see the most remarkable experiments in heat made in the whole of the hundred; for the memoir of Rumford appeared in the Philosophical Transactions for 1798; and in the very year 1800 appeared in the same place Sir William Herschel's paper, in which he describes how he placed a thermometer in successive colors of the solar spectrum, finding the heat increase progressively from the violet to the red, and increase yet more beyond the red where there was no color or light whatever; so that there are, he observes, invisible rays as well as visible. More than that, the first outnumber the second; and these dark rays are found in the very source and fount of light itself. These dark rays can also be obtained, he observes, from a candle or a piece of non-luminous hot iron, and, what is very significant, they are found to pass through glass, and to be refracted by it like luminous ones.

And now Herschel, searching for the final verity through a series of excellent experiments, asks a question which shows that he has truth, so to speak, in his hands,—he asks himself the great question whether heat and light be occasioned by the same or different rays.

Remember the importance of this (which the querist himself fully recognized); remember, that, after long hunting in the blindfold search, he has laid hands, as we now know, on the truth herself, and then see him—let go. He decides that heat and light are not occasioned by the same rays, and we seem to see the fugitive escape from his grasp, not to be again fairly caught till the next generation.

I hardly know more remarkable papers than these of Herschel's in the Philosophical Transactions for 1800, or anything more instructive in little men's successes than in this great man's failure, which came in the moment of success. I would strongly recommend the reading of these remarkable original memoirs to any physicist who knows them only at second-hand.

One more significant lesson remains, in the effect of this on the minds of his contemporaries. Herschel's observation is to us almost a demonstration of the identity of radiant heat and light; but now, though the nineteenth century is opening, it is with the doctrine in the minds of most physicists, and perhaps of all chemists, that heat is occasioned by a certain material fluid. Phlogiston is by this time dead or dying, but Caloric is very much alive, and never more perniciously active than now, when, for instance, years after Herschel's observation, we find this cited as "demonstrating the existence of caloric;"—which was, it seems, the way it looked to a contemporary.

In the year 1804 appeared what should be a very notable book in the history of our subject, written by Sir John Leslie, whose name survives perhaps in the minds of many students chiefly in connection with the "cube" which is still called after him.

Leslie, however, ought to be remembered as a man of original genius, worthy to be mentioned with Herschel and Melloni; and his, too, is one of the books which the student may be recommended to read, at least in part, in the original; not so much for the writer's instructive experiments (which will be found in our text-books) as for his most instructive mistakes, which the text-book will probably not mention.

He began by introducing the use of the simple instrument which bears his name, and a new and more delicate heat-measurer (the differential thermometer); and with these, and concave reflectors of glass and metal, he commenced experiments in radiant heat, than which, he tells us, no part of physical science then appeared so dark, so dubious, and so neglected. It is interesting, and it marks the degree of neglect he alludes to, that his first discovery was that different substances have different radiating and absorbing powers. It gives us a vivid idea of the density of previous ignorance, that it was left to the present century to demonstrate this elementary fact, and that Leslie, in view of such discoveries, says, "I was transported at the prospect of a new world emerging to view."

Next he shows that the radiating and absorbing powers are proportional, next that cold as well as heat seems to be radiated, and next undertakes to see whether this radiant heat has any affinity to light. He then experiments in the ability of radiant heat to pass through a transparent glass, which transmits light freely, and thinks he finds that none does pass. Radiant heat with him seems to mean heat from non-luminous sources; and the ability or non-ability of this to pass through glass, is to Leslie and his successors a most crucial test, and its failure to do so a proof that this heat is not affiliated to light.

Let us pause a moment here to reflect that we are apt to unconsciously assume, while judging from our own present standpoint where past error is so plain, that the false conclusion can only be chosen by an able, earnest, conscientious seeker, after a sort of struggle. Not so. Such a man is found welcoming the false with rapture, as very truth herself.

"What then," says Leslie, "is this calorific and frigorific fluid after which we are inquiring? It is not light, it has no relation to ether, it bears no analogy to the fluids, real or imaginary, of magnetism and electricity. But why have recourse to invisible agents? *Quod petis, hic est.* It is merely the ambient AIR."

The capitals are Leslie's own, but ere we smile with superior knowledge, let us put ourselves in his place, and then we may comprehend the exultation with which he announces the identity of radiant heat and common air, for he feels that he is beginning a daring revolt against the orthodox doctrine of caloric; and so he is.

The first five years of this century are notable in the history of radiant energy, not only for the work of Leslie, and for the observation by Wollaston, Ritter, and others, of the so-called "chemical" rays beyond the violet, but for the appearance of Young's papers, reëstablishing the undulatory theory, which he indeed considered in regard to light, but which was obviously destined to affect most powerfully the theory of radiant energy in general.

We are now in the year 1804, or over a century and a quarter since the corpuscular theory was emitted, and during that time it has gradually grown to be an article of faith in a sort of scientific church, where Newton has come to be looked on as an infallible head, and his views as dogmas, about which no doubt is to be tolerated; but if we could go back to Cambridge in the year 1668, when the obscure young student, in no way conscious of his future pontificate, takes his degree (standing twenty-third on the list of graduates), we should probably find that he had already elaborated and greatly improved certain already current ideas into the undulatory theory of light, which he at any rate promulgated a few years later, and afterward, pressed with many difficulties, altered, as we now know, to an emissive one.

Probably, if we could have heard his own statement then, he would have told how sorely tried he was between these two opinions, and, while explaining to us how the wavering balance came to lean as it did, would have admitted, with the modesty proper to such a man, that there was a great deal to be said on either side. We may, at any rate, be sure that it would not be from the lips of Newton himself that we should have had this announced as a belief which was to be part of the rule of faith to any man of science.

But observe how, if science and theology look askance at each other, it is still true that some scientific men and some theologians have, at any rate, more in common than either is ready to admit; for at the beginning of this century Newton's followers, far less tolerant than their master, have made out of this modest man a scientific pontiff, and out of his diffident opinions a positive dogma, till as years go on, he comes to be cited as so infallible that a questioning of these opinions is an offense deserving excommunication.

This has grown to be the state of things in 1804, when Young, a man possessing something of Newton's own greatness, ventures to put forward some considerations to show that the undulatory theory may be the true one, after all. But the prevalent and orthodox scientific faith was still that of the material nature of light; the undulatory hypothesis was a heresy, and Young a heretic. If his great researches had been reviewed by a physicist or a brother worker, who had himself trodden the difficult path of discovery, he might have been treated at least intelligently; but then, as always, the camp-followers, who had never been at the front, shouted from a safe position in the rear to the man in the dust of the fight, that he was not proceeding according to the approved rules of tactics; then, as always, these men stood between the public and the investigator, and distributed praise or blame.

If you wish to hear how the scientific heretic should be rebuked for his folly, listen to one who never made an observation, but, having a smattering of everything books could teach about every branch of knowledge, was judged by himself and by the public to be the fittest interpreter to it, of the physical science of this day. I mean Henry Brougham, the universal critic, the future Lord Chancellor of England, of whom it was observed, that, "if he had but known a little *law*, he would have known a little of everything." He uses the then all-powerful *Edinburgh Review* for his pulpit, and from it fulminates the condemnations of the church on the innovating memoir of the heretical Young.

"This paper," he says, "contains nothing which deserves the name of experiment or discovery; and it is, in fact, destitute of every species of merit. . . . first is another lecture, containing more fancies, more blunders, more unfounded hypotheses, more gratuitous fictions . . . and all from the fertile yet fruitless brain of the eternal Dr. Young. In our second number we exposed the absurdity of this writer's 'law of interference,' as it pleases him to call one of the most incomprehensible suppositions that we remember to have met with in the history of human hypotheses."

There are whole pages of it, but this is enough; and I cite this passage among many such at command, not only as an example of the way the undulatory theory was treated at the beginning of this century in the first critical journal of Europe, but as another example of the general rule that the same thing may appear intrinsically absurd, or intrinsically reasonable, according to the year of grace in which we hear of it. The great majority, even of students of science, must take their opinions ready-made as to science in general; each knowing, so far as he can be said to know anything at first-hand, only that little corner which research has made specially his own.

The moral we can all draw, I think, for ourselves.

In spite of such criticism as this, the undulatory hypothesis of light made rapid way, and carried with it, one would now say, the necessary inference that radiant heat was due to undulations also. This was, however, no legitimate inference to those to whom radiant heat was still a fluid; and yet, in spite of all, the modern doctrine now begins to make visible progress.

A marked step is taken about 1811 by a young Frenchman, De la Roche, who deserves to be better remembered than he is, for he clearly anticipated some of Melloni's discoveries. De la Roche in particular shows that of two successive screens the second absorbs heat in a less ratio than the first; whence he, before any one else, I believe, derives the just and most important, as well as the then most novel conception, that radiant heat is of different *kinds*. He sees also, that, as a body is heated more and more, there is a gradual and continual advance not only in the amount of heat it sends out, but in the kind, so that, as the temperature still rises, the radiant heat becomes light by imperceptible gradations; and he concludes that heat and light are due to one simple agent, which, as the temperature rises yet more, appears more and more as light, or which, as the luminous radiation is absorbed, re-appears as heat. Very little of it, he observes, passes even transparent screens at low temperatures, but more and more does so as the temperature rises.

All this is a truism in 1888, but it appears admirably new as well as true in 1811; and if De la Roche had not been removed by an early death, his would have not improbably been the greatest name of the century in the history of our subject; an honor, however, which was in fact reserved for another.

The idea of the identity of light and radiant heat had by this time made such progress that the attempt to polarize the latter was made in 1818 by Berard. We have just seen in Herschel's case how the most sound experiment may lead to a wrong conclusion, if it controvert the popular view. We now have the converse of this in the fact that the zeal of those who are really in the right way may lead to unsound and inconclusive experiment; for Berard experimentally established, as it was supposed, the fact that obscure radiant heat can be polarized. So it can, but not with such means as Berard possessed, and it was not till a dozen years more that Forbes actually proved it.

At this time, however fairly we seem embarked on the paths of study which are followed to-day, and while the movement of the main body of workers is in the right direction, it is yet instructive to observe how eminent men are still spending great and conscientious labor, their object in which is to advance the cause, while the effect of it is to undo the little which has been rightly done, and to mislead those who have begun to go right.

As an instance both of this and of the superiority of modern apparatus, we may remark,—after having noticed that the ability of obscure heat to pass through glass, if completely established, would be a strong argument in favor of its kinship to light, and that De la Roche and others had indicated that it would do so (in which we now know they were right),—that at this stage, or about 1816, Sir David Brewster, the eminent physicist, made a series of experiments which showed that it would not so pass. Ten years later, in view of the importance of the theoretical conclusion, Baden Powell repeated his observations with great care, and confirmed them, announcing that the earlier experimenters were wrong, and that Brewster was right; so that here all these years of conscientious work resulted in establishing, so far as it could be established, a wholly wrong conclusion in place of a right one already gained.

It may be added, that with our present apparatus, the passage of obscure radiant heat through glass could be made convincingly evident in an experiment which need not last a single second.

We are now arrived at a time when the modern era begins; and in looking back over one hundred and fifty years, from the point of view of the experimenter himself with his own statement of the truth as he saw it, we find that the comparison of the progress of science to that of an army, which moves, perhaps with the loss of occasional men, but on the whole victoriously and in one direction, is singularly misleading; and I state this more confidently here, because there are many in this audience who did not get their knowledge of nature from books only, but who have searched for the truth themselves; and, speaking to them, may I not say that those who have so searched know that the most honest purpose and the most patient striving have not been guaranties against mistakes,—mistakes which were probably hailed at the time as successes? It was some one of the fraternity of seekers, I am sure, who said, "Show me the investigator who has never made a mistake, and I will show you one who has never made a discovery."

We have seen the whole scientific body, as regards this particular science of radiant energy, moving in a mass, in a wrong direction, for a century; we have seen that individuals in it go on their independent paths of error; and we can only wonder that an era should have come in which such a real advance is made as in ours.

That era has been brought in by the works of many, but more than by any other through the fact that, in the year 1801, there came into the world at Parma an infant who was born a physicist, as another is born a poet; nay, more; who was born, one might say, a devotee of one department of physics, that of radiant heat; being affected in his tenderest years with such a kind of precocious passion for the subject as the childish Mozart showed for music. He was ready to sacrifice everything for it; he struggled through untold difficulties, not for the sake of glory or worldly profit, but for radiant heat's sake; and when fame finally came to him, and he had the right to speak of himself, he wrote a preface to his collected researches, which is as remarkable as anything in his works. In this preface he has given us, not a summary of previous memoirs on the subject, not a table of useful factors and formulæ, not anything at all that an English or an American scientific treatise usually begins with, but the ingenuous story of his first love, of his boyish passion for this beloved mistress; and all this with a trust in us, his readers, which is beautiful in its childlike confidence in our sympathy.

I should need to abbreviate and injure in order to quote; but did ever a learned physical treatise and collections of useful tables begin like this before?

"I was born at Parma, and when I got a holiday used to go into the country the night before, and go to bed early, so as to get up before the dawn. Then I used to steal silently out of the house, and run, with bounding heart, till I got to the top of a little hill, where I used to set myself so as to look toward the East." There, he tells us, he used, in the stillness of nature, to wait the rising sun, and feel his attention rapt, less with the glorious spectacle of the morning light itself than with the sense of the mysterious heat which accompanied its beams, and brought something more necessary to our life and that of all nature than the light itself, so that the idea that not only mankind, but nature, would perish though the light continued, if this was divorced from heat, made a profound impression, he tells us, on his childish mind.

The statement that such an idea could enter with dominating force into the mind of a child will perhaps seem improbable to most. It will, however, be credible enough to some here, I have no doubt.

Is there some ornithologist present who remembers a quite infantile attraction which birds possessed for him above all the rest of the animated creation? Some chemist whose earliest recollections are of the strange and quite abnormal interest he found as a child in making experimental mixtures of every kind of accessible household fluid and solid? Some astronomer who remembers that when a very little creature not only the sight of the stars, but of any work on astronomy, even if utterly beyond his childish comprehension, had an incomprehensible attraction for him? I will not add to the list. There are, at any rate, many here who will understand Melloni when he tells how this radiant heat, commonplace to others, was wonderful to his childish thought, and wrought a charm on it such that he could not see wood burn in a fireplace, or look at a hot stove, without its drawing his mind, not to the fire or iron itself, but to the mysterious effluence which it sent.

This was the youth of genius; but let not any fancy that genius in research is to be argued from such premonitions alone, unless it can add to them that other qualification of genius which has caused it to be named the faculty of taking infinite pains. Melloni's subsequent labors justified this last definition also; but I cannot speak of them here, further than to say, that, after going over a large part of his work myself, with modern methods and with better apparatus, he seems to me the man, of all great students of our subject, who, in reference to what he accomplished, made the fewest mistakes.

Melloni is very great as an experimenter, and owes much of his success to the use of the newly invented thermopile, which is partly his own. I can here, however, speak only of his results, and of but two of these,—one generally known; the other, and the more important, singularly little known, at least in connection with him.

The first is the full recognition of the fact, partly anticipated by De la Roche, that radiant heat is of different kinds, and that the invisible emanations differ among themselves just as those of light do. Melloni not only established the fact, but invented a felicitous term for it, which did a great deal to stamp it on recognition,—the term "thermochrose," or heat-color, which helps us to remember, that, as the visible and apparently simple emanation of light is found to have its colors, so radiant heat, the invisible but apparently simple emanation, has what would be colors to an eye that could see them. This result is well known in connection with Melloni.

The other and the greater, which is not generally known as Melloni's, is the generalization that heat and light are effects of one and the same thing, and merely different manifestations of it. I translate this important statement as closely as possible from his own words. They are that

"*Light is merely a series of calorific indications sensible to the organs of sight, or vice versa, the radiations of obscure heat are veritable* INVISIBLE RADIATIONS *of light.*"

The italics and the capitals are Melloni's own. He wishes to have no ambiguity about his announcement behind which he may take shelter; and he had so firm a grasp of the great principle, that, when his first attempts to observe the heat of the moon failed, he persevered, because this principle assured him that where there was light there must be heat. This statement was made in 1843, and ought, I think, to insure to Melloni the honor of being first to thus distinctly announce this great generalization.

The announcement passed apparently unnoticed, in spite of his acknowledged authority; and the general belief not merely in different entities in the spectrum, but in a material caloric, continued as strong as ever. If you want to see what a hold on life error has, and how hard it dies, turn to the article "heat," in the eighth edition of the "Encyclopædia Britannica," where you will find the old doctrine of caloric still in possession of the field in 1853; and still later, in the generally excellent "English Encyclopædia" (edition of 1867), the doctrine of caloric is, on the whole, preferred to the undulatory hypothesis. It is very probable that a searcher might find many traces of it yet lingering among us; so that Giant Caloric is not, perhaps, even yet quite dead, though certainly grown so crazy and stiff in the joints, that he can now harm pilgrims no more.

So far as I know, no physicist of eminence reasserted Melloni's principle with equal emphasis, till J. W. Draper, in 1872. Only sixteen years ago, or in 1872, it was almost universally believed that there were three different entities in the spectrum, represented by actinic, luminous and thermal rays. Draper remarks that a ray consists solely of ethereal vibrations whose lost *vis viva* may produce either heat or chemical change. He uses Descartes' analogy of the vibration of the air, and sound; but he makes no mention either of Descartes or of Melloni, and speaks of the principle as leading to a modification of views then "universally" held. Since that time the theory has made such rapid progress, that, though some of the older men in England and on the European continent have not welcomed it, its adoption among all physicists of note may be said to be now universal, and a new era in our history begins with it. I mean with the recognition that there is one radiant energy which appears to us as "actinic," or "luminous" or "thermal" radiation, according to the way we observe it. Heat and light, then, are not things in themselves, but whether different sensations in our own bodies, or different effects in other bodies, are merely effects of this mysterious thing we call radiant energy, without doing more in this than give a name to the ignorance which still hangs over the ultimate cause.

I am coming down dangerously near our own time, for one who would be impartial in dealing with names of those still living. In such a brief review of this century's study of radiant energy in other forms than light, it has been necessary to pass without mention the labors of such men as Pouillet and Becquerel in France, of Tyndall in England, and of Henry in America. It has been necessary to omit all mention of those who have advanced the knowledge of radiant energy as light, or I should have had to speak of labors so diverse as those of Fraunhofer, of Kirchhoff, of Fresnel, of Stokes, of Lockyer, of Janssen, and many more. I have made no mention, in the instructive history of error, of many celebrated experimental researches; in particular of such a problem as the measurement of solar heat, great in importance, but apparently most simple in solution, yet which has now been carried on from generation to generation, each experimenter materially altering the result of his predecessor, and where our successors will probably correct our own results in turn. I have not spoken of certain purely experimental investigations, like those of Dulong and Petit, which have involved immense and conscientious labor, and have apparently rightly earned the name of "classic" from one generation, only to be recognized by the next as leading to untrustworthy results, and leaving the work to be done again with new methods, guided by new principles.

In these instances, painstaking experiments have proved insufficient, less from want of skill in the investigator than from his ignorance of principles not established in time to enable him to interpret his experiments; but, if there were opportunity, it would be profitable to show how inexplicably sometimes error flourishes, grows, and maintains an apparently healthy appearance of truth, without having any root whatever. Perhaps I may cite one instance of this last from my own experience.

About ten years ago it was generally believed that the earth's atmosphere acted exactly the part of the glass in a hot-bed, and that it kept the planet warm by exerting a specially powerful absorption on all infra-red rays. I had been reared in the orthodox scientific church, of which I am happy to be still a member; but I had acquired perhaps an almost undue respect, not only for her doctrines, but for her least sayings. Accordingly, when my own experiments did not agree with the received statement, I concluded that my experiments must be wrong, and made them all over again, till spring, summer, autumn and winter had passed, each season giving its own testimony; and this for successive years. The final conclusion was irresistible, that the universal statement of this alleged well-known fact, inexplicable as this might seem, in so simple a matter, was directly contradicted by experiment. I had some natural curiosity to find how every one knew this to be a fact; but search only showed the same statement (that the earth's atmosphere absorbed dark heat like glass) repeated everywhere, with absolutely nowhere any observation or evidence whatever to prove it, but each writer quoting from an earlier one, till I was almost ready to believe it a dogma superior to reason, and resting on the well-known "*Quod semper, quod ubique, quod ab omnibus, creditum est.*" Finally I appear to have found its source in the writings of Fourier, who, alluding to De Saussure's experiments (which showed that dark heat passed with comparative difficulty through glass) observes that if the earth's atmosphere were solid, it would act as the glass does. Fourier simply takes this (in which he is wrong) for granted; but, as he is an authority on the theory of heat, his words are repeated without criticism, first by Poisson, then by others, and then in the text-books; and, the statement gaining weight by age, it comes to be believed absolutely, on no evidence whatever, for the next sixty years, that our atmosphere is a powerful absorber of precisely those rays which it most freely transmits.

The question of fact here, though important, is, I think, quite secondary to the query it raises as to the possible unsuspected influence of mere tradition in science, when we do not recognize it as such. Now, members of any church are doubtless consistent in believing in traditions, if they believe that these are presented to them by an infallible guide; but are we, who have no infallible guide, quite safe in believing all we do, from our fond persuasion that in the scientific body mere tradition has no weight?

In even this brief sketch of the growth of the doctrine of radiant energy, we have perhaps seen that the history of the progress of this department of science is little else than a chapter in that larger history of human error which is still to be written, and which, it is safe to say, would include illustrations from other branches of science, as well as my own. But —and here I ask pardon if I speak of myself—I have been led to review the labors of other searchers from this standpoint, because I had first learned, out of personal experience, that the greatest care was no certain guaranty of final accuracy; that to labor in the search for a truth with such endless pains as a man might bestow if his own salvation were in question, did not necessarily bring the truth; and because, seeking to see whether this were the lot of other and greater men, I have found that it was, and that, though no one was altogether forsaken of the truth he sought, or, on the whole review of his life as a seeker, but might believe he had advanced her cause, yet there was no absolute criterion by which it could be told at the time, whether, when after long waiting, there came in view what seemed once more her beautiful face, it might not possibly prove, after all, the mockery of error; and, doubtless, appeal might be made to the experience of many investigators here with the question, "Is it not so?"

What then? Shall we admit that truth is only to be surely found under the guidance of an infallible church? If there be such a church, yes! Let us, however, remember that the church of science is not such a one, and be ready to face all the consequences of the knowledge that her truths are put forward by her as provisional only, and that her most faithful children are welcome to disprove them.

What then, again? Shall we say that the knowledge of truth is not advancing? It is advancing, and never so fast as to-day; but the steps of its advance are set on past errors, and the new truths become such stepping-stones in turn.

To say that what are truths to one generation are errors to the next, or that truth and error are but different aspects of the same thing to our poor human nature, may be to utter truisms; but truisms which one has verified for one's self out of a personal experience are apt to have a special value to the owner; and these lead, at any rate, to the natural question, "Where is, then, the evidence that *we* are advancing in reality, and not in our own imagination?"

There are many here who will no doubt heartily subscribe to the belief that there is no absolute criterion of truth for the individual, and admit that there is no positive guaranty that we, with this whole generation of scientific men, may not, like our predecessors, at times go the wrong way in a body, yet who believe as certainly that science as a whole, and this branch of it in particular, is actually advancing with hitherto unknown rapidity. In asking to be included in this number, let me add that to me the criterion of this advance is not in any ratiocination, not in any *a priori* truth, still less in the dictum of any authority, but in the undoubted observation that our doctrine of radiant energy is reaching out in every direction, and proving itself by the equally undoubted fact that through its aid nature obeys us more and more; proving itself by such material evidence as is found in the electric lights in our streets, and in a thousand such ways which I need not pause to enumerate.

And here I might end, hoping that there may be some lessons for us in the history of what has been said. I will venture to ask attention to but one. It is that in these days, when the advantage of organization is so fully recognized, when there is a well-founded hope that by coöperation among scientific men knowledge may be more rapidly increased, and when not only in the great scientific departments of government but everywhere, there is a tendency to the formation of the divisions of a sort of scientific army, not to say of a scientific church—that at such a time we should yet remember, that, however rapidly science changes, human nature remains much the same; and (while we are uttering truisms) let us venture to repeat that there is a very great deal of this "human nature" even in the scientific man, whose best type is one nearly as independent as nature itself, and one which will not always work best at the word of command. Let him then never forget that the history of science, scarcely less than of theology, warns him of the tendency of authority to exceed its proper sphere, and from without it, to define belief, and to impose obedience to doctrine.

Finally, if, turning to the future, I were asked what I thought were the next great steps to be taken in the study of radiant heat, I should feel unwilling to attempt to look more than a very little way in advance. Immediately before us, however, there is one great problem waiting solution. I mean the relation between temperature and radiation; for we know almost nothing of this, where knowledge would give new insight into almost every operation of nature (nearly every one of which is accompanied by the radiation or reception of heat), and would enable us to answer inquiries now put to physicists in vain by every department of science, from that of the naturalist as to the enigma of the brief radiation of the glow-worm, to that of the geologist who asks as to the number of million years required for the cooling of a world.

When, however, we begin to go beyond the points which seem, like this, to invite our very next steps in advance, we cannot venture to prophesy, and must content ourselves with the knowledge that through our study we are beginning to apprehend the full meaning of one of the early great ones of science, who described man as the meeting point of two infinities. That there is an infinity of space above him, man has long known, but that there is another absolute infinity, and what the possibilities are which lie in the infinitesimals of space, he is but beginning to realize. The secular movements, whose accomplishment demands more than a million years of time, he has already considered; but of the consequences which may result from a more careful study of actions occurring in the infinitesimals of time, and whose whole duration may be far less than the millionth of a second, he has hardly even yet begun to think; and these are but little portions of the ungarnered field of research, open to the student of that radiant energy which sustains, with our own being, that of all animated nature, of which humanity is but a part.

If there be any students of nature here, who, feeling drawn to labor in this great field of hers, still doubt whether there is yet room, surely it may be said to them, "Yes, just as much room as ever, as much room as the whole earth offered to the first man;" for everything that has been done in the past is, I believe, as nothing to what remains before us, and that field is simply unbounded. The days of hardest trial and incessant bewildering error in which your elders have wrought, seem over. You "in happier ages born," you of the younger and the coming race, who have a mind to enter in and possess it, may, as the last word here, be bidden to indulge in an equally unbounded hope.

ART. II.—*Description of the new mineral, Beryllonite;* by EDWARD S. DANA and HORACE L. WELLS. With Plate I.

IN the October number of this Journal a preliminary account was given by one of us* of a new phosphate of sodium and beryllium, for which the name *Beryllonite* was proposed. We purpose now to give a more complete account of this species, the unusual interest of which has been developed by fuller study.

Locality and occurrence.—The first specimens of beryllonite were discovered near Stoneham, Maine, in 1886, by Mr. Sumner Andrews of Lawrence, Massachusetts. The Stoneham region is already well known,† having afforded fine specimens of topaz, phenacite, herderite and many other species of greater or less interest. The exact locality of the beryllonite is situated in the west part of the town of Stoneham at the base of a small but steep mountain, known as the McKean mountain. At this spot, work was carried on‡ sometime since in the

* E. S. Dana, this Journal, xxxvi, 290, October, 1888; the chemical work of the present paper has been done by H. L. Wells.

† Cf. George F. Kunz, this Journal, xxv, 161, 1883, xxvii, 212, 1884, xxxvi, 222, 1888. W. E. Hidden, xxvii, 73, 125, 1884. Mr. Kunz has since announced that the topaz and phenacite locality is not in Stoneham but on Bald Face Mountain, North Chatham, New Hampshire, just across the State line; this is 6 or 7 miles west of the beryllonite locality. Herderite and topaz are found on Harndon Hill, Stoneham, about 4 miles southwest of the beryllonite locality.

‡ By Mr. E. D. Andrews.

search for smoky quartz and a considerable quantity was obtained, including one crystal weighing nearly 100 lbs. The beryllonite, however, was overlooked, being not unnaturally taken for colorless quartz.

The early specimens, like those which have been obtained since, were found either detached in the soil or occasionally imbedded in a loosely coherent brecciated mass obviously not the original matrix. The material in which the crystals and fragments occur has evidently been derived from a granitic vein, fragments of partly kaolinized feldspar, smoky quartz crystals and other species to be mentioned being common. The exploration thus far carried on, however, has not brought to light the vein in an unaltered condition, although an apparent vein 4 to 6 feet wide of decomposed material has been found. The country rock is mica schist, which has been met with at a number of points in the course of the excavations.

The species which have been obtained from the same spot associated with the new mineral, and which probably represent its original associates in the vein are the feldspars, orthoclase and albite, smoky quartz sometimes in large crystals, mica, also columbite, cassiterite, beryl, apatite, triplite. The crystals bear evidence of having been implanted upon the rock on one side as if they had occurred in cavities rather than completely embedded. Some specimens, however, retain the impressions of surrounding minerals, probably mica. A single specimen is implanted upon apatite and inclusions of apatite have been noted. The chemical agencies which have kaolinized the feldspar have also left their mark on the beryllonite the surfaces of which are often roughened or in some cases delicately etched.

Crystalline form.—The specimens in hand are in large part fragments of crystals, ranging from those presenting a surface of an inch or two square and weighing 40 to 50 grams down to the size of a pea. Well formed crystals are rare; the largest is somewhat more than an inch across. All the specimens show a highly perfect basal cleavage (c), yielding easily smooth lustrous surfaces. Exactly at right angles to this (measured 90° 0′ and 89° 59½′) is a second cleavage somewhat interrupted and obtained with a little difficulty; the third pinacoidal cleavage is faintly indicated in the rectangular form of some of the broken fragments, and a fourth cleavage is sometimes distinct parallel to a prism of 60°. Twins are common in which the twinning plane is a prism also of sensibly 60°,* but it is found that the twinning prism and the cleavage prism, though having nearly

* When the preliminary notice was written, no material was at hand allowing of exact measurement and it was assumed that of the two possible twinning planes, the one present was probably also the cleavage prism; this has since been shown not to be the case, hence the change of position here adopted.

the same angle, are not identical. Of the two positions suggested by these facts it has seemed best to follow the usage in most similar cases and make the twinning plane the unit prism. Adopting this, the second cleavage corresponds to the macropinacoid (*a*), the imperfect pinacoidal cleavage is brachydiagonal (*b*) and the cleavage prism has the symbol 130 (*i*-$\breve{3}$).

The material at hand for exact measurement is very scanty. With very few exceptions the planes have lost their original luster, and give no reflections at all. A few angles, however, could be measured, and with sufficient exactness to yield a satisfactory axial ratio. For fundamental angles the following were accepted :

$$001 \wedge 111 = 47° \ 51\tfrac{1}{2}', \ 001 \wedge 021 = 47° \ 40\tfrac{1}{2}'.$$

Each of these is the mean of two independent angles on different crystals of equal degrees of accuracy, not involving a probable error of more than $\pm 1'$; these are :

47° 51′ and 47° 52′, also 47° 40′ and 47° 41′.

The axial ratio obtained is:

$$\breve{a} : \bar{b} : \dot{c} = 0{\cdot}57243 : 1 : 0{\cdot}54901; \text{ also the angles}$$

$$100 \wedge 110 = 29° \ 47' \ 17'', \ 001 \wedge 101 = 43° \ 48' \ 13'', \ 001 \wedge 011 = 28° \ 46' \ 2''.$$

The measured angles, the symmetry in arrangement of the planes and optical characters all conform to the orthorhombic system. As confirming the accuracy of these elements we have :

	Measured.	Calculated.
$021 \wedge 02\bar{1}$ =	84° 41′	84° 39′
$023 \wedge 02\bar{3}$ =	139° 46′	139° 48′
$100 \wedge 130$ =	59° 45′ Cleavage.	59° 47′

On two crystals the angle *aa̲* was measured between cleavage faces and the result 120° 22′ obtained in each case. This would give as twinning plane, if coinciding with the composition plane, the angle on 100 of 29° 49′, or if at right angles to the composition face 60° 11′. The former is the more probable relation and is shown to be the true one by the fact that the calculated angle for 100 ∧ 110 is 29° 47′, while for 100 ∧ 130 it is 59° 47′.

In habit the crystals vary from short prismatic to tabular, as shown in figs. 1 to 6 ; the aspect changes considerably with the change in relative size of the pyramids ; of these *w* (121, 2-$\breve{2}$) is usually most prominent. The crystals are remarkable for the number of planes which they present. The prismatic and brachydome zones are both highly developed, and it is not uncommon to note the presence of eight or more distinct planes in each zone on a single crystal. It is also interesting to note that eleven of the twelve prismatic planes have representatives in the brachydome series, and, furthermore, they have nearly equal angles, since the axes $\breve{a}$ and $\dot{c}$ have approximately the same length.

Some idea of the complexity of the form may be gained from fig. 8, which is a basal projection of a single crystal simplified by the omission of several minute but distinct planes. The prismatic faces are often narrow and by their oscillatory combination produce vertical striations, especially on a; the faces of the pyramid v also show sometimes striations parallel to the edge v/f. The list of planes observed is given below; this might be increased if it were thought worth while to include a number of forms the symbols of which could not be determined with accuracy.

a (100, $i\text{-}\bar{\imath}$), b (010, $i\text{-}\breve{\imath}$), c (001, O); prisms g (410, $i\text{-}\bar{4}$), h (310, $i\text{-}\bar{3}$), i (210, $i\text{-}\bar{2}$), j (320, $i\text{-}\frac{\bar{3}}{2}$), m (110, I), k (230, $i\text{-}\frac{\breve{3}}{2}$), l (120, $i\text{-}\breve{2}$), n (130, $i\text{-}\breve{3}$), o (140, $i\text{-}\breve{4}$), π (150, $i\text{-}\breve{5}$), p (160, $i\text{-}\breve{6}$), q (1·12·0, $i\text{-}\breve{12}$); macrodomes d (102, $\frac{1}{2}\text{-}\bar{\imath}$), e (101, $1\text{-}\bar{\imath}$), f (201, $2\text{-}\bar{\imath}$); brachydomes α (014, $\frac{1}{4}\text{-}\breve{\imath}$), β (013, $\frac{1}{3}\text{-}\breve{\imath}$), γ (012, $\frac{1}{2}\text{-}\breve{\imath}$), δ (023, $\frac{2}{3}\text{-}\breve{\imath}$), ε (011, $1\text{-}\breve{\imath}$), ζ (032, $\frac{3}{2}\text{-}\breve{\imath}$), η (021, $2\text{-}\breve{\imath}$), ϑ (031, $3\text{-}\breve{\imath}$), κ (041, $4\text{-}\breve{\imath}$), λ (051, $5\text{-}\breve{\imath}$), μ (061, $6\text{-}\breve{\imath}$); unit pyramids ψ (112, $\frac{1}{2}$), v (111, 1), s (221, 2), Δ (331, 3); macro-pyramids R (411, $4\text{-}\bar{4}$); u (212, $1\text{-}\bar{2}$), r (211, $2\text{-}\bar{2}$), T (421, $4\text{-}\bar{2}$); brachy-pyramids ϕ (232, $1\text{-}\frac{\breve{3}}{2}$), t (231, $3\text{-}\frac{\breve{3}}{2}$); ρ (123, $\frac{2}{3}\text{-}\breve{2}$), χ (122, $1\text{-}\breve{2}$), w (121, $2\text{-}\breve{2}$); σ (132, $\frac{3}{2}\text{-}\breve{3}$), x (131, $3\text{-}\breve{3}$); Q (142, $2\text{-}\breve{4}$), y (141, $4\text{-}\breve{4}$); z (151, $5\text{-}\breve{5}$); τ (163, $2\text{-}\breve{6}$), ω (161, $6\text{-}\breve{6}$).

It will be noted that all the planes have very simple symbols, and furthermore they are so tied together by zones that the symbols of a large part can be determined without measurement. The following are some of the prominent zones, after the pinacoidal zones: e (101), u (212), v (111), φ (232), w (121), x (131), y (141), z (151), ω (161); also r (211), s (221), t (231); again ψ (112), χ (122), σ (132) Q (142); again m (110), t (231), w (121), σ (132), ε (011); again l (120), x (131), Q (142), ε (011) and others.

It is not thought worth while to give all the measurements by which the planes were determined, since a greater accuracy than 30′ or 1° could in few cases be attained. For example, in the brachydome zone we obtained: $c\alpha = 8°$, $c\beta = 10°\frac{1}{2}$, $c\gamma = 15°\frac{1}{2}$, $c\delta = 21°$, $c\varepsilon = 29°$, $c\zeta = 39°$, $c\eta = 47°\ 41\frac{1}{2}'$, $c\vartheta = 59°$, $c\varkappa = 65°\ 30'$, $c\lambda = 70°$, $c\mu = 73°–74°$.

The important calculated angles for the planes observed are given in the following table:

		a, 100	*b*, 010	*c*, 001
g,	410	8° 9′	81° 51′	90°
h,	310	10° 48′	79° 12′	90°
i,	210	15° 58′	74° 2′	90°
j,	320	20° 53′	69° 7′	90°
m,	110	29° 47′	60° 13′	90°
k,	230	40° 39′	49° 21′	90°
l,	120	48° 52′	41° 8′	90°
n,	130	59° 47′	30° 13′	90°
o,	140	66° 24½′	23° 35½′	90°
π,	150	70° 44½′	19° 15½′	90°
p,	160	73° 46′	16° 14′	90°
q,	1·12·0	81° 43′	8° 17′	90°
d,	102	64° 23′	90°	25° 37′
e,	101	46° 12′	90°	43° 48′
f,	201	27° 32′	90°	62° 28′
α,	014	90°	82° 11′	7° 49′
β,	013	90°	79° 38′	10° 22′
γ,	012	90°	74° 39′	15° 21′
δ,	023	90°	69° 54′	20° 6′
ε,	011	90°	61° 14′	28° 46′
ζ,	032	90°	50° 32′	39° 28′
η,	021	90°	42° 19½′	*47° 40½′
ϑ,	031	90°	31° 16′	58° 44′
κ,	041	90°	24° 29′	65° 31′
λ,	051	90°	20° 1′	69° 59′
μ,	061	90°	16° 53′	73° 7′

		a, 100	*b*, 010	*c*, 001
ψ,	112	65° 11′	76° 6′	28° 55′
v,	111	49° 57′	68° 23′	*47° 51½′
s,	221	37° 45′	63° 5′	65° 39′
Δ,	331	33° 49′	61° 36′	73° 13′
R,	411	16° 34′	82° 7′	75° 32′
u,	212	47° 14′	78° 48′	44° 56′
r,	211	30° 44½′	75° 46′	63° 23′
T,	421	21° 10′	74° 31′	75° 46′
φ,	232	53° 29′	59° 16½′	51° 39′
t,	231	45° 8′	52° 43′	68° 25′
ρ,	123	73° 17′	70° 47′	25° 55′
χ,	122	67° 12′	63° 40′	36° 5′
w,	121	57° 9′	51° 36′	55° 33′
σ,	132	69° 41′	53° 24′	43° 37′
x,	131	63° 32′	40° 4′	62° 19′
Q,	142	72° 6′	45° 17′	50° 9′
y,	141	68° 19′	32° 15′	67° 21′
z,	151	71° 50′	26° 47′	71° 1′
τ,	163	77° 51′	43° 45′	43° 50′
ω,	161	74° 26′	22° 49′	73° 45′

Twins.—The existence of contact twins with *m* (110) as the twinning plane has already been noted. These have $a\,\underline{a}$=120° 25′, measured 120° 22′, also $b\,\underline{b}$ = 59° 35′. These twins are common and lead to many interesting variations in the form. A basal projection of one twin is given in figure 5. Repeated twinning is not uncommon; in several cases a large crystal mass was observed having its edge formed of highly modified partial crystals in successive twinning position; some of these suggest crystals of bournonite in aspect. In a single case a part of a stellate form was noted which is idealized in fig. 7. It was too imperfect to allow of determining the exact method of grouping, but the presence of a six-rayed star was clear. These twins are remarkable among similar pseudohexagonal forms because the variation from the required 60° is so small.*

General physical characters.—The cleavages already noted are: highly perfect parallel to *c;* less perfect and interrupted parallel to *a;* still less distinct parallel to *n* (130), and faintly indicated parallel to *b*. The fracture is very perfect conchoidal, yielding lustrous surfaces suggestive of glassy quartz.

* In the preliminary notice mention was made of an apparent penetration twin with a pyramid, inclined on *c* nearly 60°, as twinning plane. The exact measured angle $c\,\underline{c}$ is 61° 40′, giving as the angle of the supposed twinning plane on *c* either 59° 10′ or 30° 50′; as these do not correspond to any occurring pyramid, the occurrence is probably accidental.

Hardness 5·5–6. Specific gravity=2·845. Luster vitreous and brilliant, but on a natural basal face (c) sometimes pearly. Colorless to white or slightly yellowish when not perfectly clear. Transparent.

Optical characters.—The axes of elasticity coincide in position with the crystallographic axes. The axial plane is parallel to a and the acute bisectrix normal to c, so that a cleavage fragment shows the axes on the border of the field of the polariscope. The dispersion is small, $\rho < v$. The double refraction is negative, in other words $\mathfrak{a}$ is the bisectrix. Sections* cut normal to the bisectrices gave the following for the axial angles:

	Red (Li)	Yellow (Na)	Green (Tl)
2 E	120° 26′	121° 1′	121° 24′

Also

$2\ H_a$	72° 35′	72° 47′	73° 01′
$2\ H_o$	125° 13′	124° 59′	124° 30′

Also $2V_y = 67°\ 34'$.

A prism afforded by a crystal whose edge was parallel to the axis $\breve{a}$ and whose faces were formed by the planes δ (023) gave tolerable values of two of the refractive indices; the faces, however, were not quite smooth, so that no very high degree of accuracy can be claimed for them. The results for yellow (Na) are: $\beta=1·5580$, and $\gamma=1·5630$. Another prism was obtained having the same edge but the faces did not make quite equal angles, as was intended, with the axis $\bar{b}$, which should have bisected the prismatic edge; the values of β are, therefore, fairly good, while those of γ are somewhat too small. Another prism with an edge just parallel to the axis $\dot{c}$ gave good values of the index a.

	Red (Li)	Yellow (Na)	Green (Tl)
a	1·5492	1·5520	1·5544
β	1·5550	1·5579	1·5604
γ	1·5604	1·5608	1·5636

It will be seen from these results that the refractive power of the mineral is not especially high, varying but little from that of quartz, which has $\omega=1·5442$, $\varepsilon=1·5533$ for Na.

Etchings.—It has already been remarked that the crystalline faces are almost always dull, and in some cases show natural etching figures as the result of the action of some solvent upon them. These figures have often great regularity and beauty

* The sections and optical preparations used in our work were made for us very satisfactorily by Mr. H. Hensoldt, School of Mines, Columbia College, New York City.

and merit a more detailed study than our limited time has permitted us to give them. They are most distinct on the basal plane, where they appear as nearly square depressions closely crowded together, at first sight suggesting tetragonal symmetry. Figure 12 will give some idea of the appearance of a portion of the surface; in some cases these pittings run across the basal face in diagonal lines. A more careful examination shows that while square or nearly so in outline the symmetry is rhombic. The little pits are bounded within by two surfaces in the zone *bc*, making an angle of 22° with each other, and in the zone *ac* the prominent surfaces are inclined about 11°, while occasionally other deeper faces inclined 21° are also noted. The angles can be only roughly measured, but they suggest 013(β) and 1·0·10, 105 as probable symbols for the faces in question. The planes in the two series of domes also show at times distinct etching figures, especially *e* (101) and *ε* (011), but the form is less distinct, though in general acute trowel-shaped with the vertex pointed upward. In some cases those on *ε* appear to vary slightly from the symmetry about the plane of the axes $\bar{b}\,\overset{|}{c}$ which the crystallographic relations of the form demands. The *b* faces often show longitudinal figures ($\parallel \overset{|}{c}$) and others transverse, but their form is not distinct; this is also true to some extent of the prismatic faces. The other planes are almost always slightly roughened, but distinct figures are not often to be made out. Not infrequently the solvent action on the crystals has gone so far as to leave only rounded angles with indistinct planes.

Inclusions.—Another interesting feature of this mineral is the presence of great numbers of fluid inclusions. A superficial examination shows the common existence of a columnar structure normal to the cleavage plane. This is seen in thin sections to be due to great numbers of slender canals parallel to the vertical axis. In some cases these seem to be hollow or filled with earthy matter, but in others they appear as fluid cavities with long bubbles. These vertical canals and fluid cavities are often thickly crowded together, sometimes extending from base to base and again starting from a sharply defined plane within the crystal parallel to the base. The forms of some of these are shown in fig. 9 ($\times$90). Not infrequently, instead of a long cavity, we have a line of them present all lying in the same direction. Besides these regular cavities there are also groups of fine parallel or wavy lines inclined sharply to *c* and giving rise to a peculiar sheen; these are probably also hollow canals.

There are, further, multitudes of other fluid cavities, often so small as to require a high power of the microscope, either crowded together on an irregular wavy surface passing through a crystal after the manner so common in smoky quartz, or again more or less regularly orientated, parallel to the vertical axis or inclined to it in lines of 45° or 30°. The last becomes a V-shaped arrangement of the minute inclusions in some restricted areas, as is shown in figure 10. Figure 13 shows the usual arrangement and common forms of the cavities (×90). As a rule these cavities, even the smallest, contain each its own bubble, and very frequently two bubbles are noted (cf. fig. 11) often of nearly the same size. This fact, the disappearance of the second bubble with slight rise in temperature, and further the presence or absence of a broad dark rim to the bubble show the nature of the liquids and gases present. In many of the cases we have water with liquid carbon dioxide, and frequently also within this carbon dioxide gas. Occasionally the bubble appears to be air in water, and more rarely the cavity is partially filled with a liquid (CO_2) which does not wet its sides. Solid inclusions, sometimes macroscopic, are also noted.

Chemical examination.—Qualitative tests showed that the mineral is slowly but completely soluble in acids; that it is an anhydrous phosphate of sodium and beryllium containing no other acids and bases, and especially careful tests proved the absence of fluorine, aluminum, potassium and lithium. Before the blowpipe it decrepitates and fuses about 3 to a somewhat clouded glass, coloring the flame deep yellow with a tinge of green on the lower edge.

A quantitative analysis gave the following results:

	I.	II.	III.	IV.	V.	VI.	Mean.	Ratio.	Calculated for $NaBePO_4$.
P_2O_5,	56·09	55·66	55·84	----	----	----	55·86	÷142·=·392=1·	55·82
BeO,	----	19·87	19·85	19·81	----	----	19·84	÷25·2=·787=2·	19·81
Na_2O,	----	----	----	----	23·68	23·59	23·64	÷62· =·381=1·	24·37
Ign.,	----	0·07	0·09	----	----	----	0·08		----
							99·42		100·00

It is evident from this analysis that the mineral has the composition represented by the formula $Na_2O . 2BeO . P_2O_5$ or $NaBePO_4$.

Method of analysis.—In I the P_2O_5 was determined by the molybdic method in a sample of about 0·5 gr. The other five samples were of about 1 gram each. In II, III and IV the substance was fused with Na_2CO_3 and, after treating the mass with water, the BeO was filtered off and weighed, while in II and III the P_2O_5 in the filtrates was determined by the usual method.* A trace of P_2O_5 amounting to 0·17 per cent re-

* This method for separating BeO and P_2O_5 was used by Penfield and Harper in their analysis of herderite: this Journal III, vol. xxxii, p. 107.

mained in the BeO of III, which was carefully determined by the molybdic method and a correction made for it. The purity of the weighed BeO was shown by dissolving that obtained from II in HCl, evaporating off the excess of acid, dissolving the residue in the least possible amount of pure NaOH solution and precipitating the BeO by diluting largely and boiling; the BeO obtained in this way amounted to 19·81 per cent, an amount practically identical with the original weight.

For the determination of Na_2O in V and VI the mineral was dissolved in HCl, P_2O_5 and BeO were separated by the usual methods and the metal was weighed as chloride; the results are probably about 0·7 per cent too low on account of the difficulty of washing some of the precipitates.

Relations to other species.—As has been shown above, the general formula of beryllonite is analogous to that of triphylite and lithiophilite, viz:

Beryllonite.	Triphylite-Lithiophilite.
$NaBePO_4$	$Li(Fe,Mn)PO_4$.

There does not appear, however, to be as close a relation between the forms as might be expected, although our knowledge of triphylite* in this respect is scanty. The two minerals are alike in having two pinacoidal cleavages, but the third prismatic cleavage of triphylite has an angle of about 47°. The vertical axes, however, are nearly equal. The axial ratios are

Triphylite....$\breve{a} : \bar{b} : \dot{c} = 0·4348 : 1 : 0·5266$ $001 \wedge 011 = 27° 46'$

Beryllonite...$\breve{a} : \bar{b} : \dot{c} = 0·5724 : 1 : 0·5490$ $001 \wedge 011 = 28° 46'$

The optical relations† are different except as regards the size of the axial angle, for which we have $2H_{a.r} = 74° 45'$ triphylite and 72° 35′ beryllonite.

A closer relation seems to exist to the only other phosphate in which beryllium is known to exist, that is herderite. This has the composition $(CaF)BePO_4$ in which the univalent group CaF (partly replaced by CaOH) corresponds to the sodium of the beryllonite. In form the two minerals are apparently related.

Thus we have

Herderite.	Beryllonite.
$110 \wedge 1\bar{1}0 = 63° 39'$	$110 \wedge 1\bar{1}0 = 59° 34'$
$001 \wedge 011 = 22° 57'$	$001 \wedge 023 = 20° 61'$
$001 \wedge 031 = 51° 43'$	$001 \wedge 021 = 47° 41'$
$001 \wedge 331 = 67° 27'$	$001 \wedge 221 = 65° 39'$
$001 \wedge 362 = 58° 30'$	$001 \wedge 121 = 55° 33'$

* Cf. Tschermak, Ber. Ak. Wien, xlvii, 282, 1863, and J. D. Dana, this Journal, II, xi, 100, 1851.

† Cf. Brush and Dana, this Journal, xvi, 118, 1878.

Also

$$\text{Herderite} \ldots \breve{a} : \bar{b} : \tfrac{3}{2}\dot{c} = 0{\cdot}6206 : 1 : 0{\cdot}6352$$

$$\text{Beryllonite} \ldots \breve{a} : \bar{b} : \dot{c} = 0{\cdot}5724 : 1 : 0{\cdot}5490$$

The optical relations do not correspond very closely except in the size of the axial angle, for which we have in herderite $2H_{a.r} = 72° 12'$ Dx. The refractive power of beryllonite is a little lower than that of herderite ($\beta = 1{\cdot}6$). It is certainly most interesting that these two beryllium phosphates should be found within a few miles of each other, and that the same region should have yielded the rare beryllium silicate phenacite.

In conclusion we would express our high appreciation of the liberality of Mr. Sumner Andrews, of Lawrence, Mass., his brother, Mr. Charles G. Andrews, and Mr. Lorin Merrill who have placed in our hands all the best material for study of this rare and beautiful mineral. Without this it would not have been possible to have made our investigation with the completeness that the interest of the subject has made it merit.

ART. III.—*The Iron Ores of the Penokee-Gogebic Series of Michigan and Wisconsin;* by C. R. VAN HISE. With Plate II.

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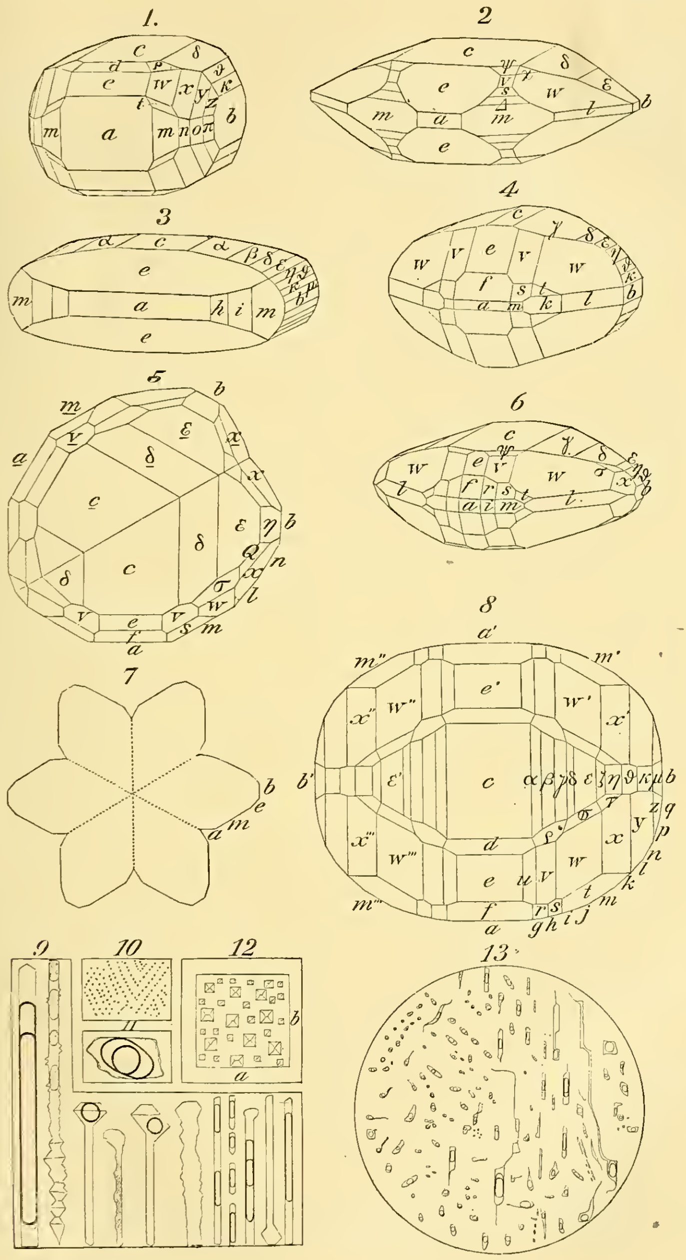
THE Penokee-Gogebic Series runs nearly continuously from the vicinity of Numakagon Lake, T. 44 N., R. 6 W., Wis., to Gogebic Lake, T. 47 N., R. 42 W., Mich., a distance of more than 80 miles. The west part of this belt was first fully described by Professor R. D. Irving, and Mr. Charles E. Wright.* A general account of the Range has been given by President Chamberlin.† Other papers have also been published in this Journal, which have from various standpoints treated particular questions in reference to this region.‡ It will, however, be necessary here to give very briefly its struct-

* Geology of Wisconsin, vol. iii, 1880, Part III, pp. 100–167, The Huronian System, by R. D. Irving; Part IV, pp. 239–301, The Huronian Series west of Penokee Gap, by C. E. Wright.

† Geology of Wisconsin, vol. i, 1883, pp. 80–94, The Huronian Age, by T. C. Chamberlin.

‡ This Journal, III, vol. xxix, pp. 237–245, Divisibility of the Archæan in the Northwest, by R. D. Irving. Vol xxxi, pp. 453–459, Upon the Origin of the mica-schists and black mica-slates of the Penokee-Gogebic iron-bearing series; by C. R. Van Hise. Vol. xxxii, pp. 263–265, Origin of the ferruginous schists and iron ores of the Lake Superior region, by R. D. Irving; Vol. xxxiv, pp. 257–259, Is there a Huronian Group? by R. D. Irving.



BERYLLONITE.

ure as a whole before considering the subject of this paper. The series of rocks runs across the country in an approximately east and west direction, the general trend being somewhat north of east. It is a simple series, which has been tilted to the north at an angle of from 60° to 80°. It contains no subordinate folds, and thus the succession of belts is easily made out; one following above the other in perfect conformity. The series rests upon a complex of granite, gneiss, and various green schists. It is overlain by the eruptives of the Keweenaw Series. In our new mapping it will be divided into four belts (see fig. 1), the principle of division being a fragmental or non-fragmental character. At the base of the series is a cherty limestone-member which, in one place, is as much as 300 feet thick, and which varies from this to disappearance. The second member is a feldspathic quartz-slate. On the average it is from 300 to 400 feet thick, and is composed of green, red and brown fragmental slates which contain a good deal of clayey matter. The upper part of this fragmental member is a pure vitreous quartzite, the induration of which has been due to the enlargement of the quartz-grains originally deposited as a sandstone.* The third member of the series is a belt of non-fragmental sediments, about 800 feet thick, which is known as the iron-bearing member from the fact that all the known ore-bodies and heavily ferruginous rocks occur within it. The uppermost member of the series is a thick layer of greywackes, greywacke-slates, and mica-schists and slates. This member is several times as thick as the three lower combined, but in its essential fragmental character it is to be considered as a unit in the series.

The origin of the ferruginous rocks and ores of the iron-bearing member has been considered in a general way in a paper by Professor Irving already referred to. The fundamental conclusion of that paper has been borne out by our later investigations, i. e. that the original rock of the iron-bearing formation is a cherty iron carbonate,† from which the various phases of rock and the ore found in it have been produced by a complex series of alterations.

The principal phases of rock in that part of the formation in which the ore-deposits occur, aside from the cherty carbonate, are heavily ferruginous regularly banded slates, brecciated and concretionary ferruginous cherts, and the ore-

* Bull. U. S. Geol. Survey, No. 8. Upon the Secondary Enlargement of Mineral Fragments in Certain Rocks; by R. D. Irving and C. R. Van Hise.

† The origin of this cherty iron carbonate is a question of great interest, but one which it would take an article of some length to discuss, so this rock is taken as a starting point.

bodies. The carbonate has proved to be far more abundant than was supposed when the paper alluded to was written, and is found at all horizons, but most plentifully in the upper ones. The regularly bedded ferruginous slates are prevalent in the middle, and the ore bodies and ferruginous cherts at the lower horizons. In this paper I have not space to add anything further to what Professor Irving has said as to the particular processes by which the different phases of rock, aside from the ores, have been produced.

Position of the ore in the iron-bearing member.—The iron-ores are all located, as far as known at present, in that part of the iron-bearing formation between Sec. 33, T. 45 N., R. 1 W., Wis., and the east line of T. 47 N., R. 45 W., Mich., a distance of about 30 miles. The greater number of the larger deposits are found in the central half of this area. Also most of the known deposits lie at the base, or very near the base of the iron-bearing member; that is, they rest upon or close to the coarse-grained fragmental quartzite which constitutes the uppermost horizon of the quartz-slates. The number of important mines is about 23, and of these all have deposits upon the fragmental quartzite except five, and three of these, situated east of Sunday Lake, at the eastern extremity of the belt of mines, have exceptional characteristics which exclude them from the present discussion. It is true that three other mines have also deposits which are north of the fragmental quartzite; but in one case, that of the Colby Mine (fig. 4), the two ore-bodies have been shown by developments to have such connections as to show that they are essentially a single deposit. It is not meant to imply that the numerous deposits resting upon the foot-wall quartzite have clean ore always in contact with it. Quite often there is a layer of what the miners denominate "paint rock," or a layer of sand rock between the quartzite and the ore. This latter material is sometimes as much as 20 feet in thickness, although it is usually not more than a few inches, or at most a few feet. Sometimes also there is, between the ore and the quartzite, a mass of greater or less thickness of the ferruginous chert or mixed ore of the miners; rarely a thin layer of nearly pure white chert is found between the ore and quartzite. Notwithstanding these exceptions, the south side of the ore never penetrates the quartzite and in a general way follows it, so that it may be spoken of as resting upon it. This quartzite, although subject to local variations, has an average dip to the north of 60° to 70°, and thus furnishes an approximately regular wall, north of which the ore lies, and is consequently called the foot-wall by the miners. The few deposits north of the foot-wall quartzite are described by Mr. J. Parke Channing as also having regular south walls which dip with the formation and are known as foot-walls. Whether the ore-deposits rest upon the fragmental quartzite or are north of it, they have then as their southern boundaries a plane dipping to the north at an angle of 60° to 70°.

Dykes in the iron-bearing member.—Mining developments have shown that the iron-bearing member is cut by numerous greenstones, the presence of which would not have been suspected from natural exposures. These greenstones are much altered; many of them are so decomposed as to be soft friable matter which can be picked to pieces with the fingers, and which now contain none of the original minerals which compose ordinary basic eruptives. They retain, however, distinctly their diabasic structure, and occasionally can be traced into comparatively unaltered phases which are true diorites. These altered greenstones are known to the miners, either as soapstones, or as diorite dykes. That they are dykes is manifest from their shape, and the way in which they cut across the layers of the iron-bearing member being traced at times into the foot-wall quartzite. This dyke-like character is well shown by figs. 2 to 7. The association of the ores and these soapstones was found to be so constant, that Mr. J. Parke Channing, Inspector of Mines for Gogebic County, Mich., was secured to work out the relation of the ore-bodies and dyke-rocks. What follows as to the position of the dykes themselves, and as to the position of the ore-bodies with reference to them, is wholly the result of data furnished by his investigations.

The position of the dykes is given with reference to the iron formation in which they occur. This formation has a northern dip and a general east and west strike. As used in reference to the dykes, an east and west direction means parallel with the iron formation, a north and south direction transverse to it. The important thing for the present purpose, is not the absolute direction in which the dykes run, but their relations to the containing formations. The dykes vary a good deal in their dip and strike in different mines, and the same dyke at times in the same mine also varies in dip and strike. However, certain of their elements are quite constant. The dykes always dip to the south, and generally the southern dip, or its component transverse to the formation, is from 20° to 30°. The northern dip of the iron formation has been said to be from 60° to 70°. *It follows from this, that if the stratified rocks were placed again in a horizontal position, the dykes would be vertical.* The true dip of the dykes is usually, however, not exactly transverse to the formation, but east of it; so that a component along the dykes, parallel to the strike of the rocks, has usually an eastern pitch (figs. 2 and 5). This pitch may be as high as 35°. From this amount it varies to horizontality, or even to a western pitch of 10°. The position of these dykes with reference to the foot-wall quartzite will be better understood by figs. 2 to 8.

The thickness of the dykes varies greatly, running from those of but a few inches in thickness, to those nearly 90 feet thick, fig. 4. In most of the mines in which the ore-deposits are of any magnitude the dykes are six feet or more in thickness ; while it is noticeable that the three largest mines have dykes of considerable thickness. At least one dyke has been found in connection with every deposit west of Sunday Lake, with the single exception of the Ironton-Puritan ore-body, and it is possible that when the workings of these mines penetrate deeper they will come in contact with a dyke—one is known to come to the surface three or four hundred feet west. As to the three mines east of Sunday Lake, it has already been noted that their character is quite exceptional. From the eastern pitch of the dykes, it is evident that they must, if they continue in their observed directions, reach the surface to the west of the present workings of each of the mines. As these workings are but a few hundred feet deep, it follows that when these dips are high the dykes would reach the surface but a short distance from the ore-deposits. It thus becomes probable that there are as many dykes in the lower horizon of the iron-bearing member as are seen in all of the different mines, while doubtless there are many more. In some mines there are as many as three or four parallel dykes. In those cases in which there are several dykes in a single mine, one is generally known as the main dyke. The smaller ones are in some cases clearly offshoots from the larger, the actual connections between them being traced.

Position of the ore in reference to the dykes.—The ore has been spoken of as resting upon the fragmental quartzite as a foot-wall, and in exceptional cases as resting upon a non-fragmental quartz-rock, which belongs in the iron-bearing member, but which nevertheless forms a foot-wall for the ore deposits, dipping north with the formation. From the description of the position of the dykes and the quartzites, it is evident that the two rocks form V-shaped troughs, which have at the apices right angles, and the south arms of which are nearer vertical than the north arms ; the first being upon an average 20° to 30° from a vertical, while the second is from 20° to 30° from a horizontal position. The relation is that of a right angled trough tilted toward the north until it lacks 20° to 30° from having its arms in horizontal and vertical positions. In one or two mines, for a short distance, these troughs do not incline either east or west, but at most of them, from what has gone before, it is evident they incline to the east. *The ore-bodies lie in the apices of these roughly shaped troughs*, figs. 3, 4, 7. Each deposit of ore in following a trough will evidently be at different depths at different places east and west, depending upon the nearness of the dykes to the surface. All ore-deposits in the position described would reach the surface if the underlying dykes dip to the east or to the west. As a matter of fact, many of them were found at the rock-surface, but others were found after cutting an overlying rock. However, at present (October, 1888), mining developments have traced all deposits which are large enough to warrant working, with two exceptions, to the surface, and these exceptions are newly discovered deposits, which in all probability will be traced to the surface in the future. As would be expected, it is also true that the development of the deposits which were originally found at the surface have carried them, in every case in which they are of any magnitude, below the surface of the country rock. Both of these facts, the tracing of the ore-deposits discovered at depth to the surface, and those discovered at surface beneath rock, are inevitable deductions from what has preceded.

Rock above the ore.—The rocks which are found above the ore-deposits are the ferruginous cherts—the rocks which have been spoken of as the characteristic ones near the base of the iron-bearing member throughout the area in which the ores occur. The upper boundary of the deposits differs from the quartzite and dyke-boundaries, in that the change from ore to the cherty rock is a transition instead of an abrupt one. In passing upward through an ore-deposit, as its border is reached, the ore becomes mixed with chert until so poor in iron as to become unsalable. In passing still farther upward, the amount of chert becomes greater, until a fractured chert and iron ore, known to the miners as "mixed ore," is found. In passing up still farther this mixed ore grades into the ordinary ferruginous chert of the lower horizons.

To summarize then, the boundaries of the ore-deposits are to the south, either fragmental quartzite or ferruginous quartz-rock in the ore-formation—generally the former; under the ore, the dyke rocks; and above the ore, the typical ferruginous cherts of the region.*

The horizon above the ferruginous cherts, is in most cases a regularly banded red ferruginous slate. This slate is composed of chert and iron peroxide and is as regularly bedded as the unaltered carbonates. Above this slate, constituting the upper horizon of the ore formation, are often found cherty iron carbonates. While this section is known to occur at several of

* Evident practical deductions for carrying on prospecting and mining follow from the foregoing, but in this paper my space is too limited to give them.

the more important mines, it cannot certainly be said to be common to all of them. Also the respective thicknesses of the ill-defined belts are very different at different mines. A general statement may be made, that at most of the mines a cross section of the iron formation shows the proportion of unaltered iron carbonate to increase in passing from lower to higher horizons. It is true that almost solid carbonate occurs at three places at relatively low horizons, although none of them are known to be at the base of the member, while one is certainly underlain by a ferruginous chert Also at several localities a typical chert is found at very high horizons. Figs. 2 to 8 illustrate as wide variations of the relations of the ore-bodies to the surrounding rocks as is anywhere found; yet all are alike in essential points.

Character of the ore.—The iron ore is a soft, red, somewhat hydrated hematite. By chemical analyses it is shown to be more or less manganiferous, the manganese occasionally running to a high percentage. Much of it is so friable that it can be broken down with a pick, although as taken from the mines it is compact enough to hold together in tolerably large lumps. These lumps are porous, often more or less nodular, and also often roughly stratiform. The strata conform in a general way to the strike and dip of the formation. Mingled with this soft hematite, in a few mines, is a small quantity of aphanitic steel-blue hematite. The south deposits carry upon an average more manganese than the north deposits, the average in the South Iron King being above 10 per cent, while from the South Colby, ore has been taken which contained as much as 30 per cent metallic manganese.

The Origin of the Ores.

We have before us the character of the iron ores, the shape of the deposits, their relations to the rocks surrounding them, the nature of the rocks of the iron formation above the ore horizon, and the character of the formations above and below that bearing iron. An attempt will now be made to suggest an explanation of the character and location of the ore-bodies.

The shape of the deposits and their relations to the strata of the iron formation are such as to exclude the idea of original sedimentation in place; neither can they be considered as the result of oxidation of iron carbonate in place alone. All of the unaltered iron carbonate now found contains a much larger quantity of silica than the ores, so much as to make them entirely valueless. Also the red banded slates found at the middle horizons give every evidence of being a material which has resulted from the oxidation of the bedded carbonate in place.

Further, the large amount of manganese which the ores, especially the south deposits, contain is greater than that found in any carbonate from which analyses have been made; and the average content of manganese in the ore is much greater than the average of the carbonates. While it is thus true that the ores are not carbonates of iron which have altered in place, it is almost as certainly true that the iron carbonates of the belt have been the source whence the iron oxides for these ores have been derived. The nature of the evidence upon which this statement is based has been suggested; but the conclusion would be much clearer if there were place to give a detailed description of the rocks of the iron formation as a whole.

Since, then, the iron ores cannot be explained by oxidation of carbonate alone in place, and since the carbonate was the source whence they were derived, they are necessarily concentrations of iron oxide, combined perhaps with iron oxide furnished by oxidation of carbonate in place. If this explanation is adopted, however, it is not only necessary to explain the presence of the iron oxide in its peculiar position, but the nature of the whole lower part of the formation. The explanation must account for the great increase in the amount of silica in the lower horizon of the ore formation as compared with the original cherty carbonate; for its almost total absence in the ore; for the concentration of the iron oxide; for the almost complete absence of carbonate of iron at the lower horizons; for the red banded slates and carbonates in the middle horizons; and for the relatively much more abundant unaltered carbonate in the upper horizons.

A particular occurrence of iron ore.—Before attempting to give a general explanation of these facts, it will first be well to refer to one of several occurrences of narrow belts of iron ore in natural exposure. At Sunday Lake outlet, in Sec. 13, T. 47 N., R. 46 W., Mich., the actual transformation from cherty iron carbonate to iron ore is seen in all its phases. In clefts, joints and partings along the bedding of the exposure are narrow seams of hematite. In passing from the seams, the hematite becomes mingled with some chert; going still farther, the chert increases in quantity until a groundmass of silica contains many rhombohedra of iron oxide. The iron oxide then gradually passes into siderite. This siderite is in perfect rhombohedra, and it is evident, in thin section, that the iron oxide adjacent is pseudomorphous after it. The rock has now passed from an ore into a sideritic chert, which is of a light-gray color, aphanitic texture, and breaks with conchoidal fracture. The latter rock is manifestly in its original condition. The processes by which the seams of iron oxide occupied the space once taken by sideritic chert are plain. The iron carbonate has decomposed in place to iron oxide, the rock becoming a hematitic chert. Along the seams, waters bearing iron in solution have passed. These waters have particle by particle dissolved out the chert and replaced it with iron oxide, and where once was lean sideritic chert is rich ore. A part of the iron oxide is due to the oxidation in place of iron carbonate, but the larger part has come from a greater or less distance there to be deposited. The seams of iron oxide at this point are but a few inches in thickness, but it is probable that the series of changes which have here taken place upon a small scale, will upon a large scale explain the concentration of workable ore-deposits.

Time at which concentration of the main ore-bodies occurred. —It has been stated that the iron belt rocks are much less altered as a whole in the upper horizons, being there composed largely of unaltered cherty carbonate, while the lower horizons contain very little carbonate and are mostly composed of ferruginous chert and iron ore. It follows as a deduction from this succession, that the series of changes which have so completely altered the lower horizons of the formation have occurred subsequently to the uplifting of the series. The alterations can only be explained by the action of percolating waters bearing oxygen, and which therefore came from above. If the layers were horizontal when the changes occurred, the waters passing downward would have altered most that part of the formation nearest the surface. The reverse would be the case if the alteration was subsequent to the tilting, for the upper layers of the member would partially escape the action of percolating waters, as will readily be seen by glancing at figs. 1 and 9, and taking into consideration the nature of the belt of rock above the ore formation. It is a member composed of black and gray clay-slates, greywacke and greywacke-slates, all of which contain a large amount of clay, rocks particularly impervious to water. A rock underlying any great thickness of such a formation in a horizontal position could not be greatly affected by waters from above. However, when the series had been uplifted and eroded, this upper impervious member would have been removed, and the waters would come directly in contact with the lower horizons of the ore formation, while the upper horizons of the belt would still be somewhat protected.

Before going farther, it is necessary to consider the porosity of the rocks which underlie the ore formation. They have been said to be composed of quartzites and feldspathic quartz-slates. Included in the latter are clay-slates; consequently the rocks of this member are also almost impenetrable to percolating waters. The uppermost layer of the member, the quartzite, is not itself a perfect barrier to the passage of water, on account of the joints which are always found in such a brittle rock. These joints do not affect the underlying slates, for these thinly laminated clayey rocks are so flexible that under the slight bowing which they have received, they are scarcely fractured at all.

Process of Concentration.—An attempt will now be made to trace the passage of percolating waters through the inclined layers of the iron formation. Fig. 9 is a section showing the condition of this member at the present time at the surface, and illustrating how this state of affairs was reached. The strata of the formation are now exposed by their dipping at a high angle, 65°, to the north. The whole Penokee-Gogebic series, more than 13,000 feet thick in some places, of which the iron formation is a part, is exposed in the same fashion. Therefore thousands of feet of the iron member have certainly been carried away by erosion. The figure assumes that about 2000 feet have been eroded from this member since it was upturned. It would, however, make no difference with the argument if this erosion occurred during the time of the upturning. The upper part of the figure represents the surface of the iron formation, and a part of the underlying and overlying rocks at some past time. Near the bottom of the figure is the present land surface, showing the succession of rocks from north to south which are now actually found. A transition from unaltered cherty carbonate to completely decomposed carbonate is noted. At the time when the upper supposed land surface was an actual one, the present surface would be but little exposed to the action of percolating water. It could not pass through the slates which overlie the iron formation; neither could it get in through the underlying feldspathic quartz-slates. Therefore, most of the water which at that time was able to reach the present land surface, must have done so by passing down, along and through the layers of the iron formation itself. The dotted broken line represents a perpendicular course which the water would follow were its passage not deflected by the laminated character of the rocks; but there would be a tendency for this water to follow the bedding, so that, entering the iron formation at its uppermost horizon, it would follow an irregular course marked by a broken line and would reach the foot-wall quartzite at the line of the present surface of the country. It is immaterial to the argument whether this line ought to vary farther from the perpendicular than marked or not; for, in any case, nearly the whole of the present surface of the iron formation would escape the percolating waters, or if not this surface, some other yet lower down. It is, however, probable that the lowest horizon would not thus escape until a great depth was reached; for the waters entering the formation, would steadily work their way to a greater and greater depth along the foot-wall, until such depths were reached as to prevent its farther penetration.

Now, suppose erosion to gradually sweep away the rocks which are between the old surface of the country and the present surface. Beginning at the base of the formation the rocks at the present surface would be more and more exposed to the action of percolating waters, which would in turn affect the middle, and finally the higher layers until its whole width was subject to the agencies of alteration There is, then, a gradual increase in the time that percolating waters have acted upon the various layers of the formation in passing from south to north. The difference in time to which the highest and lowest layers have been subjected to such action, is at least the length of time that it has taken erosion to remove the thickness of rock between the old surface of the country and the present surface; therefore the slower the erosion is taken to have been, the greater the difference in time.

Next suppose that erosion had continued until the surface of the land is at some intermediate point. In tracing the percolating waters, it is necessary to take into account the deflection to which they would be subjected by its layers, and the impenetrable character of the underlying slates and intersecting dykes. The relative position of the ore-bodies, quartzites and dykes has already been given. The water which fell upon the layers of the iron formation near its base, would readily pass through the rock, it being here already much altered and broken by the long action of water. Passing through these ferruginous cherts, the water would quickly reach a dyke or the fragmental quartzite, and would follow along this barrier, deflected to the north if upon the quartzite, and to the south if upon a dyke, until it reached a trough made by the dyke and quartzite, along which it would follow, traveling toward the east as it penetrated deeper. Such water would be likely to contain oxygen in solution, and would be capable, if it contained alkalies, which might be readily obtained from the alteration of the basic dykes, of taking up a small amount of silica. Other water falling upon higher layers would make its way slowly and with difficulty through these less altered parts, and would oxidize iron carbonate until all oxygen had been extracted from it. This oxidation of a part of the iron carbonate would liberate carbon dioxide, which would be taken into solution and added to the carbon dioxide which the water already contained.* Such

* In this discussion carbonated water is taken as the agent of solution. It is likely enough that organic acids have helped to take the iron carbonate in solution and bear it to the points of precipitation.

water would take into solution unaltered iron carbonate. It would also in its upper course take up what silica it was able to carry. As it penetrated farther and took more carbon dioxide in solution, and consequently also more iron carbonate, it would be less able to carry silica, and would deposit that material as chert in the lower horizons. The water thus traveling on with an increasing amount of iron carbonate, would finally reach a dyke and be deflected toward the foot-wall quartzite. It would follow this dyke until the apex of the trough was reached; here it would mingle with a larger amount of water more directly from the surface bearing oxygen, and therefore capable of oxidizing the iron carbonate. The iron would then be precipitated in the apex of the trough as more or less hydrated sesquioxide of iron.

Upon the other hand, the silica would here be dissolved; for the carbon dioxide solution containing iron carbonate would be greatly diluted by the large amount of water which bore the precipitating agent for the iron, and the resultant abundant dilute solution of carbon dioxide bearing perhaps alkalies with it, would be capable of taking up silica which was either originally present or had been subsequently deposited in the apex of the trough. Such solutions may have furnished the silica which has enlarged the particles of quartz in the foot-wall and thus indurated it. The result of this leaching would be to steadily add iron oxide to and remove the silica from the apices of the trough formed by the quartzite and dyke, and thus to form ore-bodies. At the same time the other parts of the formation would be steadily impoverished in iron content. Much of that which remained disseminated through the formation would have been changed from carbonate to oxide. In its lower part, the silica which was taken into solution in the upper part of the water's course would be precipitated.*

The processes thus outlined would penetrate to deeper parts of the formation as erosion steadily advanced until the present surface of the country is reached, and the ore-bodies thus formed at depth are now found at surface. It follows that a large amount of iron found in the ore-bodies was originally in rock which has been removed by erosion. So far as the deposits are at the surface, all of the iron oxide, except that

* The chemistry of the processes thus outlined assumes the following: that the oxygen of percolating waters is sufficient to oxidize iron carbonate not in solution and set carbon dioxide free; that the resultant carbonated waters are sufficient to take iron carbonate in solution; that if such waters bearing dissolved carbonates are mingled with other waters bearing oxygen, the iron carbonate or a portion of it will be precipitated; that silica may be carried in percolating waters; that carbon dioxide is sufficient to precipitate silica from such solutions; and that a carbon dioxide solution strong enough to precipitate silica, by dilution, may be made so weak in carbon dioxide that it would be capable of taking silica into solution. All of these facts and principles of chemistry are so well known that no discussion of them or reference to authorities is needed.

which came from the oxidation of carbonate in place, must have come from such a source, while it is probable that a large part of the deposits located at considerable depths have been stored from rock which has been broken down and scattered far and wide. These are not so much concentrations of iron oxide which were originally deposited as a carbonate above them, as from the layers which stretched to the southward, but which were subsequently by upturning placed over the ore-bodies. Also the large proportion of silica now found near the surface, and particularly in the southern half of the belt, is probably much greater than was here originally present. The silica of these highly cherty rocks associated with the ores may represent a concentration from many hundreds, or even thousands of feet of rock which have been swept away, just as the ore-bodies are concentrations from the iron carbonates which these same rocks contained. A portion of the silica may have come from the alteration of the dyke-rocks contained in this removed material, but doubtless most of it came from the original cherty carbonate.

The only exceptions of moment to the facts as assumed in the above discussion, are the occurrence of iron ore at a higher horizon than the foot-wall quartzite, and the ore-bodies east of Sunday Lake, which, so far as present developments go, are not known to be associated with dyke-rocks. It has been said that those ore-bodies in the main part of the range which are north of the fragmental quartzite have a well-defined cherty quartz foot-wall of a regular character. In these cases, this quartz-rock has served as the plane which checked the waters in their downward passage before reaching the fragmental quartzite. Here the relation of the ore to the dykes, and its other characters, are the same as when the ore is found upon the fragmental quartzite. It is of interest to note that in one of the largest mines of the region, the Colby, as shown by Fig. 4, the north and south deposits have as their basement the same great dyke, the two ore-bodies being separated merely by a gigantic horse of rock which served as the impervious layer to form the foot-wall of the north deposit. The explanation given of the origin of the ore found upon the fragmental quartzite, applies perfectly to these north deposits with the modifications above indicated. That there are layers of the iron-bearing formation which are not readily pervious, and therefore become basements along which the down-flowing waters passed, is not at all strange. It would be stranger if, in a thickness of water-deposited sediments of 800 feet, there were no layers which, at least for a short distance, were effectual barriers to the passage of percolating waters. The chemistry of the process of concentration of the ore-deposits east of Sunday Lake, in all probability, is like that of the typical deposits of the range. Their concentration is apparently, however, more nearly analogous to the narrow seams of ore described in the early part of this paper than to the typical deposits. The formation here apparently being cut by no impervious dykes, the waters have not been carried over to the quartzite, thus forming main channels of percolation, but the comparatively small ore-bodies have developed here and there as favorable conditions for concentration occurred.*

The above explanation of the origin of the ore-deposits accords well with the facts of their occurrence, and also with the idea that the iron formation deposits were originally an impure cherty carbonate of iron. It explains perfectly the peculiar position of the ore-bodies with reference to the dykes and the foot-wall quartzite; it explains their presence in a similar position in the few instances in which the deposits are north of the fragmental quartzite; it explains the flat wedge-shaped character of the ore-deposit; it explains the nature of the ore, a soft somewhat hydrated hematite, bearing more or less of manganese; it explains the excess of manganese which the ore carries beyond the amount found in the unaltered carbonates, and its relatively greater abundance in the south deposits; it explains the presence of large quantities of unaltered carbonates in the upper horizons of the iron formation, the gradual lessening of this carbonate in passing to lower horizons, and its absence at the base of the formation; it explains the large percentage of silica contained in the greater part of the lower horizons and the low percentage at the apices of the troughs.

Probable extent in depth of ore-bodies.—This explanation of the origin of the ores may throw some light upon the depth to which the ore-bodies extend. The fact that all of them have been traced to the erosion surface, is favorable, rather than otherwise, to their extending to a considerable depth. The ore-bodies, at the depths now penetrated, must have formed almost wholly before the sweeping away of the rocks of the iron formation above them. They could, then, have received but little of the iron they contain since the end of the Glacial epoch, for erosion was then terminated by the mantle of drift dropped over the region. The deposits, with some degree of probability, may be said to continue to a depth at which the agencies of concentration could effectively work. Whether this distance will be found to be measured in hundreds or thousands of feet, the data at present are too scant to indicate. I am inclined to believe, however, that they may be depended upon to con-

* As bearing upon the truthfulness of the above theory as a whole, it is an interesting fact that the practical miners, in prospecting, eagerly follow underground water channels, hoping that they will lead to ore-deposits.

tinue for a considerable depth. While they may extend in unimpaired richness and magnitude to a depth as great as can be penetrated by workings, it is certain that they do not continue to an indefinite distance. There is also a possibility that the deposits may become poorer than at the surface at comparatively small depths; for it may be that percolating waters, since the termination of the Glacial epoch, have been able to remove from the upper parts of the deposits a small percentage of silica. Such a removal, even to the extent of five per cent, or less, would have an important influence upon the value of the deposits.

Emmons on Ore-deposits.—It is of interest to compare the conclusions reached, to those of Emmons* as to the origin of the silver-lead-deposits of Leadville, Colorado. He finds that the ore did not form in pre-existing cavities, but by a gradual replacement of the rock materials by substances brought in solutions; and also that these solutions did not come up from below, but have reached their "immediate locus" by passing downward through the rocks above. In his discussion upon ore-deposits in general, he maintains that a like origin is much more common than has been believed. It will be seen that my conclusions as to the origin of the iron ore of the Penokee-Gogebic Series, arrived at independently of Mr. Emmons's work, are in exact harmony with his general conclusions.

Iron ores in other parts of the Lake Superior country.—Before closing this paper, some allusions must be made to the nature and origin of the iron ores which are found in other regions in the Lake Superior country. Large deposits of ore are found in rocks remarkably like those of the Penokee-Gogebic series, in the Vermilion Lake, Marquette and Menomonee regions. These ores are associated in almost every mine with a somewhat varying peculiar rock, universally known as soapstone. The connection between the ore and these soapstones is so constant that the appearance of this peculiar greasy altered material is considered as a very favorable indication in prospecting. It is true that the rock which miners denominate soapstone, in different localities has quite different appearances, and frequently schists are called soapstones which have no essential likeness to the material with which the ore is found associated. These so-called soapstones, in the regions referred to, are at times peculiar green banded schists, at other times are compact strongly foliated sericite-schists, and only occasionally do they retain the structure of

* U. S. Geol. Survey; Monograph XII; Geology and Mining Industry of Leadville; Samuel Franklin Emmons, pp. 375–379. Trans. Am. Inst. Min. Eng., vol. XVI, pp. 804–839. Structural Relations of Ore Deposits, S. F. Emmons.

an eruptive rock; but in the few cases of which we have definite knowledge, the manner in which the soapstones cut the adjacent rocks is that of dykes. This is particularly well shown at the large open pits at the Jackson Mine, Negaunee, Michigan, and at the Champion Mine, Champion, Michigan. This same dyke-like character of the peculiar schistose rock at one mine in the Vermilion Lake series is described and figured by Professor Alexander Winchell.* Mr. James R. Thompson, Mining Engineer for the Iron Cliffs' Mining Company, of Negaunee, Michigan, also finds in quite a number of mines in the Marquette region, that the soapstones have a dyke-like character. With most of the soapstones of these regions, the only evidence that they are of eruptive origin is their relations to the rocks which they intersect. They have not been shown in many cases, as in the Penokee-Gogebic region, to have the typical structure of eruptive diabases; but the transition phases between these much altered rocks and the comparatively unaltered massive eruptives have in some instances been found, and it is probable that many of them are altered eruptives. At any rate, the close association between the soapstones and the ores can hardly be accidental, and, taken in connection with what has been given in reference to the Penokee-Gogebic ores, it is very suggestive that they, in some way, and perhaps in a way similar to that in the Penokee-Gogebic region, have influenced the concentration of the iron in the ore-bodies at the places found. To certainly determine the origin of all these "soapstones," and their stratigraphical and other relations to the ore-bodies will require a detailed investigation. It would, however, be an interesting illustration of the uniformity of nature's processes, if such future investigation should show that the iron ores in the other regions of the Lake Superior country have an origin like those of the Penokee-Gogebic series.

Madison, Wisconsin, October, 1888.

DESCRIPTION OF FIGURES. PLATE II.

FIGURE 1.—Cross-section of the Penokee-Gogebic series at Penokee Gap, showing the relations of this series to the underlying Laurentian and the overlying Keweenaw series. The figure also shows the conformable succession of the four members of the series itself. At this particular place, the quartz-slate member, as compared with the iron-bearing member, is thicker than usual. Scale 1″=4000′.

FIGURE 2.—Elevation of First National mine, looking south. The eastern pitch of the dyke is shown, and the resultant greater depth of the ore in passing to the eastward. Scale 1″=130′.

FIGURE 3.—Cross-section of same mine, looking east. Scale 1″=130′.

* Geol. and Nat. Hist. of Minn.; 15th annual report, pp. 24–25.

FIGURE 4.—Cross-section of Colby Mine through both north and south ore-deposits. The perpendicular line running through the figure is drawn because the two parts of the section are not exactly upon the same plane. They differ from this so slightly, however, that the true relations of the ore-bodies to the surrounding rocks are shown by the combined figure. Scale 1″=210′.

FIGURE 5.—Elevation of Pence Mine, looking north. The eastern pitch of the dyke is again observable. The right-angled trough made by the dyke-rock and quartzite is in this case not filled with ore throughout the whole figure. At the eastern end of the figure after passing through a heavy bed of drift, the ore constitutes the rock surface. Scale 1″=210′.

FIGURES 6, 7 and 8.—Cross-sections of same at No. 1, 2 and Father Hennepin shafts respectively. In figure 8, the shaft has not yet passed through the ore. Scale 1″=210′.

FIGURE 9.—Section designed to show the variation from unaltered carbonate to ferruginous chert and ore-bodies in passing from higher to lower horizons, and to illustrate the manner of ore-concentration: S=Upper Slate, Q=Quartzite, FQ = Feldspathic Quartz-slate. Scale 1″=1230′.

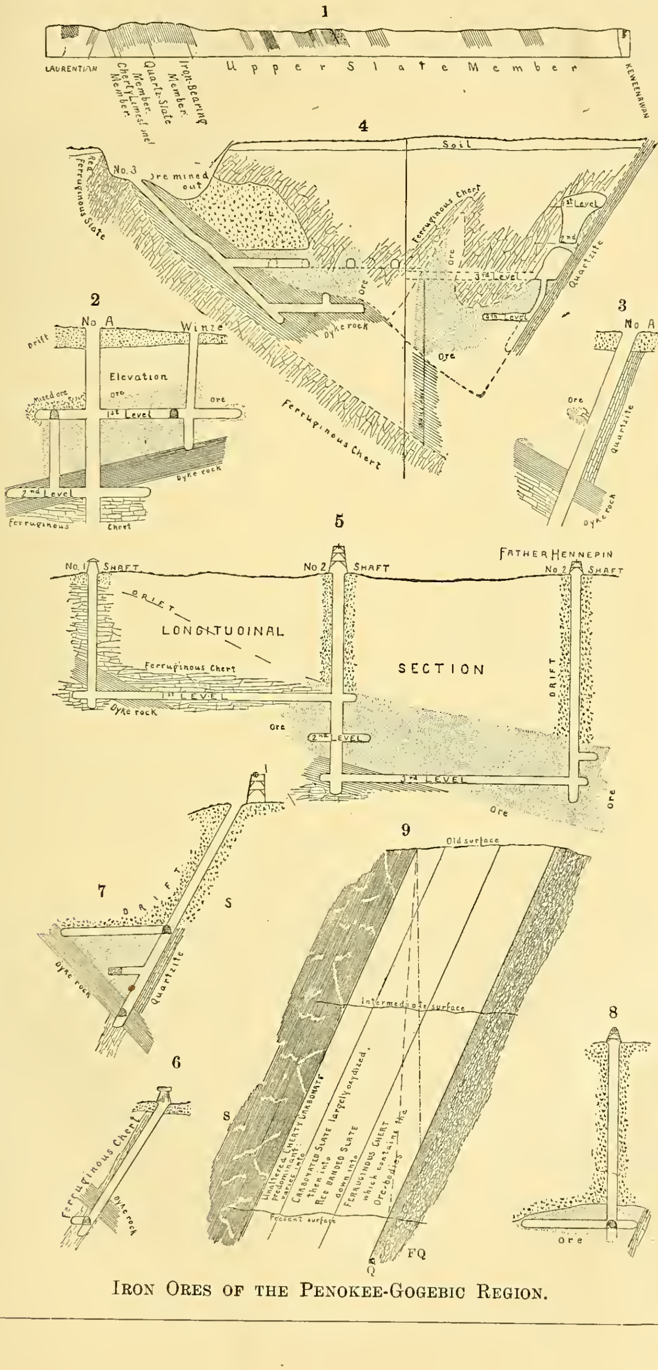
Figures 2 to 8 inclusive are from surveys made and blue-prints furnished by Messrs. J. Parke Channing and C. M. Boss, of Bessemer, Mich.

ART. IV.—*Recent Observations of* MR. FRANK S. DODGE, *of the Hawaiian Government Survey, on Halema'uma'u and its debris-cone;* by JAMES D. DANA.

MR. FRANK S. DODGE has recently made a new survey of Halema'uma'u, the great South Lake basin of Kilauea, which gives definite facts as to the gradual lifting of the debris-cone of the basin, and sustains his conclusions from previous observations that the cone has been floated upward on the column of lavas beneath the floor of the basin.

The accompanying map and the sections 2 to 5, reduced from copy recently received by the writer from him, present the chief results of his survey. In addition I have from him a brief letter of explanations. The scale of the map is 2000 feet to the inch, which makes the distance across the basin from east to west (New Lake not included) a little over 3000 feet. The outline of the debris-cone at base is approximately indicated by the dotted line. The numbers give the level, below the Volcano House datum, of three points at the top of the cone as well as of the floor of the basin and of the crater outside. At *m*, *n*, *o*, *p*, *q*, *r* are small discharging cones, ten to twenty feet high. Two of these small cones, *m* and *n*, were at such a height, owing to the rising of the floor of the basin, that their lava streams overflowed the rim of the basin; and from *o*, the lavas had flowed into New Lake.

Figures 2 to 5 are four profile sections by Mr. Dodge, AB, CD, EF, GH, of the basin and its cone. The height in these sections is exaggerated five times, but in fig. 2, the profile *a b* has the true proportions. In 2 and 3, *p* is the pit within the



IRON ORES OF THE PENOKEE-GOGEBIC REGION.

debris-cone. No attempt to obtain the depth could be made on account of the discharging vapors. The projection above the

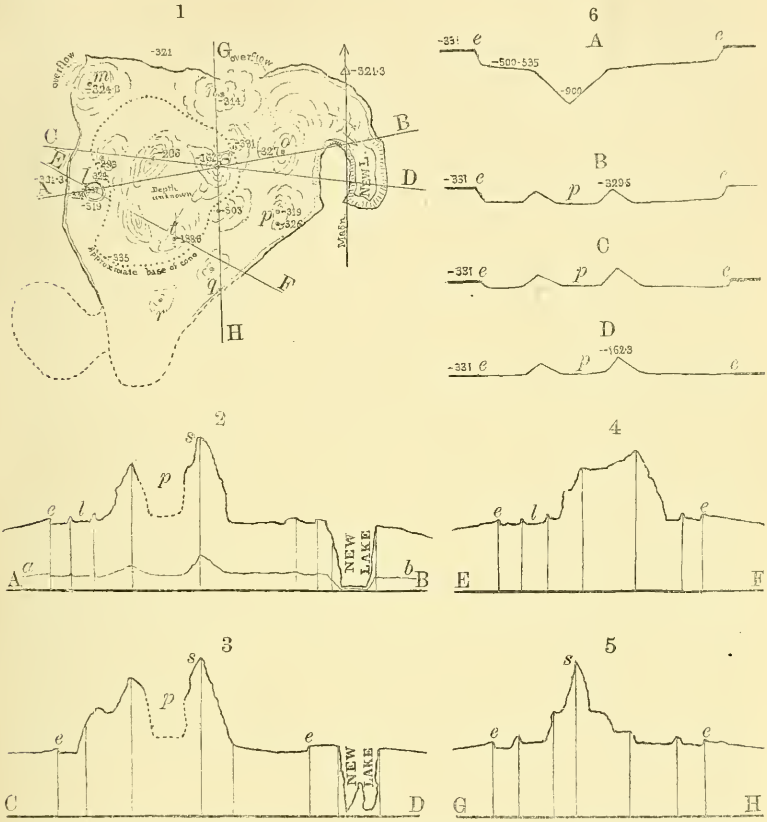


Fig. 1. Map of Halema'uma'a in July, 1888, by Mr. F. S. Dodge, reduced to one-fourth. AB, CD, EF, GH, courses of the sections in Figs. 2 to 5; *m*, *n*, *o*, *p*, *q*, *r*, small cones; *s*, highest summit; *t*, next highest; New L., New Lake.

Figs. 2–5. Sections by Mr. Dodge of Halema'uma'u in July, 1888, along the lines AB, CD, EF, GH, vertical scale 400 feet to the inch, horizontal, 2000 feet; *e*, edge of basin of Halema'uma'u; *l*, active lava lake at west foot of debris-cone; *p*, pit in debris-cone; *s*, highest summit of cone.

Fig. 6. Diagram sections of the Halema'uma'u basin and its debris-cone, prepared from the descriptions and maps; *p*, the pit of the cone; *ee*, edges of the basin; A, condition in May, 1886; B, Oct. 1, 1886; C, Aug., 1887; D, July, 1888.

floor of New Lake in fig. 2 is due to the "stranded floating island."

It will be remembered that in April, 1886, a month after the eruption, Mr. J. S. Emerson found the basin 570 feet in depth at middle and 175 to 200 feet deep over a broad border region. The condition is represented approximately (from Mr. Emerson's measurements) in the profile section, A. Three months later, July 20th, Prof. Van Slyke reported that "a cone of loose blocks" had been formed within the basin "perhaps 150 feet high." This is the first notice of the cone.*

In the first week of the following October (1886), less than six months after Mr. Emerson's survey, Mr. Dodge made his first survey. He found the cone standing at the center of the basin, with the "broad border region" around it little changed from the condition observed by Mr. Emerson; but owing to its depth, the top of the cone at *s* was only 2 to 5 feet above the level of the western rim and at *t*, 28·7 feet below the same level. The width of the cone *at top* on an east-and-west line was found to be 1100 feet. The general profile, deduced from the survey, is shown in section B. Ten months later, in August, 1887, the writer found the position of the cone, judging from his estimates, as represented in fig. C. After another eleven months, in July, 1888, Mr. Dodge made his recent survey. The basin was very nearly obliterated, and some parts, as already mentioned, were higher than the level of the rim; as a consequence the debris-cone stood with its whole height emerged. This is illustrated in the fourth of the above sections, D.

From the levels obtained by Mr. Dodge at his two surveys in October, 1886, and July, 1888, and by Mr. Emerson in April, 1888, we have data for determining the rate of change of level. (1) The change in the western rim of Halema'uma'u was nothing; (2) in the summit *s*, 167·2 feet; in the summit *t*, 171·4 feet. The time during which this rise of approximately 170 feet took place was about 650 days, giving for the mean daily rate of rise 3·15 inches.

The small ejections, going on over the basin outside of the cone during the two years past, raised to some extent the level of the floor. But whatever the amount it does not affect the calculation, this being based on changes in the level of the summit, which received no additions from ejections or any other source.

The conclusion of Mr. Dodge that the cone within Halema'uma'u, and the floor of the basin about it had been "floated upward" on the rising lavas appears, therefore, to be the only satisfactory explanation of the change of level.

* Emerson, this J., III, xxxiii, 87; Van Slyke, ibid., 95, 1886.

ART. V.—*Notes on Mauna Loa in July*, 1888.

I. *On an Ascent of Mount Loa by* W. C. MERRITT, *President of Oahu College.* From a letter to J. D. DANA, dated July 28.

PRESIDENT MERRITT reached the summit of Mt. Loa at noon of the 18th of last July, and encamped near the southeast angle of the crater. The spot was considerably lower than the highest point on the west side of the crater, and probably about 13,400 feet above tide-level. Water boiled at 185° F. between 7^h and 8^h in the morning when the temperature was at 56° F. The thermometer was at 62° F. at noon, 40° F. at 7 P. M., 30° F. at 11 P. M. and 26° F. at daybreak, so that during the night water froze in a large crack, ten feet below the surface. About half a mile south-by-west from the southern end of the crater of Mokuaweoweo (see map, Plate II, vol. xxxvi), there was a small but deep pit-crater. Having descended the east wall of the central pit of Mokuaweoweo to its bottom, a small cinder cone was found not far from the eastern wall; and just southwest, a pumice cone in the midst of an aa flow, the summit of which was very hot and reddish from the action of vapors. In the southwest corner of the pit, there was a cone at F (for all positions see same map), from which vapors were escaping, and south of it, at *m*, a circular pit 300 and 400 feet in diameter by estimate, and 150 to 175 feet deep. The walls of the pit consisted of the edges of layers of basaltic rock one of which was 40 to 50 feet thick, and vertically columnar in structure. The floor of the central pit had, as a whole, a slope from the southwest to the northeast, confirming the view that the southwest part of the pit had been the seat of greatest activity, as it is in Kilauea. Southwest of *m*, the outer wall of the central pit was cut through from top to bottom by two parallel fissures, which had a S.S.W. direction, and thence pointed nearly toward the place of chief eruption of 1887. East of *m* and near the wall in the direction of L, there were great numbers of small fumaroles, from which sulphur vapors were escaping freely, and large deposits of sulphur had been made about them. Near *h* two dikes, 2 to 2½ feet thick, intersected the walls, crossing one another at a small angle, the rock of which had a feldspathic aspect.

From a rough measurement, the depth of the crater on the east side was made not over 350 feet. If this small depth is sustained by careful observations, a great change of level had taken place since the survey of Mr. Alexander in 1885. Such a change might have been among the effects of the eruption of February, 1887.

In Prof. Dana's paper of July last, accounts are cited of a fountain of lavas in the summit crater in 1873—in June, by Mr. W. L. Green and Miss Bird, and in August, by Dr. O. B. Adams. President Merritt obtained from Mr. E. G. Hitchcock the following facts observed by him and Mr. H. R. Hitchcock on a visit to the summit in October, 1873. They spent one night at the summit near the site of Wilkes's camp, on the east side of the central crater or pit. At the time a fountain of lavas was playing in the southwestern end of the crater, to a height of 600 feet. The height was ascertained by lying upon the brink and looking across the pit to the top of the opposite wall; the column of fire ascended at least one-half higher than the distance from the floor to the top of the walls, and taking this distance at 400 feet, the height of the fountain was decided to be approximately 600 feet. Moreover the descending lava of the fountain, falling into the basin, flowed off northward nearly the whole length of the western side of the pit.

President Merritt also visited Kilauea on July the 14th. His letter speaks of the walls of Halema'uma'u as in part wholly obliterated, as represented by Mr. Dodge; it was 15 to 20 feet high in some places. The nearly circular lake (at *l*) on the west side of the cone (which he calls "Dana Lake") was in ebullition, but not more active than in August, 1887. The enclosing walls of this small lake were 10 to 15 feet high above the liquid lava within, and 15 to 20 feet above the floor outside. With regard to the rising of the cone in Halema'uma'u Mr. Merritt expresses full confidence in the view of Mr. Dodge.

II. *Notes on Mount Loa by* Rev. E. P. Baker.

In the month of July, Rev. E. P. Baker of Hilo, made an excursion to the summit of Mt. Loa, and also to the sources of several of its great eruptions, and, in addition, visited the lava stream of Kilauea of 1849 and the Kau "desert." Mr. Merritt's trip to Mokuaweoweo was made with Mr. Baker. The following notes are from a letter on his excursions addressed to the writer. Mr. Baker also made a valuable collection of rock-specimens which will add much of interest to the paper on Hawaiian lavas soon to be published by Prof. E. S. Dana. J. D. D.

To the facts respecting the summit of Mt. Loa, reported by President Merritt, Mr. Baker adds that he observed six parallel fissures ten to twenty rods apart at the south end of Mokuaweoweo which had a course toward the place of eruption of 1887, and which were probably there produced at the first outbreak, before the outflow of the lavas in Kahuku. (See vol. xxxvi, p. 24.) A descent was made into the southern crater of Mokuaweoweo —probably the first ever made—and the depth found to be seventy-five feet greater than that of the central crater. A fresh-looking lava stream descended into it down the northern wall, which may have been made in 1887.

Mr. Baker, speaking of the source of the lava streams of the great eruption of 1880–81, states that the two streams from the source, the Kau or southern and the Hilo or eastern (see map, Plate I, vol. xxxvi) originated together at the extremity of a long fissure. This fissure follows the course of a "divide," so that a small obstacle was sufficient to turn the flow to one side or the other. The outflow took place on this divide; a northern stream flowed first, then the Kau stream, and then the Hilo. The fissure ran by the north side of Red Hill, a cone with a deep crater which is still giving out vapors, and this hill was apparently the occasion of the turn off southward of the Kau stream, it standing at the point of their divergence. Water boiled near this hill at 196° F. This Kau stream is in general aa, but near the source it is pahoehoe. At the upper extremity of the fissure there is a pit crater, Pukauahi, which is described as the source of the lavas and is still smoking. At this place also water boiled at 196° F.

On the route from Ainapo to the source of the outflow of 1852, the lavas of the 1852 stream, where they were first reached, were of the aa kind; but after awhile there was a change to pahoehoe, and soon after this the source was reached —a red cone in the midst of an extensive bed of pumice. Long ditches or trenches occur in the surface of the region which were evidently the beds of lava streams, their sides having been the banks. The flow appears to have had a single outlet. Water boiled at the source at 200° F.

Going from Ainapo to the source of the eruption of 1887, in Kahuku, about 6000 feet above the sea-level, Mr. Baker passed through regions of woods and grass and saw seven running streams and three or four ponds of water. There had been heavy rains. The fissure of 1887, about 400 feet above the place of outflow, was still giving out vapors. No deep crater marked the place of discharge.

Over the wide region beween Mt. Loa and Mt. Hualalai it is hard to tell where the slope of one ends and that of the other begins. The 1859 flow of Mt. Loa as it came down heading northwestward, turned just enough northward to fetch by the northeastern flank of Hualalai.

The *Kau desert*, lying to the south and southwest of Kilauea, has a surface of whitish or light colored sand with areas of pahoehoe lava, which is decomposing at places into a reddish soil. It is about eight miles by six in area. It is destitute of vegetation and owes its dryness to its being under the lee of Kilauea.

ART. VI.—*A Quartz-Keratophyre from Pigeon Point and Irving's Augite-Syenites;* by W. S. BAYLEY.

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(I.) INTRODUCTORY.

ONE of the most striking features in the geology of Pigeon Point,* Minnesota, is the occurrence there of a bright red rock along the borders of the large mass of olivine-gabbro, which forms the main portion of the point. This rock is best seen along the south or Lake Superior side of the point near its eastern extremity, where its brilliant color when moistened by the water, forms a beautiful contrast to the dark gray of the gabbro with which it is in contact.

The first mention of the rock was made by Dr. Norwood,† Assistant U. S. Geologist, in 1851, who described it as a reddish colored syenitic rock, containing but a small amount of quartz. About thirty years later Professor N. H. Winchell, of the Minnesota State Survey, saw a red rock‡ associated with gabbro near the extremity of Pigeon Point, and a rock§ red with orthoclase, from its north shore about a mile from its eastern extremity, which latter he mentions as having probably originated by the fusion and recrystallization of the sedimentary beds through which the gabbro cuts. A microscopical examination of this rock has very recently been made by Dr. M. E. Wadsworth,‖ who regards it as an altered phase of some eruptive, the original nature of which he is unable to decide from the single section at his command. Professor R. D. Irving¶ in 1881, described a red rock from Brick Island, one of the smaller of the Lucille group of islands, about a mile south of Pigeon Point. He says: "Its thin section reveals a rock very close to those red rocks of the Keweenaw Series which I have described under the names of augite-syenite and granitic porphyry." On Pigeon Point also Professor Irving found a red rock which "resembles in every particular the rock from Brick Island."

Similar red rocks have been observed by several geologists at various other places in the Lake Superior region, but no careful study has been made of any one of them.

* For exact location see this Journal. June, 1888, p. 388.

† Report of a Geological Survey of Wisconsin, Iowa and Minnesota. By D. D. Owen, U. S. Geologist, Philad., 1852, p. 399.

‡ Geol. and Nat. Hist. Survey of Minnesota for 1880, p. 70.

§ Ib. for 1881, p. 57.

‖ Geol. and Nat. Hist. Survey of Minnesota, Bulletin 2. Preliminary Description of the Peridotytes, Gabbros, Diabases, etc., of Minnesota, 1887, p. 81.

¶ Copper Bearing Rocks, etc. Monog. V., U. S. G. S., 1883, p. 369.

(II.) Macroscopical and Microscopical.

The red rock of Pigeon Point presents several phases differing in some respects from one another. In its most typical aspect it is a brick-red, fine grained, drusy rock, speckled with little spots of a dark green color. Scattered through the prevailing red feldspar are small grains of white quartz, which sometimes present well-defined crystal outlines. The feldspar itself is occasionally observed with a well marked cleavage and rarely with a crystal outline. Usually it has no distinctive morphological characteristics. In some cases a small quantity of a light colored feldspar can be detected intermingled with the red variety. The green spots consist of little plates of chloritized mica.

Under the microscope the coarser grained of these non-porphyritic varieties are seen to be composed essentially of an hypidiomorphic granular aggregate of at least two feldspars, quartz and chlorite, with a few subordinate constituents—muscovite, rutile, leucoxene, magnetite, hematite and apatite.

The feldspars embrace a striated plagioclase, twinned according to the Carlsbad law, and in one instance according to the Manebach law, and a second, less well individualized feldspar, which is younger than the plagioclase, but slightly older than the accompanying quartz. It surrounds the plagioclase and is intergrown with the quartz in micro-pegmatitic and granophyric forms. Both the plagioclase and the granophyre feldspar are colored by numerous little plates of hematite, the plagioclase, however, containing fewer of these than the granophyre variety. When the latter occurs with its own outlines, as it occasionally does, it appears to be unstriated, though frequently in Carlsbad twins. After hematite, apatite, leucoxene, and little plates of muscovite or kaolin, are the most common inclusions of both varieties of feldspar. In no case could crystals be found fresh enough to yield measurements of sufficient accuracy to determine their true nature.

The quartz is in irregular areas filling in the interstices between the other constituents, and is also intergrown with red feldspar as has already been described. It contains numerous fluid cavities with little dancing bubbles, and also inclusions of a dust-like substance and little areas of red feldspar.

The chlorite owes its origin principally to a formerly existing biotite. It occurs both in little radiating spherulites crowded close together, and in plates enclosing quartz and feldspar. Calcite, rutile and leucoxene are its most common inclusions, while the little pleochroic halos* (Höfe) characteristic of this mineral when derived from biotite, are not rare.

* For the discussion concerning the nature of these halos, see Neues Jahrb. f. Min., etc., 1888, i, p. 165.

Associated with the chlorite is oftentimes a very light green fibrous mineral, which from its bright polarization colors is probably to be referred to sericite. Rutile forms quite a prominent constituent in some specimens. It is found in irregular masses of a dark brown color, and also in long rod-like forms, in both cases intermingled with leucoxene and frequently with chlorite.

A second phase of the red rock resembles quartz-porphyry. Well terminated quartz crystals and occasional brick-red and greenish-white feldspars are scattered through a very fine grained groundmass of a dark red or purplish color. This variety is characterized under the microscope by the beauty of its granophyre structure. All gradations between the granular structure just described, and the typical porphyritic structure have been examined, and in all there is more or less of the true granophyre. In the most typical porphyritic varieties the porphyritic crystals are both quartz and feldspar. In the less perfectly developed phases the quartz occurs in round, elliptical and even crescent-shaped areas, and includes in many places portions of the groundmass. This quartz is perfectly clear and is free from inclusions other than the little fluid cavities with movable bubbles (see fig. 1.)

A very few irregularly outlined feldspar areas represent the porphyritic crystals of this mineral in their earliest stages of development. They are now so altered as to prevent the identification of their species.

Other areas which appear in the hand specimen as crystals are seen under the microscope to be composed of granophyre substance in which the feldspathic portion is very highly colored by little plates of hematite.

The groundmass, in which these crystals are imbedded, consists of quartz and highly altered feldspathic substance in granophyric intergrowths. This is in part sometimes replaced by coarser areas in which the two minerals form a micropegmatite. The fine granophyre is found more particularly around the distorted and corroded porphyritic quartzes, and in the undeveloped feldspars mentioned above. It radiates from all porphyritic quartzes forming a zone, which in ordinary light resembles the "quartz globulaire" of Lévy, but in which the quartz fibers, between crossed nicols, are seen to be optically independent of the orientation of the substance of the crystals.

Chlorite, iron hydroxides, leucoxene, and tiny flakes of a dark brown biotite are the accessory constituents of the groundmass. Calcite is quite abundant as an alteration product of some of the fibres intergrown with the quartz, and also in the little cavities contained in the rock. Green alteration-products are also common. Fig. 1 is an ideal representation of the most characteristic peculiarities of the groundmass and its porphyritic ingredients as exhibited by several thin sections.

The microscopical characteristics of both the porphyritic and the granular varieties of this red rock indicate the probability of the identity of the two. Although the most typical quartz-porphyry is quite different in structure from the typical granular variety, all gradations between the two types can be recognized. Their mineralogical composition is the same, and, as will be shown later, their chemical composition is identical. There can be little doubt that the porphyritic variety is a true eruptive rock. It presents all the features of Rosenbusch's* "Vogesen granophyres." Since the granular varieties are so similar to this, it is also probable that these also are eruptive. No trace of fragmental structure could be detected in any one of them, nor is there any field evidence that they are altered fragmentals. All the field relations seem to point to the *original* character of the rocks. They occur in dykes and veins intersecting other rocks, and the contact between them and the quartzites which they cut, is sometimes clearly seen. It must be confessed, however, that without microscopical and chemical evidence of the identity of these rocks with the quartz-porphyry their true nature would be difficult to discover from the field relations alone. A more careful examination of the structure of the point than has thus far been possible, will probably reveal facts which will place beyond doubt the conclusions reached by the microscopical examination.

1.

The quartz-porphyries are very similar in macroscopic and microscopic appearance to the Keweenawan quartz-porphyries described in Irving,† as flows in the copper-bearing rocks on both sides of Lake Superior. The granular red rock approaches more nearly this author's augite-syenites, though the best developed and most characteristic augite-syenites are more nearly allied to the third phase of the red rock. The rock of Brick Island, which is classed by Irving among the augite-syenites agrees in most of its minute features with the rock described above as the most prevalent type of the red rock on Pigeon Point, as Irving‡ himself states.

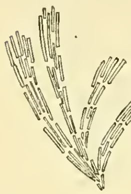
* Die Steiger Schiefer, etc. Strassburg, 1876.

† Copper-Bearing Rocks, p. 95.

‡ L. c., p. 369.

The third variety was noticed more particularly at the contact with an olivine gabbro, which occurs on the point in larger masses. As the red rock approaches the gabbro it is clearly seen to be affected by the latter in such a way as might be expected if both rocks were in a pasty condition at the same time, or if one had been intruded in or next to the other under enormous pressure. The red rock becomes darker as it approaches the gabbro. The green spots, which are scattered over the red groundmass, become more prominent. They are larger in size and more abundant in number than in the two varieties above described, and in some cases are united into red-like bodies and arborescent forms (fig. 2). A light colored feldspar is also much more frequently discernible in this variety.

2.



Still closer to the gabbro a rock is observed which is very dark in color, and can be distinguished from the gabbro only by the possession of a reddish feldspar among its components. The darkest of these rocks resembles very closely the orthoclase gabbros* of Irving, which are supposed by Dr. Wadsworth† to be but altered forms of olivine-gabbro. A discussion of this point can not be entered upon in this place, but it is hoped soon to obtain results from the work now being carried on, which will determine whether or not the orthoclase gabbros may have been derived by the action of an acid magma upon a basic gabbro with which they are always associated.

The lighter colored of these intermediate rocks (as we shall call them for the sake of brevity) when examined under the microscope are found to differ but little from the red rocks described above. They contain a larger amount of plagioclase (oligoclase ?), of chlorite, and of biotite, and much more magnetite and apatite than do the latter, but otherwise resemble them very closely. Micropegmatite is more frequent than is the granophyre intergrowth of quartz and feldspar, and it is especially to be remarked that in almost every case examined the extinctions of the little quartzes are in the direction of their longer axes. The most noticeable fact in relation to them is the freshness of their plagioclase, which is usually in large tabular or lath-shaped crystals.

When examined carefully and compared with sections of Irving's augite-syenites they are seen to bear a strong resemblance to some of these—a resemblance so strong that pictures‡ representing the augite-syenites might as well be used to illustrate the appearance of the Pigeon Point rocks under the microscope.

* Copper-Bearing Rocks, p. 50.
† L. c., p. 54. Cf. also Herrick et al., American Geologist, June, 1888, p. 340.
‡ Copper-Bearing rocks, p. 112, and figs. 1, 2, 3, 4, Pl. XIV.

After a careful microscopic examination of every one of the thin sections of rocks described by Irving as augite-syenites and a comparison of these with the typical red rock of Pigeon Point and its associated intermediate varieties, the conclusion is established beyond doubt that some of the former are in every respect similar to the typical red rock of the point, while the others are as certainly identical in all essential particulars with those varieties which have been called its intermediate varieties.

(III.) Chemical and General.

From a mere microscopical examination of different sections of the various phases of the red rock on Pigeon Point, one would naturally be lead to regard them as portions of the same magma which had crystallized under different conditions, and then had undergone more or less decomposition. They both possess the same mineralogical composition and present gradation in structure from the granular to the porphyritic, with granophyric groundmass.

In order to obtain more positive evidence on this question, analyses of the quartz-porphyry and also of the granular rock were made by Mr. W. F. Hillebrand in the laboratory of the U. S. Geological Survey, with these results:

I. Analysis of the powder of seven of the freshest specimens of the granular rock.

II. Analysis of the powder of three of the quartz-porphyries.

III. Analyses of the granite from Bejby, Sweden; containing red orthoclase, gray and brownish gray quartz, black mica, and a few flakes of a golden yellow mica.*

	I.	II.	III.
SiO_2	72·42	74·00	73·32
TiO_2	·40	·34	----
Al_2O_3	13·04	12·04	14·25
Fe_2O_3	·68	·78	----
FeO	2·49	2·61	2·60
MnO	·09	·05	·09
CaO	·66	·85	·83
BaO	·15	·12	----
MgO	·58	·42	----
K_2O	4·97	4·33	4·96
Na_2O	3·44	3·47	3·21
Li_2O	tr.	tr.	----
H_2O	1·21	·86	1·22
P_2O_5	·20	·06	----
Cl	tr.	tr.	----
	100·37	99·93	100·48
Sp. Gr.	2·620	2·565	

* Gerhard: Neues Jahrb. f. Min., etc., 1887, ii, p. 271.

After an inspection of these figures there can be no reasonable doubt that the two rocks from Pigeon Point are parts of the same mass. The very slight differences in amount noted in the case of the silica, alumina and potash are not greater than are frequently found in different portions of the same hand specimen of most rocks. The slight difference in specific gravity are what might be expected from a study of the structure of the rocks.

Unfortunately no complete analyses of Irving's Keweenawan quartz-porphyries are given by that geologist, but a few silica determinations have been recorded, which are of interest in showing the close agreement, in this respect, between these rocks of undoubted eruptive origin and the Pigeon Point rock. The percentages of silica in three Minnesota quartz-porphyries* are respectively 71·10, 73·87 and 76·83; thus differing but slightly from the 74 per cent. of the Pigeon Point rock.

In consideration of the large amount of sodium indicated in analysis I, it was thought interesting to separate the feldspar from one of the freshest of the red rocks and subject it to a chemical examination. This was done in the usual way, and it was found that the greater portion fell when the specific gravity of the solution used was 2·577. This was analyzed by Mr. Whitfield of the U. S. Geological Survey with the following result:

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Ign
65·00	18·22	2·64	1·06	0·06	4·18	8·40	·46=100·12

When examined under the microscope the powder of this mineral is seen to be free from quartz and quite homogeneous, although slightly altered and filled with little plates of hematite. Its optical constants could not be accurately determined, but from the figures given above there can be but little doubt that the feldspar is an anorthoclase.†

If this be true the rock would fall into the quartz-keratophyre group as defined by Rosenbusch.‡ Its microscopical characteristics correspond to those of the quartz-keratophyres, as described by Gümbel and Lossen, and the composition of its feldspar is that of an anorthoclase.

Many of the quartz-porphyries of the Keweenawan series, as well as some of the augite-syenites will probably be found to belong to this same class of rocks—a class which up to the present time has not been known to have a representative on this side of the Atlantic.

One of the most interesting points in the study of the red rocks of Pigeon Point, has reference to the origin of those

* Copper-Bearing Rocks, pp. 108, 109, 100, 441.

† Anorthoclase separated from a liparite of Pantelleria, has a composition (according to Förstner, Zeitschr. f. Kryst., 1883, p. 125) as follows: SiO_2=66·06, Al_2O_3 19·24, Fe_2O_3 0·54, CaO 1·11, MgO 0·11, K_2O 5·45, Na_2O 7·63.

‡ Rosenbusch: Mikroskopische Physiographie, 1887, ii, pp. 434–442.

phases which are found upon the contact with olivine-gabbro. As has already been stated, the macroscopical and microscopical characteristics of these rocks are such as would lead to the supposition that they were produced by the mutual interfusion of the basic and acid rocks at their points of contact. The field relations of the three rocks leave no doubt as to the fact that the intermediate rock is the result of contact action. That this action took place at some distance below the surface is proved by the perfect crystallization of the constituents of the intermediate rock. That it was not confined to the effect of solutions passing from the gabbro to the keratophyre, or the reverse, is shown by the perfect freshness of the plagioclase, and its well-defined crystal outlines in both rocks.

The best place upon the point at which to study these rocks is on its south side, near its eastern extremity. Here the space between the fresh olivine gabbro and the typical quartz-keratophyre is occupied by a series of rocks which exhibit in the field a gradual transition between the heavy, dark basic rock, and the light red keratophyre.

Analyses and specific gravity determinations of several of these intermediate products substantiate the conclusions arrived at above.

IV. Olivine gabbro, analysed by Mr. Hillebrand.
V. Intermediate rock (No. 11211) near the gabbro.
VI. Intermediate rock (No. 11209) midway between the red rock and the gabbro.
VII. Intermediate rock (No. 11210) near the keratophyre, analyzed by Mr. Hillebrand.
VIII. Quartz-keratophyre, as given on p. 59

	IV.	V.	VI.	VII.	VIII.
SiO_2	49·88	50·69	57·88	57·98	72·42
TiO_2	1·19	----	----	1·75	·40
Al_2O_3	18·55	----	----	13·58	13·04
Fe_2O_3	2·06	----	----	3·11	·68
FeO	8·37	----	----	8·68	2·49
MnO	·09	----	----	·13	·09
CaO	9·72	7·94	4·68	2·01	·66
SrO	*tr.*	----	----	*tr.*	----
BaO	·02	----	----	·04	·15
MgO	5·77	----	----	2·87	·58
K_2O	·68	----	----	3·44	4·97
Na_2O	2·59	----	----	3·56	3·44
Li_2O	----	----	----	*tr.*	*tr.*
H_2O	1·04	----	----	2·47	1·21
P_2O_5	·16	----	----	·29	·20
Cl	*tr.*	----	----	----	----
	100·12			99·91	100·33
Sp. Gr.	2·923		2·741		2·620

In these results can be traced the gradual transition from the basic gabbro, rich in calcium and magnesium, and poor in potassium, to the acid keratophyre, which is poor in calcium and magnesium and rich in potassium. We can hardly imagine the conditions under which a rock of the composition of the gabbro (IV) could be changed into a rock of the composition of the intermediate rock (VII), by means of solutions* emanating from the keratophyre, unless these solutions contained in them the materials of the keratophyre in about the proportions in which they are present in that rock, a supposition which is not at all probable.

It would seem, then, that we are justified in regarding the intermediate rock as due to the fusion and recrystallization of the materials of both the keratophyre and the gabbro, in consequence of the irruption of one of these rocks into the other at some considerable depth below the surface of the earth, where the conditions were such as to produce a rock with the characteristics of a plutonic rock. In other words the intermediate rock is the result of deep seated contact action.

Analyses of Irving's augite-syenites are not given, so that a comparison of their composition with that of the intermediate rock (No. 11,209) cannot be made. Their thin sections, however, as has already been stated, exhibit a very close similarity to many of those of the contact rocks. Further, those with these characteristics are always, so far as could be determined, in close association with gabbro, and in many cases are also very near a more acid red rock resembling the quartz-keratophyre in one of its phases.

The augite-syenites of Irving, then, may be divided into two classes, those which are like the quartz-keratophyre, described above, and those which are similar to the contact rock. In neither case are they altered eruptives, in the sense that they owe their present characteristics to the alteration of a more basic eruptive. They have both resulted from the solidification of a molten magma.

Of course it is not affirmed that no alteration has taken place in any of the augite syenites, for such is not the case. Some of them have suffered the kaolinization of their feldspar, and the chloritization of their augite and mica, with the production of secondary silica. Their most characteristic properties, however, are not due to this alteration, but are due to the chemical composition of the magma by whose cooling they were formed.

* Cf. American Geologist, June, 1888, p. 343. Messrs. Herrick, Clarke and Deming: Some American Norites and Gabbros.

(IV.) Conclusions.

The red rock on Pigeon Point is not an altered gabbro nor an altered sedimentary rock, but is the result of the solidification of a magma, which under certain conditions gave rise to a rock with the characteristics of a granophyre. These two rocks contain a sodium-potassium feldspar, and thus should be classed among the quartz-keratophyres.

Upon the contact of the quartz-keratophyre with an olivine-gabbro is a series of rocks, which possess a composition intermediate between those of the keratophyre and the gabbro. They may be regarded as the result of contact action at great depths

Irving's augite-syenites are similar to the Pigeon Point quartz-keratophyre, in some instances, and in others are like the intermediate rocks. They are neither altered gabbros nor altered forms of a previously existing augite-syenite.

Geological Laboratory of Colby University, June 25, 1888.

Art. VII.—*On the occurrence of Hanksite in California;* by Henry G. Hanks.

The best known locality of hanksite in California is Borax Lake, owned by the San Bernardino Borax Company. This lake lies in township twenty-five South, range forty three East, Mount Diablo base and meridian, and in the northwest corner of San Bernardino county, the largest in the state, very near the Inyo county line. This vast deposit of soluble salts was discovered and located February 14, 1873, by Dennis Searles and E. M. Skillings. Up to the present time it has produced 10,500 tons of borax, and is still far from being exhausted. When the state becomes more populous, and facilities for cheaper transportation multiply, other minerals will also be extracted, to the benefit of those interested, as well as to the State.

The so-called "Dry Lake," "Alkali Flat" or "Salt Marsh," is a pan-like depression in the desert, ten miles long and five wide more or less. It is the sink of a wide spread water-shed and a small stream which heads some fifty miles south. It is the opinion of those who have long resided at or near the locality, that it is a secondary sink of Owens Valley and is partly fed by seepage from Owens and Little Lakes. The climate is generally very dry, but during some seasons, considerable water finds its way to this depression. Having no outlet, the water spreads out and forms a shallow lake or marsh. In the dry season the surface is covered with an alkaline incrustation, which is principally common salt. On the western margin of the large depression lies a small basin known as "Borax lake proper," which has approximate dimensions of one mile and a half in length by half a mile in width. From this secondary lake, and the dividing ridge referred to below, most of the borax produced has been taken.

Between Borax Lake, which is a few feet higher than the general level, and the wide alkali flat, there is a slight ridge, which acts as a natural dam and prevents the water from flowing away. It is covered with crude borax which is believed to be of semi-volcanic or solfataric origin. This barrier prevents the water of the borax lake from flowing to still lower depressions on the great alkali flat beyond. The water of Borax Lake is a dark brown highly concentrated alkaline liquor, having a density of 28 degrees Beaumé. The salts obtained from it by crystallization contain carbonate, chloride and bi-borate of sodium, with much organic matter. There has never been an exhaustive analysis made, which would, no doubt, be very interesting.

For a number of years it was planned to explore or prospect the underlying formations both as a matter of general interest, and in the hope of finding the source of the borax and other salts. After much delay, work was finally commenced in 1887, and carried on under many difficulties, owing to the nature of the ground. The bottom of the lake was found to be of a remarkably sticky, tenacious, plastic clay, described as being "tough as wax." To avoid the difficulty of keeping back the alkaline water by coffer dams or other similar contrivances, the first experimental well was commenced on the ridge before mentioned. It was sunk by spring-pole drills to a depth of three hundred feet. The following is a section carefully kept by Mr. Searles:

1. Two feet salt and thenardite.
2. Four feet clay and volcanic sand containing a few crystals and bunches of hanksite.
3. Eight feet volcanic sand and black tenacious clay with bunches of trona of black shining lustre from inclosed mud.
4. Eight-foot stratum, consisting of volcanic sand in which is found glauberite, thenardite and a few flat hexagonal crystals of hanksite.
5. Twenty-eight feet of solid trona of uniform thickness. Other borings show that this valuable mineral extends over a large area.
6. Twenty-feet stratum of black, slushy, soft, mud, smelling strongly of hydrosulphuric acid, in which there are layers of glauberite, soda and hanksite. The water has a density of 30° Beaumé.
7. Two hundred and thirty feet (as far as explored), of brown clay, mixed with volcanic sand, and permeated with hydrosulphuric acid.

Overlying No. 5, is a thin seam or stratum difficult to penetrate, to which the name "hard stuff" has been given, the exact nature of which is unknown.

Borax is produced at these works by three different methods. By evaporating natural solution of borax; by lixiviation of crude material; and by solution and re-crystallization of tincal. What is known as "crude material" is a somewhat pulverulent, slightly yellowish, amorphous incrustation which yields about eight per cent. of borax when worked on a large scale.

Borax is obtained from this crude material by solution and evaporation The plant, which is very extensive, and owing to the distance and isolated position of the deposits, costly, consists of a large steam flue boiler, and a multitude of boiling and crystallizing tanks, of wood and boiler iron. Steam is conveyed in pipes to the various tanks, instead of utilizing the heat of the sun, which would be more economical and the yield and quality quite as good. The peculiar dryness of the climate is specially favorable for solar evaporation and graduation. Fifty men and thirty-five animals are employed in these works. The product is hauled in wagons to Mohave station, a distance, of about seventy miles, over a sandy desert, so dry and sterile that a supply of water must be hauled in other wagons for the use of men and animals. The fuel used has been generally the sage-brush which is gathered at heavy cost, and thrown under the boilers with pitchforks, like hay into a barn: but recently, California crude petroleum has been substituted.

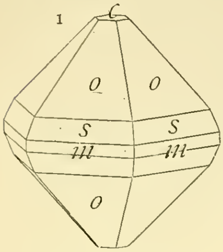
Hanksite first came to San Francisco in the massive form and was called by the borax miners "Ice," which it certainly resembled. It was examined in the usual manner and found to be an anhydrous sulphate of soda, and was labelled thenardite. No analysis was made and the small proportion of carbonic acid was overlooked in the blowpipe examination. The next specimens received were small hexagonal plates, found in the highly concentrated waters of the lower lake. These went to New Orleans with the California exhibit, and were shown at the exposition of 1884–5, where they attracted the attention of Mr. William Earl Hidden, who was the first to suspect a new species. The results of his study of the crystals led to a paper by him, which he read before the New York Academy of Sciences, May 25, 1885.*

The magnificent crystals recently discovered were taken from the sandy clay No. 2 of the section, and No. 7, seventy feet or more below the surface. There were not more than

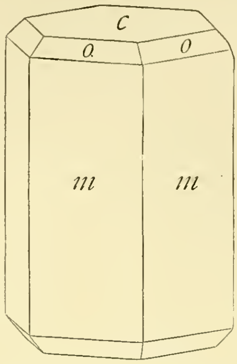
* This Journal, xxx, 133, 1885.

thirty in all. About the time of their discovery, work was suspended. It will not be resumed for several months, when it is to be hoped that enough will be obtained to supply the scientific world with specimens. The form of these crystals is shown in figure 1,* the planes present are: *c* (0001, *O*), *m* (10$\bar{1}$0, *I*), *o* (10$\bar{1}$1, 1), *s* (20$\bar{2}$1, 2).

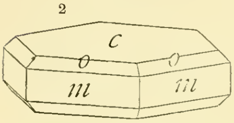
1



3



2



What Mr. Searles calls "bunches of hanksite" are aggregations of flat hexagonal plates joined together in a confused irregular manner. They vary in size from an inch or less in diameter to eight inches or more. One of these crystals is shown in figure 2. The crystals also vary in size, the largest being three inches, and the smallest half an inch or less in diameter. Some of the bunches have been accidentally subjected to the action of comparatively pure water, by which partial solution has taken place, not only marring the beauty of the individual crystals, but leaving the clusters in a dilapidated, cavernous condition. In the dark, concentrated, amber-colored water of the borax lake, they remain unchanged. A rare prismatic form is shown in figure 3.

Hanksite is known to occur also in the borax fields of Death Valley, Inyo County, and there are several known localities in the state of Nevada.

The following minerals have been found associated with borax in San Bernardino County:

Anhydrite, calcite, celestite, cerargyrite, colemanite, dolomite, embolite, gay-lussite, glauberite, gold, gypsum, halite, hanksite, hydrosulphuric acid, natron, soda niter, sulphur, thenardite, tincal, trona.

It is the opinion of the writer that instead of being a rare mineral, hanksite will be found in great abundance, and it will be proved that it plays an important and active part in the metamorphoses that produce gay-lussite, thinolite and perhaps borax.

San Francisco, October 20, 1888.

* These figures have been drawn by Mr. E. F. Ayres of Yale University.

ART. VIII.—*Sperrylite, a new Mineral;* by HORACE L. WELLS.

A SMALL quantity of the remarkable mineral which is the subject of this article was sent to the writer in October of the present year by Mr. Francis L. Sperry of Sudbury, Ontario, Canada, chemist to the Canadian Copper Co. of that place. A few tests sufficed to show that it was essentially an arsenide of platinum and consequently of great interest, since platinum has not been found before, at least as an important constituent, in any minerals except the alloys with the other metals of the platinum group.

Since the time mentioned Mr. Sperry has furnished, with great liberality, an abundance of the material for investigation and has given the following account of its occurrence:

"The mineral was found at the Vermillion Mine in the District of Algoma, Province of Ontario, Canada, a place 22 miles west of Sudbury and 24 miles north of Georgian Bay, on the line of the Algoma Branch of the Canadian Pacific Railway. The mine was discovered in October, 1887, and a 3 stamp mill was put up for the purpose of stamping gold quartz. Associated with this gold ore are considerable quantities of pyrite, chalcopyrite and pyrrhotite, and, at the contact of ore and rock and occupying small pockets in decomposed masses of the ore, there is a quantity of loose material composed of gravel containing particles of copper and iron pyrites. It was in milling this loose material that several ounces of the arsenide of platinum were gathered on the carpet connected with the stamp-mill. Through the kindness of Mr. Charlton, the genial President of the Vermillion Mining Co., all of the mineral that was available was generously placed at my disposal."

It may be mentioned here that Mr. Sperry sent me, a few weeks before sending the arsenide, a minute bead which he had obtained in making a fire-assay for gold on an ore, consisting chiefly of chalcopyrite and pyrrhotite, which came from the same mine where the arsenide was found but which was not the material in which it actually occurred. This bead on examination proved to be composed largely of metals of the platinum group, and, from the color of the precipitate produced by ammonium chloride, it was thought that it contained a large proportion of iridium, but its small size prevented a satisfactory examination. With this bead in mind, I expected that the new mineral would contain a considerable amount at least of iridium, but, strangely enough, none of this metal was found in it. The material as received consisted of a heavy, brilliant sand composed largely of the arsenide; but intermixed with this a considerable amount of fragments of chalcopyrite, pyrrhotite and some silicates could be seen. In order to purify the substance it was treated for a short time with warm aqua regia to remove sulphides, etc.; then it was treated for a long time with hot hydrofluoric acid to remove the silicates. After these treatments the sand possessed great brilliancy, but it was found by microscopic examination to contain some transparent grains which on chemical examination proved to be stannic oxide. Prof. S. L. Penfield kindly examined these grains and found that they corresponded perfectly in their optical properties with cassiterite.

Nearly all the grains of the new mineral showed extremely brilliant crystal-faces, though most of the crystals were fragmentary; in size they were mostly between ·05 and ·5^{mm} ($\frac{1}{500}$ and $\frac{1}{50}$ inch) in diameter.

The color of the mineral is nearly tin white or about the same as that of metallic platinum; the fine powder is black.

The specific gravity taken twice on the same 8 grams of material, was 10·420 and 10·424 at 20°; this material was the same that was used for analysis, and, correcting the average of these results for 4·62 per cent of cassiterite, the true specific gravity becomes 10·602.

The sand is not easily wet by water and shows a marked tendency to float when brought to its surface. By placing a shallow layer of water upon the mineral in a vessel it is easy to nearly cover the surface of the water with a continuous layer of the crystals by inclining the vessel repeatedly so that they are brought to the surface. This phenomenon is not due to any oily substance upon the particles, for they float with equal readiness after being boiled with a strong solution of potash and washed with alcohol and ether. When they are floating upon water it is quite difficult to cause them to sink, and when carried to the bottom by a stream of water they frequently carry down small bubbles of air which they completely surround and hold down by their weight. If ether is poured upon water on which they are floating, they remain suspended between the two liquids, and, by agitation, can frequently be made to sink to the bottom in spherical clusters surrounding globules of ether.

The mineral is only slightly attacked by aqua regia; even when it is very finely pulverized and the strongest aqua regia is repeatedly applied with the aid of heat for several days, the solution is only partial.

Pyrognostics.—The mineral decrepitates slightly when heated. In the closed tube it remains unchanged at the fusing-point of glass. In the open tube it gives very readily a sublimate of arsenic trioxide and does not fuse if slowly roasted, but if rapidly heated it melts very easily after losing a part of the arsenic. Perhaps its most characteristic reaction is the following: when dropped on a red hot platinum foil it instantly melts, gives off white fumes of arsenic trioxide having little or no odor, and porous excrescences are formed on the platinum which do not differ in color from the untouched foil.

Chemical analysis.—The following analyses of the mineral were made after a considerable amount of preliminary work had been done on it, the results of which confirm these figures.

	I.	II.	Mean.	Ratio.
As	40·91	41·05	40·98÷ 75=·546	·550=2
Sb	0·42	0·59	0·50÷122=·004	
Pt	52·53	52·60	52·57÷197=·267	·274=1
Rh	0·75	0·68	0·72÷104=·007	
Pd	trace	trace	trace	
Fe	0·08	0·07	0·07	
SnO_2	4.69	4·54	4·62	
	99·38	99·53	99·46	

The composition is consequently represented by the formula $PtAs_2$, a small portion of the platinum and arsenic being replaced respectively by rhodium and antimony. In composition this mineral appears to be nearer Wöhler's laurite* than any other mineral now known. The form of both is isometric,† but their composition is apparently not quite analogous since the formula of laurite is given as $RuS_2+\frac{1}{20}Ru_4Os$. It is possible that the latter formula is slightly incorrect since Wöhler used an extremely small quantity (·3145 gram) for his analysis and acknowledged the uncertainty of his results. It is also to be noticed that the composition of the mineral corresponds to that of the artificial platinum arsenide made by Murray.‡ The writer has confirmed the composition of this artificial arsenide by heating a known weight of platinum to redness and passing over it vapor of arsenic in a current of hydrogen. The following are the results of the experiments:

	Pt taken.	As absorbed.	Ratio. Pt : As
I	·3806	·2922	1 : 2·02
II	·5725	·4354	1 : 2·00
III	1·0657	·8112	1 : 2·00

It was noticed in these experiments that the arsenic combines with the platinum with incandescence and the alloy melts even below a red heat after a part of the arsenic has been taken up. At the end of the operation, however, the fused globule solidifies, throws out peculiar, arborescent forms and the $PtAs_2$ remains as a porous and very brittle mass which is neither fused nor changed in composition when heated to bright red-

* Ann. Ch. Pharm., cxxxix, 116.

† See next article for crystalline form of Sperrylite. ‡ Watt's Dictionary.

ness in hydrogen. In its behavior with solvents and its pyrognostic properties the artificial compound agrees exactly with the natural mineral.

Method of analysis.—The amount of substance taken for each analysis was about 1·5 g. The pulverized substance was gradually heated in a current of chlorine gas and the volatile chlorides were absorbed by water in a receiver.* This liquid was made ammoniacal after adding a very small quantity of tartaric acid to keep the small amount of antimony in solution and the arsenic was determined as magnesium pyroarseniate. From the filtrate from the ammonium magnesium arseniate, antimony and a trace of platinum were precipitated as sulphides, the sulphide of antimony was dissolved in strong hydrochloric acid, the sulphide was reprecipitated, filtered on asbestus and weighed after proper heating in a current of carbon dioxide, while the trace of platinum sulphide was ignited and the residue was added to the main part of the platinum left by treatment with chlorine. This part was treated with dilute aqua regia; this left an insoluble residue consisting of cassiterite and a finely divided black substance which had been found by previous qualitative tests to be rhodium. This residue was fused with sodium carbonate and sulphur, the insoluble rhodium sulphide formed was ignited in air, then in hydrogen and weighed, while the tin was determined as stannic oxide in the usual way. The purity of the rhodium was shown by its complete solubility in fused potassium disulphate, also by finding that it gave no sodium double chloride soluble in alcohol after ignition with sodium chloride at a faint red heat in a current of chlorine. About $\frac{2}{3}$ of the total rhodium was found here. The purity of the stannic oxide was shown by reducing it in hydrogen and dissolving the metal in hydrochloric acid.

The solution in aqua regia containing platinum with a little rhodium and iron and a trace of palladium was treated for the platinum metals essentially by the method of Claus;† the main variations being a repeated separation of platinum from rhodium and the weighing of platinum as metal. A distinct but extremely small precipitate of palladium cyanide was obtained, but the amount of palladium was too small to sensibly affect the balance when an attempt was made to weigh it.

The name.—The writer takes great pleasure in naming this interesting mineral after Mr. F. L. Sperry, to whose efforts this investigation is due.

Sheffield Laboratory, Dec. 12, 1888.

* Preliminary experiments with the artificial compound, $PtAs_2$, had shown that all the arsenic passes off in this operation if the heat is applied slowly enough so that the substance does not melt after losing a part of its arsenic

† Rose und Finkener, analytische Chemie, 6[te] Aufl., vol. ii, p. 2 ;6.

ART. IX.—*On the Crystalline form of Sperrylite*; by S. L. PENFIELD.

THE crystalline form of sperrylite is isometric; pyritohedral. Simple cubes are common, octahedrons are exceptional, while the majority of the crystals, which are usually fragmentary, show combinations of cube and octahedron. The first crystal which was selected for measurement was a fragment showing the above mentioned combination; one of its central octahedral faces being imperfect, the best measurements were obtained from a cubic to an adjoining octahedral face. The results, which are given below, are very satisfactory considering the small size of the crystals, and prove that the mineral is isometric; it may also be said that where the reflections were sharpest and best the values came nearest to the theoretical.

			Calculated.
$a \wedge o$	$001 \wedge \bar{1}11$	54° 34′	54° 44′
"	$001 \wedge 1\bar{1}1$	54 46	"
"	$100 \wedge 1\bar{1}1$	54 35	"
"	$100 \wedge 11\bar{1}$	54 45	"
$a \wedge a$	$100 \wedge 001$	90 2	90°

At first only the above mentioned forms were detected, but on sifting off the smallest crystals and carefully looking over the largest ones some were detected which suggested pyrite forms. The chemical relation of the mineral $PtAs_2$ to the minerals of the pyrite group caused me to make a very careful search for pyritohedral forms, which was fortunately successful. Cubes with replacement of the edges are very exceptional; a number of them were found, however, and in all cases the replacements, which were necessarily small and frequently failed on some of the edges, had the arrangement required by the combination of cube and pyritohedron. The best crystal selected for measurement was the top of a cube measuring 0·35 × 0·45^{mm} in combination with octahedron and two small but well developed pyritohedral faces; the latter gave very good reflections. The measured angles are

			Calculated.
$i\text{-}i \wedge i\text{-}2$	$001 \wedge 102$	26° 28′	26° 34′
"	$001 \wedge \bar{1}02$	26 31	"

Another crystal which was carefully measured was an irregular one measuring 0·35 and 0·55^{mm} in two diameters; this was developed in all directions; in one zone the four cubic and four pyritohedral faces were all present in their proper order and gave satisfactory measurements, in a second zone four cubic and two pyritohedral faces were found and in the third zone four cubic and one truncating rhombic dodecahedral face were detected; this is the only case in which a dodecahedral (110) face was found. In a few cases the characteristic combination of octahedron and pyritohedron was detected, but the latter faces were always very small. These results are most satisfactory and from the number of crystals which have been examined and measured, in all of which the pyritohedral faces occur with their proper order and arrangement, the hemihedral nature of the mineral can not be doubted. Some of the crystals are somewhat rounded and probably other isometric forms are present but none of them were determined. The faces on the crystals are usually very flat and must be very highly polished to give such satisfactory measurements. It may also be noted that the cubic faces are not usually striated parallel to their intersection with the pyritohedron as is common in pyrite, although it was a slightly striated cube which first called my attention to the pyritohedral nature of the crystals.

The first attempts to determine the pyritohedral faces of the mineral yielded results which were very perplexing but which are not without interest. Cubes with pyritohedral faces were found and measured giving repeatedly the angle of cube on pyritohedron between $29\frac{1}{2}°$ and $30\frac{1}{2}°$, the pyritohedral faces always giving poor reflections. The calculated value of *i-i* on $i\text{-}\frac{7}{4}$, $001 \wedge 407$ being 29° 45′. The pyritohedral arrangement of the faces was perfect but I always failed to find the common pyrite form $\frac{1}{2}(i\text{-}2)$ $\pi(210)$. On talking this over with Professor Wells he stated that all of the material which he had given to me had been cleaned, as for analysis, with aqua-regia and that perhaps the acid had had some action on the faces, as the mineral was not wholly insoluble. He therefore gave me some material which had not been cleaned with acid and the results which were given earlier in this article were obtained from it. The aqua-regia seems to have no effect on the cubic and octahedral faces, at least not enough to diminish their power of reflecting light, for the first measurements given in the article of cube on the octahedron were obtained from a crystal which had been cleaned with acids; the acids have, however, a very decided action on the pyritohedral faces, nearly destroying their power of reflecting light and perceptibly changing their angle.

To sum up the crystallographic observations, the crystals usually show the combination of cube 100, *i-i*; octahedron 111, 1; pyritohedron $\pi(210)$, $\frac{1}{2}(i\text{-}2)$ and very rarely dodecahedron 110, *i*. Taken in connection with the chemical results the mineral takes a place in our classification in the pyrite group where an atom of a metal, usually Fe, Co or Ni is united with two atoms of either S, As or rarely Sb, or an isomorphous mixture of them. As this is the first time that platinum has been found in combination as a mineral it may be noted that

Fe, Co, and Ni and the metals of the platinum group fall in the same series in Mendelejeff's periodic system of the elements, which gives additional grounds for putting this mineral in the pyrite group.

The hardness of the mineral is between 6 and 7, which was determined by placing selected crystals on a bright feldspar surface, pressing down on them with a soft pine stick and rubbing back and forth; the sperrylite repeatedly cut into the feldspar but could not be made to scratch quartz. The crystals have no distinct cleavage but are very brittle and break with an irregular, probably conchoidal fracture.

Mineralogical Laboratory, Sheffield Scientific School, Dec. 12th, 1888.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Vapor-density of the Chlorides of Indium, Gallium, Iron and Chromium; and on two new Chlorides of Indium.*—Nilson and Pettersson have determined the vapor density of the chlorides of indium, gallium, iron and chromium by V. Meyer's method, employing for the purpose vessels made either of hard Thuringen glass or of porcelain. In the course of their researches upon the indium chlorides they discovered two new ones; the mono-chloride, having a vapor density of 5·402 at 1300°–1400° and the formula $InCl$; and the dichloride $InCl_2$ whose vapor density was found to be 6·885 at 1100°. The third chloride carefully purified gave a vapor density of 8·156 at 606°; of 7·391 at 850°; of 6·716 at 1048; and of 6·234 at 1100°–1200°. The formula $InCl_3$ gives 7·548; and hence the authors consider this formula correct. The higher chloride of gallium gave the vapor density 8·846 at 350°; 6·118 at 440°; 6·144 at 606°, and 5·185 at 1000°–1100°; corresponding to the formula $GaCl_3$ which requires 6·081. The lower chloride gave a density of 4·823 at 1000°–1100° and 3·568 at 1300°–1400°; the formula $GaCl_2$ requiring 4·859. Ferrous chloride at 1300°–1400° gave a vapor density of 4·340; and at 1400°–1500°, one of 4·292; the formula $FeCl_2$ requiring 4·375. The higher chloride of chromium gave values varying from 6·135 at 1065° to 4·580 at 1350°–1400°, the formula $CrCl_3$ requiring 5·478. The lower chloride gave a vapor density of 7·800 at 1300°–1400°; 7·278 at 1400°–1500°, and 6·224 at 1500°–1600°. At a higher temperature the authors believe it would reach 4·256 the value required by the formula $CrCl_2$.—*J. Chem. Soc.*, liii, 814, October, 1888. G. F. B.

2. *On the Vapor-density of Ferric chloride.*—Friedel and Crafts have determined the vapor density of ferric chloride by the method of Dumas taking the same precautions as with alumi-

num chloride.* In a nitrogen atmosphere in which the partial pressure of the vapor was 0·75, they obtained at 433° the value 10·86 as a mean of two experiments, the formula Fe_2Cl_6 requiring 11·25. The vessel used could be examined readily during the operation; and it was found that even at 440°, the ferric chloride was decomposed into ferrous chloride and chlorine; the former not being volatile at this temperature was deposited in crystals on the walls of the vessel, and combined again with the chlorine on cooling. The authors thus explain the results obtained by V. Meyer and Grünewald.† To avoid this dissociation, further experiments were made in an atmosphere of chlorine, in which the chloride has only a slight pressure. At temperatures between 321° and 442° the density remained nearly constant at about the value required by theory. The chloride boiled at 280°–285.—*C. R.*, cvii, 301; *Ber. Berl. Chem. Ges.*, xx, (Ref.) 579, October, 1888. G. F. B.

3. *On the Vapor Density of Gallium chloride.*—Friedel and Crafts have also determined by the same method the vapor density of the higher chloride of gallium. This density decreases as the temperature rises, falling from 10·6 at 307° to 7·8 at 440°. At 237° –273° approximately constant values are obtained agreeing closely with the theoretical value 12·2 calculated from the formula Ga_2Cl_6. Constant values corresponding to the formula $GaCl_3$ were not observed.—*C. R.*, cvii, 306; *Ber. Berl. Chem. Ges.*, xxi, (Ref.) 580, October, 1888. G. F. B.

4. *On the Molecular Mass of Sulphur, Phosphorus, Bromine and Iodine in Solution.*—Paterno and Nasini have made use of Raoult's method for the purpose of determining the molecular mass of sulphur, phosphorus, bromine and iodine in solution, the researches of van't Hoff upon the osmotic pressure of liquids leading directly to the assumption that the law of Avogadro holds good in dilute solutions as in gases, the osmotic being substituted for the atmospheric pressure. In the case of sulphur, the solvent used was benzene, the experiments being made with solutions of different strengths. The depression-coefficient obtained was constant and led to the molecular formula S_6, corresponding to that obtained by means of the vapor-density at 500°. For bromine, solutions in water and in glacial acetic acid were used; and numbers were obtained leading to the formula Br_2. For iodine, the solvents employed were benzene and glacial acetic acid. For very dilute solutions in the former, the results corresponded to the formula I_2. But for solutions in the latter, values were obtained leading to a formula between I and I_2, although the molecular depression was constant. The phosphorus employed was not quite pure. But its solution in benzene gave a value intermediate between the formulas P_2 and P_4.—*Ber. Berl. Chem. Ges.*, xxi, 2153, July, 1888. G. F. B.

5. *On the Atomic Mass of Osmium.*—The atomic mass of osmium has been determined by Seubert, by reducing ammonium

* This Journal, III, xxxvi, 465, Dec., 1888.

† See this Journal, III, xxxv, 494, June, 1888.

or potassium osmiochloride in a current of hydrogen, the chlorine being also determined. The ammonium osmiochloride was prepared by adding ammonium chloride to an alcoholic solution of osmium chloride. The potassium salt was obtained by heating the metal mixed with potassium chloride in a current of chlorine. A second portion of the ammonium salt was prepared by precipitating sodium osmiochloride with ammonium chloride. The results of analysis gave 191·12 as the mean of several experiments. The author thinks this too high and gives 190·8 as the more probable atomic mass.—*Ber. Berl. Chem. Ges.*, xxi, 1839, June, 1888. G. F. B.

6. *A Class Book of Elementary Chemistry;* by W. W. FISHER, M.A., F.C.S., Aldrichian Demonstrator of Chemistry. 12mo, pp. xvi, 272. Oxford, 1888. (Clarendon Press).—In his preface the author states that, in the main he has followed in his selection of subjects the syllabus of the Oxford Local Examinations for Senior Candidates and the Examination of Women. After a few pages upon the laws of chemical combination, atomic weights and formulas, he takes up hydrogen, oxygen, water, nitrogen, air, carbon, sulphur, etc. In chapter xv, he considers quantivalence and the periodic law, and then discusses the metals, closing with chapters on specific, atomic and molecular heats, and the physical properties of gases. It is one of the best books of its grade that we have seen recently. The cuts are clear and well selected and the mechanical execution of the book is good. G. F. B.

7. *Examples in Physics;* by D. E. JONES, B.Sc., Lecturer on Physics at the University College of Wales, Aberystwyth. 16mo, pp. viii, 261. London and New York, 1888. (Macmillan & Co.).—This little book contains a carefully prepared series of physical problems, over one thousand in number, intended to test both the student's knowledge and his facility of applying it practically. The value of such tests is beyond dispute. The introductory chapter is a concise exposition of units and dimensions, and the subsequent chapters are devoted to Dynamics, Hydrostatics, Expansion, Specific and Latent Heat, Conductivity and Thermodynamics, Light, Sound, Magnetism, Electrostatics, and Current Electricity. We have failed to find at the end of the book, however, the four-place logarithm tables mentioned on pages 19 and 21. The problems themselves are most excellent, many of them being selected from examination papers of repute. The book will be found a valuable adjunct in the physical class room. G. F. B.

8. *Oxygen lines in the Solar Spectrum.*—M. JANSSEN ascended Mt. Blanc on October 13th, and succeeded on October 15th and 16th in making some observations under the most favorable conditions. The results show that both the band and lines of oxygen, identified previously by him in the solar spectrum, are due entirely to the earth's atmosphere. The systems of bands, those in the red, in the yellow, and the blue, the intensity of which varied with the square of the density of the absorbing oxygen,

were altogether wanting, and the groups of dark lines A, B and α which M. Janssen had previously found to vary as the simple density, were so much enfeebled as to leave little doubt that they too would disappear, could we entirely eliminate the effects of the earth's atmosphere.—*Nature*, Nov. 8, 1888, p. 40. J. T.

9. *Effect of staining upon dry plates.*—" At the meeting of the Physical Society of Berlin, Nov. 2, Professor Kundt exhibited a number of photographs of spectra photographed upon dry plates which had been stained with various substances. The plates stained with chlorophyl gave especially interesting results. The spectra obtained upon them consisted of a bright strip ending near F followed by a dark portion intercepted by an extremely bright line at the spot where the absorption band of chlorophyl is present in the red. Plates stained with eosin similarly showed a bright strip corresponding to the absorption band of this substance in the yellow, whose brightness was much greater than that of the rest of the spectrum. These experiments showed that the rays of light which are absorbed by the above coloring matter exert an extremely active chemical action on the plate. Experiments made with a view to determining whether absorption of light has a similar effect on fluorescence yielded negative results. It still remains to investigate whether the maximum brightness of the spectrum photographed on a plate stained with chlorophyl corresponds exactly with the absorption found of this substance, taking into account the influence of the solvent used for the solution of the chlorophyl on the position of its absorption band."—*Nature*, Nov. 29, 1888, p. 120. J. T.

10. *Electrical currents produced by light.*—Stoletow employed the following apparatus in his investigation upon this subject. A glass cylinder is closed at one end by a quartz plate which is silvered in net form, though the other end of the cylinder passes a micrometer screw terminating in a silvered iron plate. This iron plate and the silver net work on the quartz plate served as electrodes. The cylinder was filled with various gases which were submitted to the rays from an electric light. No difference could be perceived in the behavior of moist and dry air and hydrogen at ordinary pressures. Carbonic acid, however, gave double the effect of the above mentioned gases. With diminishing pressures the effect increases until the pressure of 3–4 mm. is reached and then diminishes.—*Comptes Rendus*, 107, 1888, pp. 91–92. J. T.

II. Geology and Natural History.

1. *Cambrian of Bristol County, in Eastern Massachusetts.*—Professor N. S. Shaler has reported, in the Bulletin of the Museum of Comparative Geology of October, 1888 (vol. xvi, No. 2), the discovery of Cambrian fossils near Attleborough, a few miles from the northeast angle of Rhode Island. The region lies on the west of the main belt of the Carboniferous of the Narragansett basin. East of it is an area of gneiss, which is probably

pre-Cambrian. On the colored geological map accompanying the paper, the Cambrian is made to pass south and southwest over Falls Village into Rhode Island. The rocks of the Cambrian are shales and conglomerates. The Cambrian area of Braintree, where the *Paradoxides Harlani* occurs, is twenty-five miles to the north; but it was not possible to make out the stratigraphic relations between the two. The fossils discovered are: *Obolella crassa* Hall, *Fordilla Troyensis?*, *Scenella reticulata* Billings, *Stenotheca rugosa*, *Stenotheca curvirostra*, sp. n., *Platyceras primævum* Billings, *Pleurotomaria* (*Raphistoma*) *Attleborensis*, sp. n., *Hyolithes quadricostatus*, sp. n., *H. communis* var. *Emmonsi* Ford, *H. Americanus* Billings, *H. princeps* Billings, *H. Billingsi* Walcott?, *Hyalithellus micans* Billings, *Salterella curvatus*, sp. n., *Aristozoë?*, *Microdiscus bellimarginatus*, sp. n., *M. lobatus* H., *Paradoxides Walcotti*, sp. n., *Ptychoparia mucronata*, sp. n., *P. Attleborensis*, sp. n. The fossils are figured on two plates. In the study of the fossils, Professor Shaler was aided by Mr. A. F. Foerste. The authors remark that while the fossils are those of the "Olenellus group," the beds contain no species of Olenellus, and that the presence of a Paradoxides "diminishes the importance of the Paradoxides division of the Cambrian." The species of Paradoxides is very small, or the specimen is young.

2. *Silicified wood of Arizona;* by F. H. Knowlton.—A large trunk of silicified wood from the vicinity of Fort Wingate, Arizona, which has been on exhibition for several years at the U. S. National Museum, Washington, has been studied by Mr. Knowlton, and named (Proc. U. S. Nat. Mus., 1888, p. 1) *Araucarioxylon Arizonicum.* A plate (Plate I) accompanies the paper. Mr. Knowlton also describes two new species of fossil coniferous wood from Iowa and Montana, which he refers to the genus *Cressinoxylon* (Plates II, III).

3. *Dahllite, a new mineral.*—Brögger and Bäckström have described a new mineral from the apatite region in the parish of Bamle, Norway. It occurs as a rather thin crust, which has a rounded lustrous surface and a fibrous structure, the fibers being perpendicular to the base of massive reddish apatite. The color is pale yellowish white or reddish yellow, but appears colorless in a thin section; it is translucent and somewhat resembles chalcedony. It is optically negative. The hardness is about 5 and the specific gravity 3·053. An analysis gave the following results:

P_2O_5	CO_2	CaO	FeO	Na_2O	K_2O	H_2O
38·44	6·29	53·00	0·79	0·89	0·11	1·37 = 100·89.

This corresponds essentially to the formula $4Ca_3P_2O_8 + 2CaCO_3 + H_2O$. The microscopic and chemical examination convinced the authors that the mineral was homogeneous, notwithstanding its remarkable composition.—*Œfv. Vet-Akad. Förhandl.*, p. 493, 1888.

4. *Das Protoplasma als Fermentorganismus;* von Professor Dr. Albert Wigand. Marburg, 1888, pp. 294.—Few scientific

men, upon the summons of failing health, relinquish their work with feelings of greater disappointment than the late Professor Wigand of Marburg. Attached to the manuscripts left by him was this touching inscription, "Folgende von mir festgestellte Thatsachen und Beobachtungen wurden ignoriert oder todtgeschwiegen." Some of these manuscripts edited by an assistant, Dr. Dennert, form the present work. A few of the facts have been given before, and many of the speculations thereon have already been published in other forms. Having these papers before us, it is fair to ask the reason of the neglect of which Wigand complained. The style is not obscure, but the course of the argument is very tedious and one feels compelled to inquire once in a while whether the task of reading it will pay. This defect has diminished the value of about all the scientific work done by Wigand, but this will not alone explain the utter neglect. If one remembers that almost, if not quite, alone among teachers of science in Germany, Wigand was up to the last an opponent of Darwinism, giving much of his time to controversial writings, the neglect is measurably accounted for. The extent to which his antagonism to Darwinism influenced all his thought is shown by an expression which he once used in a conversation with Dr. Dennert, "my whole life has revolved around Tannin, Darwinism and Bacteria."

We may smile at this odd collocation, but it expresses a truth. His researches in regard to Tannin possesses much merit, and were justly viewed by the author as entitling him to higher recognition than he received. His writings on Darwinism are speculative and unconvincing but they demanded a large share of his energy. The results of his studies regarding the last subject, Bacteria, we have now in part before us. Although the treatise is divided into three distinct portions, they may be considered for practical purposes as one, and embodying a single hypothesis. Without doing any injustice to the author, this hypothesis may be given in a few words, namely, that organized matter (protoplasm and its active living derivatives), possess the power under certain circumstances of being broken up and converted into minute organisms (bacteria in the widest signification). This hypothesis of transformation or "anamorphosis" is, in one sense, the logical outcome of ideas which the author expressed in a now forgotten work of a partly popular character, Der Baum.

The experimental part of the author's work can be fairly illustrated by a single case (No. XI), in which, having taken every precaution for securing perfect freedom of all his apparatus and appliances from germs (and, as he says, being assisted by Dr. Mueller who was familiar with Koch's methods), he introduced a fragment of carefully-washed muscle into a sterilised receptacle, where, after being kept a fortnight, at a temperature of 35° C., the organized matter was found to be filled with bacterial forms. These forms he concludes must have come from the anamorphosis of the protoplasmic matter. The experiment recalls those reported by Béchamp and is open to the same criticism.

Wigand's experiments cover many kinds of organized matter, and all of them are interpreted by him in the same manner, namely as proving that these organisms which cause and accompany putrefaction, etc., may or *must* arise from the transformation of protoplasm. According to him we need not postulate in any case the pre-existence of germs as necessary to putrefaction. The author touches with his hypothesis many points in physiology and pathology. G. L. G.

5. "*Ringed*" *Trees.*—W. L. Goodwin, Queen's University, Kingston, gives in the Canadian Record of Science, for October, 1888, the following details regarding a remarkable case of survival of a pine tree after girdling. The case came under his observation in the summer of 1883. The tree is "a common pine tree which had been ringed several years before I saw it,—just how many I cannot say. The tree stands at the edge of the pine woods of Studley, Halifax, Nova Scotia, and is one of two rising from a common trunk which bifurcates immediately above the surface of the soil. The trees are about 22 feet high, and begin to branch freely at about six feet from the ground. The ring is about four feet from the fork and is eight inches broad. The exposed wood is dead and no signs of life appear within half an inch of the surface. That the tree has grown considerably since it was ringed is shown by the following measurements made this summer:

Circumference below ring,	19½ inches.
Circumference above ring,	26½ inches.

The diameter of the tree has thus become two inches greater above than it is below the ring. The condition of the bark and cambium layer below the wound shows that the surface of the tree has died for a considerable distance (over six inches). Above the wound the bark and cambium are living and seem to have pushed down over the scar about half an inch. The same process had been evidently begun below the ring before the death of the cambium layer. From measurements made five years ago, I should judge that the tree must have been ringed at least ten years before that date, so that the tree has survived its injury probably fifteen years. Unfortunately the notes of the first measurements are not at hand for comparison. At that date the ringed tree seemed almost as thrifty as its companion, but the foliage showed some signs of imperfect nutrition. At present the tree is in much poorer condition; many of its branches being dead and the foliage scanty on those that are living."

Cases of survival after the injury by girdling or "ringing," have been noticed by many observers, but this is, on the whole, the most striking that has yet come to our notice in this climate. On the Pacific coast cases of survival of orange and olive trees are not rare, but they are not so difficult to explain as this of a pine. G. L. G.

6. *A Provisional Host—Index of the Fungi of the United States;* by W. G. Farlow and A. B. Seymour. Cambridge,

1888, pp. 51.—This, the first part of a most important work, comprises the polypetalæ. Under each species are enumerated the species of fungi reported as living thereon. When the number is small, the names are given in alphabetical order, but, where the number is large, the species are placed under their proper orders, and there alphabetically arranged. A list prepared with the care which has been given to every page of this work, is not only a convenience to some mycologists and a necessity to others, but it exerts a useful influence from its conservative tendency. It will possibly check the multiplication of specific names in this too inviting field for the making of new species; in fact the hope that this might be the case, was one of the inducements which has led to its publication. The great amount of time and labor given to the preparation of a critical index like this can be appreciated only by those who have seen its slow growth under the untiring hands of its authors. G. L. G.

7. *Bibliotheca Zoologica II, bearbeitet von* Dr. O. TASCHENBERG, 6te Lieferung, sig. 201–240, pp. 1651–1970. Leipzig, 1888 (Wm. Engelmann).—The sixth part of this important work, devoted to the bibliography of Insects, including the Hemiptera, Aphaniptera, Diptera and Lepidoptera, has recently been issued.

Bulletin of the N. H. Society of New Brunswick. No. VII, (Saint John, 1888), contains a paper by W. F. Ganong, on the Echinodermata of New Brunswick; on the Mollusca of the Oyster beds of New Brunswick, by W. H. Winkley; and on the question, Does our Indigenous Flora show a recent change of climate, by J. Vroom

The Geological Record for 1880–1884, inclusive; a list of publications on Geology, Mineralogy and Paleontology published during these years, etc. Edited by William Topley and Charles Davies Sherbon, Vol. I, Stratigraphical and Descriptive Geology. 544 pp. 8vo. London, 1888 (Taylor and Francis).

A short account of the History of Mathematics by Walter W. Rouse Ball. 464 pp. 12mo. London and New York, 1888 (Macmillan and Co.).

Bulletin No. 47, of the U. S. Geol. Survey, contains analyses of waters of the Yellowstone National Park by F. A. Gooch and J. E. Whitfield.

Thirty thousand years of the Earth's Past History, read by aid of the discovery of the Second Rotation of the Earth, by Maj. Gen. A. W. Drayson, F.R.A.S. London, 1888 (Chapman & Hall).

Missouri Rainfall, by Prof. F. E Nipher. 6 pp. 8vo, with maps of the rainfall for the year and each month of the year. St. Louis, 1888.

Darwinism, a brief history of the Darwinian theory of the origin of species, by Dr. D. S. Jordan. 64 pp, 12mo. Chicago, 1888 (A. B. Gehman & Co.).

Soaps and Candles. Edited by James Cameron, F. I. C. 306 pp. 12mo. Philadelphia, 1888 (P. Blakiston, Son & Co.).

A Text Book of Euclid's Elements, for the use of schools. Parts I and II, containing Books I–VI, by H. S. Hall and F. H. Stevens. 382 pp., 12mo. London and New York (Macmillan & Co.).

Elemente der Palæontologie bearbeitet von Dr. G. Steinmann, unter Mitwirkung von Dr. Ludwig Döderlein. 1te Hälfte (Bogen 1–21). Evertebrata (Protozoa-Gastropoda). 336 pp. 8vo. Leipzig, 1888 (Wm. Engelmann).

Œuvres complètes de Chr. Huygens, publ. par la Soc. Hollandaise des Sciences. The first volume, in 4to, has been recently issued.

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VOL. XXXVII. FEBRUARY, 1889.

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THIRD SERIES.

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THE

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[THIRD SERIES.]

Art. X.—*Points in the Geological History of the islands* Maui *and* Oahu; by James D. Dana. With Plates III and IV.

The subjects prominently illustrated by the islands Maui and Oahu are: the conditions of extinct volcanoes in different stages of degradation; the origin of long lines of precipice cutting deeply through the mountains; the extent and condition of one of the largest of craters at the period of extinction; and the relation of cinder and tufa cones to the parent volcano. The other islands of the group present facts bearing on these subjects, but the writer's knowledge of them is too imperfect for review in this place.

I. Island of Maui.

The accompanying map, Plate 3, reduced from the recent large government map,* shows the general features of the island of Maui:

(1) The volcanic mountain of East Maui, Haleakala, 10,032 feet in height, having at summit, a crater 2500 feet in greatest depth and twenty-three miles in circuit.

* On this Plate, as on that of Hawaii in the last volume of this Journal, most of the lettering of the original map is omitted, with necessarily also minor details as to erosion and topography.

(2) The abrupt depression of Kipahulu, to the southeast of the summit, surveyed but not geologically studied, which looks as if it were the site of another great crater.

(3) The slopes of eastern Maui, little gullied by erosion, but most so on the side facing northeast—the windward side; and here the longest valleys scarcely reaching to the summit.

(4) The mountain of west Maui, a volcano in ruins, being profoundly cut up by valleys, and the original height reduced to 5788 feet as the maximum.

(5) The low intermont area of Maui, made of the united bases of the two volcanoes, but covered for the most part by the lava-flows of Haleakala, whose fires continued in action long after the western volcano was turned over, dead, to the dissecting elements; the width from north to south at the narrowest part, near the line reached by the lavas of Haleakala, about six miles, and the height at the survey station near its middle, 156 feet.

From my use of the maps of the Hawaiian government survey through the preceding memoir, and my frequent reference to them for facts about the volcanoes, craters and lava-flows, as well as the topography of the island, it has been apparent that they have been a very prominent basis for the conclusions presented. The government map of Maui has still greater geological importance; for Prof. Alexander, the surveyor-general, has made it, by his accurate work and his appreciation of the importance of details, a contribution to science of the highest value and interest. What I have to say of the extent, depth, form and discharge-ways of the great crater, of the heights and positions of cinder cones, and of the erosion of the mountains, should be put mainly to the credit of the map, which was Prof. Alexander's work not only in superintendence and geodetic measurement, but largely also in the details of the survey. The survey of the island, which is still in progress, reflects great credit on the Hawaiian people, and we trust it may be continued until in all parts complete. Every cone, or precipice, or fissure, terrace-level, or lava-stream located is a contribution to the history of the island and to physical and geological science.*

* I am, moreover, personally indebted to Prof. Alexander's kind providings, guidance and instructions for the success of my trip in 1887 (August 4 to 6) up Haleakala and into the crater, where a night was spent—an exceptionally brilliant night after a day of clear views from the slopes and the summit; and also for my excursion up Wailuku valley on western Maui.

I owed much also, while on the island, to the hospitality of Mr. Henry Baldwin of Haiku, Mr. Edward M. Walsh and Rev. Thomas Gulick of Paia, and Mr. Bailey and Rev. Mr. Bissell of Wailuku.

An excellent model of the island of Maui has been made by Prof. C. H. Hitchcock, who devoted much time to it during his recent visit to the Hawaiian Islands. The government map was the chief source of data for the details. The verti-

1. *East Maui.*

I. *The Mountain.*—The crater of Haleakala has been many times described, but first with a detailed map in illustration by Captain Wilkes. Captain Wilkes states that he is indebted for the map to his artist, Mr. Joseph Drayton;* and considering that it was from an artist's survey, not that of a surveying party with instruments, it is a remarkable piece of work. The expedition owes much to Mr. Drayton, not only for his excellent labors as draftsman in all departments at sea, but also, after his return, for his management of engravers, printers, etc., during the publication of the various Reports.

The mountain is usually ascended from Paia, a village on the north coast. The path (see map) passes Olinda and reaches the edge of the crater where the nearly vertical western wall bounding it is not less than 2500 feet in height. Thence it follows the summit southwestward to the southwest angle passing Pendulum Peak† on the borders of the crater just before reaching it. Here are three cinder cones, and the top of one is the culminating point of the mountain, 10,032 feet above tide. They stand at the head of a long line of cinder cones extending southwestward down the mountain to the sea; and near the sea at the foot of this line are three or four comparatively recent lava-streams, enough to illustrate the process of seashore extension by such sea-border outflows. From the southwest angle of the crater and the base of one of the three cinder cones, a cinder-made slope of rather easy grade descends into the crater, making a convenient place of descent; and thence the path continues eastward to the usual place of encampment, 4½ miles from the top.

2. *The two great discharge-ways of the crater.*—Besides its lofty walls and great area, the most remarkable features of the crater are the two openings, a northern and a southern, a mile to a mile and a half wide between precipitous walls of rock—the walls of the northern 2,000 feet and over, of the southern, 1,000 to 2,000 feet—through which poured the lava of probably the last of the great eruptions. The Kaupo lava-stream, the southern, has much the smoother surface, as if more recent; but the broader Koolau stream descended the *wind-*

cal height is increased four times, and the craters and valleys are thus strongly brought out. All such exaggerated relief maps, whether of a mountain or sea-basin, need a note of warning attached to prevent wrong conclusions as to slopes and heights; for the ratio of 4 to 1 instead of 1 to 1 changes a slope of 14° to one of 45°, a low to an acute cone. The light shading used on the map of Hawaii in the last volume of this Journal and here on that of Maui, is intended to bring out the idea as nearly as may be of a mean slope of 7 to 10 degrees.

* Wilkes's Narrative, vol. iv, p. 255. In the Exploring Expedition I had no chance to visit Maui, and saw it only from ship-board when passing it.

† The Pendulum station of Mr. E. D. Preston, of the Coast Survey, in 1887 This Journal, last volume, page 305.

ward slope, and the consequent erosion may have made all the difference.

3. *The Cinder-cones and Lavas at the bottom of the crater.* —Another striking feature of the crater is the group of red and gray cinder-cones which stand over the bottom, sixteen in number; the highest 900 feet above its base and all over 400, and yet looking small in the view from the summit of the great area. The sight to the northward, when half way to the bottom, comprising the northern discharge-way in the distance, the highest of the cinder-cones in the foreground, and beyond these and two other cones the broad stream of lava of the crater-floor as level apparently as a river, stretching away between precipices of more than 2,000 feet and then terminating in an even line at the limit of vision as if there began the plunge to the sea, is wonderfully like the real river of lava on its downward way.

The cinder-cones of the bottom were evidently the last work of the fires. The ashy surface of the cones is without a trace of erosion and thus bears no distinct marks of age. The slopes are mostly 25° to 30° and less, and hence they may have had the pitch diminished somewhat by the winds and rains and earth-shocks, but there are no channelings by descending waters. The material is scoria in coarse fragments and sands, and though in part originally reddish and purplish, the red color has generally been deepened by oxidation from exposure.

Besides the scoria, there are on some of the cones, especially those toward the borders of the pit, numerous large blocks of gray, compact, scarcely vesiculated rock. Some of the masses about a cone near the place of descent measured over a hundred cubic feet. The masses must have been torn off from the throat of the volcano's conduit, this being the only conceivable source. They indicate therefore the action of vast projectile force at these isolated centers when the cones were in progress, and its continuation even to the close of the ejections; and they also are probable evidence of very rapid work in the cone-making. A few of the other cones were grayish in color as if from the abundance over their slopes of these projected grayish stones; but I was unable from want of time, to verify this supposition.

The cones stand, or appear to stand, on the rough, fresh-looking, scoriaceous lavas of the bottom, these lavas spreading away from beneath them. It was evident that the opened fissures or vents which gave exit to the cinders, first poured out the lavas; and then followed the cinder ejections as the fires declined and the liquid lavas of the vent became somewhat stiffened. The cinder material is proof of powerful projectile work; for the fragments of the exploding bubbles were thrown upward, as the heights of the cones prove, many hundreds of feet—more than nine hundred to make the highest cone.

The fresh-looking lavas, occurring about the base of the more western of these cones, were found to continue eastward throughout the crater, with little change of features and with the same relation to the bases of the several cones, as if all were of one epoch of eruption—the epoch of the last outbreak of Haleakala; the lavas seemed to have come from the latest outflows of several subordinate vents, after the crater had made its great discharge through the two gateways down the mountains.

This scoriaceous lava of the crater contained in many places much augite and chrysolite in largish grains or crystals, being both augitophyric and chrysophyric.

4. *Lavas of the walls and summit.*—The lava of the walls was in part scoriaceous; but, where examined on the south and southwest sides, it was commonly a very compact, rather light gray variety of basalt, like that of the projected blocks about some of the cones. The layers of compact basalt had often one or more parallel planes of fine or coarse vesiculation, sometimes at intervals of one to three or four feet.

At one locality on the ascent of the mountain the solid gray rock had been found to be a convenient stone for stone implements of various kinds, and a large manufacture had apparently been carried on there; and yet near by, the lavas that were so solid had occasional planes of coarse vesiculation, each one to three or more inches thick. Pendulum Peak, near the summit, just north of the southwest corner of the crater (the place of descent) consists largely of this compact light-gray basalt, with rarely any vesiculation visible without the aid of a pocket lens.

This compact basalt or doleryte is a common rock also over the lower slopes toward Paia. It appears thus to be to a large extent the material of the older lavas; yet not only of the older. But at the summit on the west side, along the two miles passed over before reaching the place of descent, the compact variety of the basalt was rather the exception. There were large areas of the same scoriaceous lava that covers the bottom of the crater, and in some places it was equally augitophyric and chrysophyric, the augite in well-defined crystals. One of these areas was just north of Pendulum Peak; and a large region on the west border of the crater, looked as if successive streams of lava had recently flowed one over another, piling up layer on layer, so that by this means the surface for a breadth of a mile or more westward from the summit line had derived its unusual steepness of 15° to 16°. The lava-streams of the surface had the appearance of being overflows from the crater; as if the great pit had been full to the brim before the outbreak and had poured out from time to time small streams like those of a full lava-lake in Kilauea. But they more probably came from fissures cut through to the summit at the time of the last or some one of the later eruptions.

The fact that lavas of the summit are so very chrysolitic, even at a height of nearly 10,000 feet, has an important bearing on the question as to the effect of high specific gravity in determining the distribution of materials in liquid lavas.

Crystals of augite and large grains of chrysolite are common in the loose material at the base of the cinder cones at the summit, near the place of descent, and colored glassy crystals of labradorite occur with them—facts first learned from Rev. T. L. Gulick after our return. These summit cones have the recent appearance and other features of those over the crater's bottom, and appear to be of the same series and time of origin; and the cinder-slope of that side of the crater was probably made in part from the ejections of these summit cones.

5. *The probable nature of the last eruption.*—The great discharge-ways of Haleakala, one to one and a half miles wide, with the walled valleys confining them, look as if the results of enormous rents of the mountain, made when the mountain emptied itself by the wide channels. But they may have been in existence before, and have been simply used for the last of the outflows. They are, nevertheless, evidence of rents at some time, and of a vast amount of removal of material some way—by subsidence, or otherwise. The height of the walls at the gaps, 2000 feet and over at the Koolau gap, and 1000 and over at the Kaupo, are a minimum measure of the amount of material removed. In my Exploring Expedition report I suggest that the mountain was fissured across along the lines of the two discharge-ways, and the eastern block shoved off a mile or two. But a subsidence of the masses that occupied them into caverns below, leaving the walls as fault planes, may be more probable. The abyss which received them in this case had been prepared during a long period of undermining through ejections. Still there is some reason to believe in the grander view of a subsidence of the whole eastern block, after the cross-fracturing. The island, as is seen on the map, is abruptly narrowed (instead of widened) at the spots where the Koolau and Kaupo streams reach the sea; and the part to the eastward is small, as if narrowed by such a subsidence. Moreover, the mean height of the eastern crater-wall is lower than that of the opposite or western by 500 to 1000 feet. A subsidence of 1000 feet increasing in amount to the eastward would account for the narrowing and for the very short eastern radius of the eccentric volcano. The question merits consideration.

The evidence that the lavas were discharged in both directions at once at the last eruption consists in the nearly uniform appearance of the fresh lavas over the bottom of the crater from one end to the other, and their continuing into and apparently being the streams that descend the Kaupo and Koolau discharge-ways. Mr. J. M. Alexander has remarked that the crater is probably a double one, a combination of two great craters, as Mokuaweoweo at the summit of Mt. Loa is compound in structure. This is no doubt historically true; but at the latest of the eruptions there was probably one action over the whole; the distinction for the time obliterated.

The period of the last summit eruption is unknown. I learn from Mr. Bailey of Wailuku, Maui, that, according to an island tradition, a *lateral* eruption of the mountain occurred about 150 years since in the district of Honuaaula of the southern part of East Maui, at an elevation above the sea probably of about 400 feet.

6. *Activity of the Crater ending in Cinder-ejections.*—The origin of the *crater* of Haleakala needs, I believe, no explanation beyond that given in the remarks on the origin of craters generally: that a volcanic crater and the mountain containing it commence to form together about an opened vent which discharges both vapors and lavas; that the crater is a result of the projectile action and the discharge of material from below, and generally also of subsidence into the cavity which is made by the discharge; and that it does not become closed before the central vent ceases to discharge, and commonly is not then closed.*

Haleakala is an example of a basaltic volcano which reached its end, through declining fires, in cinder ejections; but it left its great crater open, and 2000 to 2500 feet deep, with the greater part of the bottom free from the cinders notwithstanding the amount discharged. The latest down-plunge or subsidence by which the vast pit and perhaps also its discharge-ways were made, may therefore have filled full the empty subterranean chambers which former outflows had produced, and left the mountain solid instead of hollow. Mt. Kea on Hawaii, 13,805 feet in height, also ended its work with cinder eruptions; but the ejected material of lavas and cinders obliterated so far the old crater that no visitor of the region has yet found traces of its former limits. Whether Mt. Kea is a hollow mountain or not remains to be ascertained.

Since the above was written, the results of the pendulum investigations of Mr. E. D. Preston at the summit of Haleakala have been made known in a paper published in the number of

* This J., xxxv, 33, Jan. 1888. The view is the same published in my Exploring Expedition Report, 40 years since.

this Journal for November last,* and have afforded unexpected evidence on these doubtful points. They have led him to the important conclusion that "the density of the mountain is at least equal to its surface density," and that, therefore, unlike some results obtained on the continents, "it is a solid mountain," so that the interior must have been left filled by the subsidence of rock that made the great crater at the summit. He states also that "the zenith telescope observations at the foot of the mountain indicate the same fact."

Mr. Preston states further that at Kohala, on the *north* coast of the island Hawaii, the plumb-line deflections were half a minute *southward*, which, he adds, is well explained by the position to the southward of all the great mountains of Hawaii. He records also that at Hilo, on the *east* coast, the deflection was a fourth of a minute *to the northward.* Mr. Preston remarks that "there is no explanation" of this result at Hilo "unless we assume that the south side of Hawaii, where the volcanoes are active, is much less dense than the north side where the fires have been slumbering for centuries." But to the north of Hilo is a long reach of ocean, the coast of Hawaii there trending northwest; the summit of Mt. Kea, 13,805 feet high, is 25 miles distant and bears N. 75° W.; and that of Mt. Loa, 13,675 feet high, is 35 miles distant and bears S. 63° W.; and the center of gravity of the combined mass (the lowest level over 5000 feet) bears probably a little south of due west. It appears, hence, that we have here evidence that Kea is like Loa, *not* solid; that it is a hollow mountain, as inferred above from the absence of a summit crater; but Mr. Preston is probably right in his inference that Mt. Loa is the more cavernous of the two. Additional plumb-line and pendulum observations are, however, much to be desired.

2. *West Maui.*

West Maui has lost the original slopes of its great cone and its crater through erosion. It has been supposed that remains of three great craters may be distinguished in the mountains: the largest at the head of Wailuku or Iao valley on the north border of which rises the highest peak, Puu Kukui, 5788 feet high; another in the less deep valley of Waihee, just north of this; and a third at the head of the Olowaiu valley, to the south.

I examined only the Wailuku valley, the largest of the three, —so named from the village on the coast near its entrance. The valley is a deep cut into the mountains, remarkably grand in its precipitous walls with thin crested summits. It widens

* Vol. xxxvi, 305.

somewhat toward its head, and in this upper part an extensive plateau occupies the center. The torrent of the valley is here divided between two tributaries, one running either side of the plateau. The height and rather bold sides of the plateau at the head of the valley, and its size and position, taken in connection with its location near the center of the mountain range, appear to make it pretty certain that the plateau represents the floor, or rather what is left of the central area, of the great crater. I looked for the edges of lava streams in the enclosing walls in order to make out their pitch and the thickness of the beds. But dense vegetation so covers everything that distant views are of no geological value, and one day's excursion was not sufficient for a climb of the heights.

As to the former crater condition of the other two valleys mentioned, I know nothing from personal observation. The idea of their having been craters is based on the size, depth, and boldness of the walls and the ampitheater-like head. But these features are common results of denudation in old volcanic islands, and therefore, in the question here considered I give them little weight.

3. *The Eccentric form of the Maui Volcanoes.*

The map of Maui illustrates a Hawaiian feature of volcanic mountains which may be common in other regions. The chief crater of the mountain is not at its center. In Haleakala the ratio of the radii east and west of the crater is 2 : 3; and in West Maui, 8 : 11. The shorter radius is to the south-southeast of the crater in one and to the southeast in the other.

In Hawaii it is not easy to mark off the true base of Mt. Loa. But we have the fact that in both the summit crater and Kilauea, the form is oblong, and each has its intenser activity in the more southern portion—the south-southwestern in one, and the southwestern in the other. The effect is not due to the to the winds, for the mountains consist almost solely of lava-streams.

4. *Drift-made ridge of consolidated coral sand.*

The positions of the high ridge of consolidated coral sand of Wailuku are indicated on the map. Whether proof of elevation or not is yet undecided. I was informed that the sands are at the present time drifted by the trade-winds to the farther inland limit of these ridges and over their surfaces—a fact which seems to show that present conditions are sufficient for their production.

II. Island of Oahu.

From the map of Oahu, Plate 4, it is apparent that the island (*a*) consists of two eroded mountain regions, an eastern and a western, separated by a plain sloping gently downward to the opposite coasts and upward toward the eastern mountains. A more remarkable feature (*b*) is the long and high precipice fronting northeastward, and thus facing the tradewinds. Besides these characteristics (*c*), there are lateral or subordinate volcanic cones on the sea-border, of which Diamond Head and its companions, Punchbowl, and the Koko Head craters on the eastern cape (Plate 4, figs. 1, 2, 3), are examples. The island is the only one of the group that has (*d*) a nearly continuous coral reef fringing the shores. It owes to this reef the harbor of Honolulu, the one good harbor of the group, and also the possibility of a much larger and better one at Pearl River, seven miles west of Honolulu; the cutting of a channel through the reef is all that is needed, as has long been recognized, to make these capacious inner waters available for shipping*. Another interesting feature (*e*) is the existence of an *elevated* coral reef on the borders of the island, having its inner limits approximately indicated on the map by a dotted line.

The facts on which the following account of the island is based and the views deduced from them are for the most part contained in my Expedition Geological Report. The visit in 1840 gave me nearly a month for study, which was industriously employed in excursions over and around the island. The accompanying map, on Plate 4, differs little, excepting in improvement in outline and topography, from the colored geological map of my Report, and the outline of the elevated coral reef and its coral rock and sand bluffs are copied from it. The view of the tufa cones on the same plate are simply new drawings from some of my old sketches. For fuller particulars and some views not reproduced—as those of Kaneohe Point and Aliapaakai, I refer to the Report. My recent visit (in 1887) gave me an opportunity for another excursion around a large part of the island (taken with President Merritt), and

* Honolulu, the capital of the Hawaiian Kingdom, was a collection of thatched huts in 1840, with exceptions only in a Custom House, an unfinished coral-rock church, and a few dwellings of civilized aspect. To-day it is city-like in its houses, its streets electrically lighted, its public squares, large Hospital grounds, spacious Government buildings—among them a palace good enough for any potentate—and its excellent hotel; and, through the addition of groves and avenues of introduced palms and tropical trees (some of which are always in flower or fruit) it is fast becoming a place of ideal beauty. Honolulu is the center of all the island activities, including inter-island navigation. It is not out of place to repeat here that steamers start every week or two for Hawaii and Kilauea—one route by Hilo to Keauhou, and thence up by horseback and wheels, the other by Punaluu on the south coast, where there is a good hotel and a carriage road all the way to the volcano. A carriage road from Hilo to Kilauea is in prospect.

for further explorations, refreshing old memories and adding new facts; and this return to the subject affords an occasion also for reconsidering former conclusions.

1. *Features, structure, and origin of Oahu.*

1. *General features; Contrast with the island of Maui.*—Like Maui, Oahu is in origin a volcano-doublet—that is, as regards rock-structure, it was the united work of two great volcanoes, a western and an eastern. But unlike Maui, its two volcanic cones or domes have suffered so great loss that the position of either crater is wholly a matter of conjecture.

A large part of the loss Oahu has suffered is due to denuding agencies. East Maui, as the map on Plate 3 illustrates, has lost in this way comparatively little of its original evenness of surface owing to the recency of its extinction. Its windward gorges are narrow, and only shallow gulches occur over the leeward surface. The ratio of its diameters at base, 1:1·3, is probably very near the original ratio. West Maui is profoundly gorged on all sides and most deeply so to windward, illustrating results of longer wear than East Maui has had. But something of the old slopes remain, and in the base we have still the ratio of its old diameters, 1:1·4, with the outline little indented. The double lesson is taught: (1) what denudation from descending waters does to a volcanic cone 5° to 10° in slope in the region of the trades; (2) what, on the contrary, the sea cannot do, no encroachments of note existing to attest to its power, notwithstanding the length of the era of denudation.

Oahu resembles Maui in having the western mountain-cone the most time-worn and the smaller in area, but here the likeness ends. Both of its mountains are deeply eroded. Further, East Oahu has only part of its old slopes left. They remain only on its southern, western and northern sides; the northeastern are cut off by the great precipice, twenty miles long, which is made for the most part of the edges of the lava-streams that slope southward and westward. The sharp-edged serrated ridge, making the summit of the precipice, is from 1000 to 3000 feet in height, and at its northeastern base, from Kualoa eastward, there is in general only a narrow strip of low land with low hills, the width but three or four miles except in the Kaneohe peninsula. The precipice continues beyond Kualoa northwestward, but not the low land at its base.

These features have occasioned peculiarities in the results of denudation on East Oahu. The leeward or south and southwestern sides have long and deep valleys, some of them heading in broad amphitheaters under the crested mountain ridge. The windward side, along the 20-mile precipice, on the contrary, has buttresses and shallow alcoves, with a buttress here and there lengthening out into a ridge; and only farther northwest, beyond Kualoa, are there the longer valleys or gorges and ridges and the mountain architecture characteristic of deeply worn windward slopes.

The only broad valley of the leeward or south and southwestward slope that is continued upward with gradual ascent to the very edge of the precipice is that of Nuuanu, behind the city of Honolulu. It is the valley to the left in fig. 2 on Plate 4. Six miles up it ends in the "*pali*," or precipice, and overlooks the northeastern sea-border plains and hills. The height of the "pali" is only 1207 feet above the sea; but on either side are the highest peaks of the range, Konahuanui 3105 feet in height, and Lanihuli, 2775 feet.

Great denudation on the *leeward* side of an island is an exception to the usual rule. It is a consequence, on Oahu, of the sharp-crested 20-mile precipice. The trade winds become chilled on striking the summit of the precipice and ready, therefore, to drop their moisture; but as they are moving on, they get beyond the summit before much of the moisture falls, and so the *leeward* slopes receive the water. In the upper part of the Nuuanu valley, within two miles of the *pali*, 132 inches of rain fall a year, and nearly 100 inches less than this at Honolulu, although brief sprinklings occur almost daily over the city. Konahuanui and Lanihuli, as seen from Honolulu are generally under clouds, but from Kaneohe they are usually uncovered.

A nearly similar condition exists in West Maui, owing to the thinness of the rocky walls at the head of its great valleys. Very broad valleys are consequently made on the leeward side, as in Oahu; but these valleys soon end below in a slender gulch, which may be, for the most of the year a "dry run;" the excessive dryness and heat of the lower plains evaporating powerfully and supplying no water.

2. *Orographic condition of East Oahu.*—From the facts mentioned, it appears to be plain that the chief structural difference between East Oahu and East Maui is that the latter is a whole volcanic mountain, and the former a piece of one. By some means the Oahu mountain-cone or dome has lost, as I concluded in 1840, a large piece from its mass—all that once existed northeast of the 20-mile precipice. The size of the lost piece it is not easy to determine. The lava streams of the leeward slopes, which dip away from the precipice mostly at an angle of 3° to 5° (as seen in the intersecting valleys), must have come from some point or points beyond it to the northeastward.

Following the leeward slopes around westward and northward we find all pointing upward toward the higher part of the mountains, as if the source were somewhere in that direction; but just where, remains in doubt; and it may be even questioned whether there may not have been two or more great craters along the line.

No point or region has a more reasonable claim for consideration in this respect than the head of Nuuanu valley. In situation and width, and the features at its head, it is just what should be looked for in a great discharge-way. On my recent visit I sought for facts bearing on the question and found the dip of the beds to diminish from 3° to 1° toward the top, and at the "pali," the beds were very nearly or quite horizontal. This is favorable to the conclusion that the crater was either at its head or near by it, just beyond the precipice. The low land below, over the Kaneohe peninsula and between this peninsula and the "pali," is a region of tufa hills and other small cones, unlike any part elsewhere of the north or northeast coast. In addition, at the head of Nuuanu valley, very near the top of the "pali," there are the remains of a red cinder cone. Besides this, on descending the steep "pali" by the path, there is to the east of the path a long broad slope, 35° to 40° in angle, consisting of reddish layers of volcanic cinders, scoria, earth and stones—indicating cinder ejection from some point above.

It is therefore most probable that the center of volcanic activity for East Oahu was in the vicinity of the "pali," above the low region a little to the northeast of it. The cinder cones above mentioned may have been results of the last efforts of the declining fires, like those of Haleakala and Mt. Kea.

In 1840, I was led to locate the central crater on the Kaneohe peninsula, because the head of the "pali" was so near the southern foot of the mountain; I thought it must have been farther off. But the fact that the volcanic mountains of East and West Maui are eccentric in ground-plan, and that the same feature quite certainly characterized this Oahu cone, makes the position near the "pali" the most probable. In Haleakala the center of the crater is only six miles from the southern shore; and this distance in the Oahu crater, on the above supposition, would be about seven miles. The idea of an eccentric cone fourteen or fifteen miles in the transverse diameter through the crater is thus strongly favored. On further comparison with Haleakala, we find that the part of the longer diameter of the mountains which lies northwest of the center of the crater is about 19 miles in length on Maui, and on Oahu it would be nearly 25 miles. The small dip of 1° to 3° prevails widely about the mountains at Kualoa point and to the northward, as well as in the upper part of the Manoa valley, west of the Nuuanu; and from this it may be inferred that the East Oahu mountain was a dome, like Mt. Loa, rather than a cone like Haleakala. The existence of one or more craters west of the "pali" has been urged, and is possible. I know of no special facts sustaining it. The amphitheater at the head of Manoa valley is referred to by Mr. Brigham as probably the site of a crater; but I was more inclined from my examination to make it an amphitheater of erosion.

3. *Origin of the long precipice on Oahu.*—The long precipice of East Oahu has been attributed to erosion. But I have found no evidence that such transverse walls are legitimate effects of erosion, either fluvial or marine. As illustrated on Maui (p. 91), the sea works with extreme slowness in battering lava-cliffs, and cannot work at all below the limit of forceful wave-action—a level not twenty feet beneath the surface. Fluvial action makes long valleys in the long descending mountains and capes which the sea is incapable of obliterating. Land waters have done grand work in alcoving the long precipice, and carving battlements and temples out of the rocky piles that were left, as is well exhibited in the Kualoa bluffs, while the sea has not even scraped away the small tufa cones on its borders. It might be said that the cones of Kaneohe and the "pali" have been made since the era of erosion; but this disconnects their origin by a very long era from the period of activity in the crater.

Another view with regard to the origin of the precipice is that of my Expedition Report, namely that it was made by a profound fracturing of the mountain-dome across from southeast to northwest, and a drop-down of part of the outer or eastern section. The line of fracture was irregular—the course rather of a series of fractures; and subsidences of varying extent may have taken place along the line, becoming smaller to the northwest, where high ridges are left between the precipice and the coast. The amount of displacement was not less than the height of Konahuanui, 3105 feet, and probably much exceeded this.

Great catastrophic subsidences are not uncommon in volcanic regions. In the account of Maui and its crater the fact of a subsidence not less than 2500 feet, accompanying and following some one of its eruptions, appears to be placed beyond doubt. Hawaii has plain evidences about its crater of subsidences hundreds of feet in amount of displacement if not thousands; and there are high precipices, like that at Kealakekua Bay, for which there appears to be no other probable source of origin.

The small western island of the Hawaiian group, Niihau, has a bold precipice as its eastern face, 1500 to 1800 feet in height above the sea, and the lava-streams of the island pitch from the precipice to the westward, showing that the streams flowed from a point to the eastward, and that a large piece, perhaps the larger part, of an old volcano has disappeared. Kauai, north of Niihau, has its Napali cliff, a dozen miles long, along its southwest side, in a line with the Niihau cliff. Molokai, to the east of Oahu, was once, as its lava-streams prove, a doublet of volcanoes, like Maui; but it has been shaved down to a strip of land 35 miles long, and not a fifth of this in mean width. The eastern part has an alcoved precipice facing the north, which rises to a height of 2500 feet above the sea. It encloses a strip of land along the sea shore, and on this spot, thus walled in, it has been found convenient to locate the Leper quarantine-ground of the islands. Lanai, a narrow island south of Molokai about 20 miles long, has a bold front to the south and gradual slopes from it in other directions. Thus such precipices are rather the rule in the Hawaiian group; and if seashore erosion is not the origin—as an island like Tahiti, with its profound radiating gorges as a result of fluvial action and its non-gorged coast, appears to show*—fractures and subsidence must be.

A great volcano is a disgorger of lava in vast floods and so it makes its mountain; and it may make also empty cavities at the same time and as a consequence. As long as the ascensive force keeps the liquid lava-column of the active volcano fully up to the summit crater, the mountain may have only local cavities. But whenever a great discharge takes place, a coequal cavity may result; and if the discharge is from fissures at the base of the cone, 15,000 to 18,000 feet below the sea level (not a greater depth than exists in the neighboring seas) an enormous cavity may be left, which only the renewed action of the ascensive force would fill. If the mountain *then* became extinct with no return of the liquid, it would be a hollow mountain; and the greatest of subsidences which the Hawaiian facts seem to indicate, are small compared with the possible consequences of such a condition.

4. *The Tufa and other Lateral cones of East Oahu.*—Several of these cones, as already stated, are represented on Plate 4.

Punchbowl, fig. 2, stands on the northern border of Honolulu (at P on the map).† Its highest point is 498 feet above tide-level. The tufa of the beds constituting it, though rather feebly consolidated, is quarried on the west side of the cone, and specimens may there be conveniently obtained. It is a yellow to brown, in part resin-lustered, palagonite-like rock, bearing evidence in its constitution and in the dip of the beds,

* This Journal, xxxii, 247, 1886.

† The sketch was taken in 1840 from the deck of the ship Peacock as she lay in the harbor. The native huts at its foot are omitted.

that mud-making warm waters were concerned in the deposition; and its being of brown, in place of red, color, is probable evidence that the temperature of the water was below 200° F.

Diamond Hill, fig. 1, makes the prominent cape east of the city; its bold southern brow has a height of 761 feet above the sea at its base. It is, like Punchbowl, a fine example of the typical tufa-cone in its broad and shallow, saucer-shaped crater, with the stratification parallel to the bottom of the saucer and to the original outer slope. These slopes have become deeply trenched, as the view shows, by descending waters; and since 1840, the southern brow has lost something of its boldness. Two other cones stand in a line to the north of it, the first, a place of lava outflow. The three vents appear to be situated on a single line of fracture.

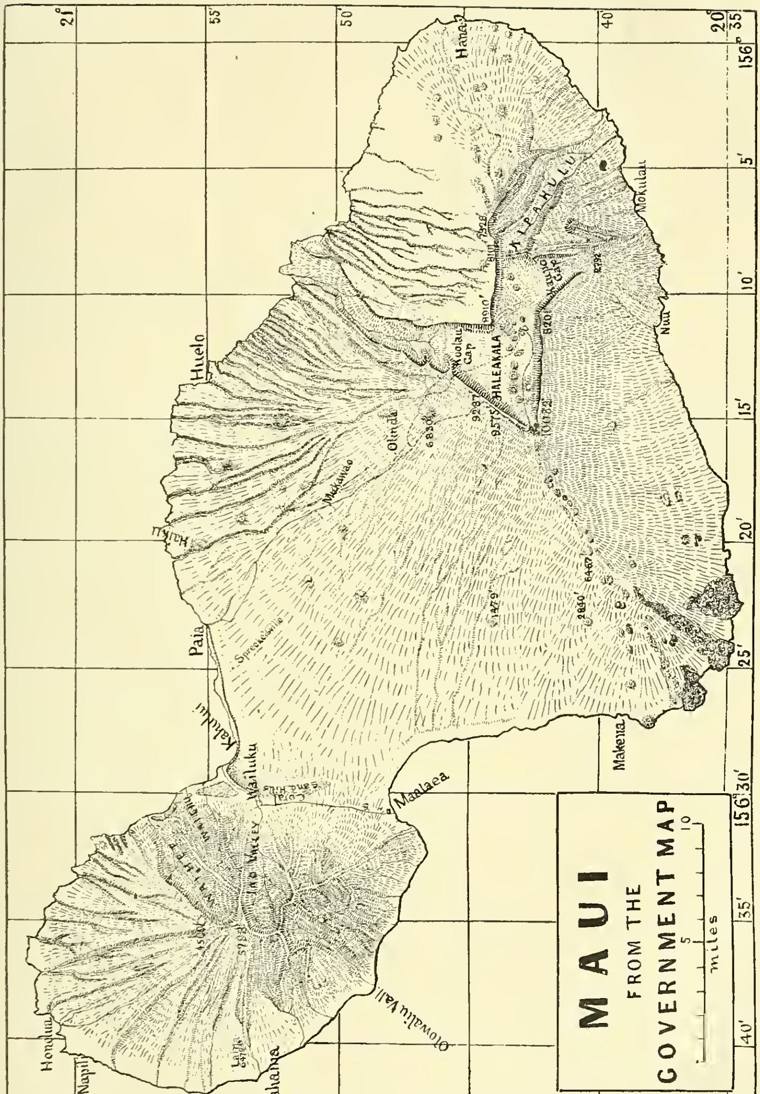
The Koko Head tufa-cones are situated at the east extremity of the island. The view (fig. 3) was taken from the eastward at sea The larger or more northern of the two cones is much denuded inside and out. The other low cone, situated on the Point, is worn to its center by the sea, and has thereby been made to exhibit to the passing vessel (as it goes from or toward Honolulu) the dip of its tufa beds inward and outward, and thereby the true structure of such a cone.

Artesian borings on Oahu afford some facts bearing on the history of Diamond Head and Punchbowl. The borings were made by Mr. J. A. McCandless of Honolulu, and records of a number of them have been received from him through Prof. W. D. Alexander.

The following section is from James Campbell's well, at the west foot of Diamond Head, not far from the sea-level.

	Thickness.	Depth.
Gravel and beach sand	50 feet	----
Tufa like that of Diamond Head	270	320 feet
HARD CORAL ROCK, like marble	**505**	**825**
Dark brown clay	75	900
Washed gravel	25	925
Deep red clay	95	1020
SOFT WHITE CORAL	**28**	**1048**
Soapstone-like rock	20	1068
Brown clay and BROKEN CORAL	110	1178
Hard blue lava	45	1223
Black and red clay	28	1251
Brown lava	249	1500

The well went down 1178 feet before reaching the solid lava of the bottom. In its upper part it passed through 270 feet of tufa, indicating that the tufa-cone extended below the sea-level to this depth, and therefore had a total height of over 1000 feet. Below the tufa, between the 320-foot and 825-foot


MAUI
FROM THE
GOVERNMENT MAP
miles
Hana
Huelo
Haiku
Paia
Kahului
Wailuku
Maalaea
Makena
Nokulau
Nuu
Lahaina
Honolua
Napili
Olowalu Vall.
Olinda
Makawao
HALEAKALA
Koolau Gap
Kaupo Gap
KIPAHULU
Iao Valley
Spreckelsville
Sand Hills
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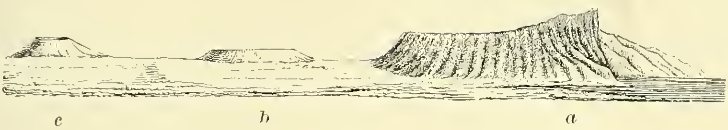
1



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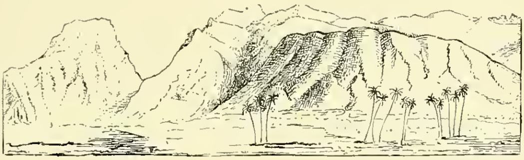

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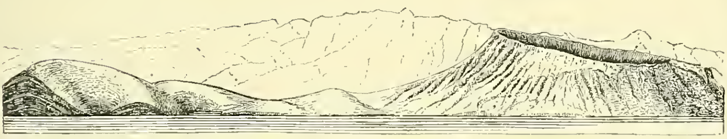

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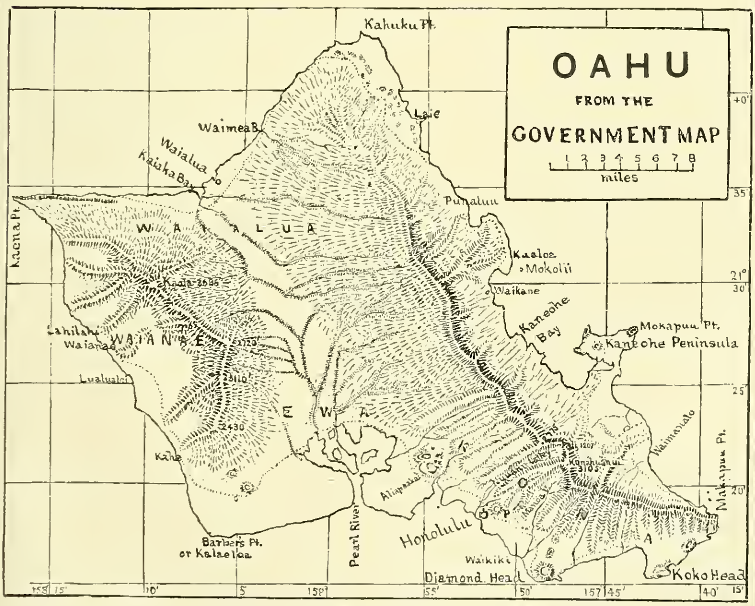


1. The volcanic cones: *a*, Diamond Head, or Leahi; *b*, Kaimuki, or Telegraph Hill, and *c*, Maaumae. 2. Punchbowl, or Puowaina, with Nuuanu valley to the left, and the peaks Konahuanui and Lunahili, right and left of the pali. 3. The Koko Head craters.

levels, there are 505 feet of *hard coral rock;* and then on the 1045-foot level, a 28-foot layer of *soft white coral* and at a greater depth, brown clay and broken coral. As the well is close by the west foot of the Head and passes through so much of its tufa, it is quite certain that the 505-foot stratum of limestone was made before the tufa-eruption; and that the beds underneath it mark earlier conditions over the site.

As regards a supply of fresh water the well was a failure—an exception to the usual experience. The water came up salt and a much stronger brine than sea-water. It was under some pressure, as it stood a foot above the level of surface wells near by.

Other borings have been made in Waikiki—the sea-border district just west of Diamond Head. The section afforded by the deepest of the Waikiki wells is here inserted for comparison. It is that of the King's well, No. 2—about half a mile west of Diamond Hill and 350 yards from the seashore.

	Thickness.	Depth.
Sand and coral	38 feet	----
WHITE CORAL ROCK	**22**	**60**
Yellow sand	43	103
Hard lava	47	150
WHITE CORAL ROCK	**110**	**260**
Blue clay	25	285
Tough clay and CORAL	65	350
Blue clay	30	380
HARD CORAL ROCK	**40**	**420**
SOFT CORAL	**30**	**450**
Tough clay	5	455
WHITE CORAL ROCK	**40**	**495**
Tough clay	30	525
WHITE CORAL ROCK	**100**	**625**
Tough clay	5	630
CORAL and clay	**70**	**700**
Tough clay	28	728
Black sand	2	730
Lava	120	850

In this well, the upper 320 feet probably correspond approximately to the upper tufa-made portion of the preceding. It is remarkable that tufa is wholly absent, although the distance from the active vent was so small; but this is accounted for by the direction of the trade winds, which would have carried the ejected material seaward—the direction in which the hill is elongated. Moreover the tufa-cone although 1000 feet high may have been thrown up in a single year or less. Instead of tufa for the upper part, there are, underneath 38 feet of sand and coral, 22 feet of white coral rock; 110 feet more of the coral rock above the 260-foot level, and 65 feet of "tough clay and coral" next above the 350-foot level. Further, beginning with the 385-foot level, coral rock is continued to the 700-foot level, or for 315 feet, with the exception of 40 feet of clay divided between three layers; and this 315-foot layer of limestone appears to correspond to the 505-foot layer between 320 and 825 feet in the other section. The solid lava-stream of the bottom of the well was reached at 730 feet. The amount of water obtained proved that the lava-stream was one of those from the mountain. It is overlaid by 2 feet of volcanic sand and 28 of tough clay, the sand serving to contain the water and the clay to confine it, conditions suited to make the well a success.

In these sections the intercalated beds of so-called "clay" vary widely in position and thickness, and appear to be, in general, local deposits from mountain streams, or tufa deposits from one source or another. In another boring in Waikiki, a bottom of solid lava was reached at 375 feet; and in a third, Goo Kim's well, at 475 feet. The former had an intercalated lava-stream at a depth of 206 feet, and the other at 150 feet. In Goo Kim's well, which was nearly a mile from the seashore, there were 26 feet of coral rock above the 150-foot level, and 194 feet of coral rock above the 430-foot level but with two intercalations of a 20-foot layer of "clay" in the stratum. The facts as to the varying levels of the "clay" beds and the intercalation of lava-streams show what accidents the living species of the sea and its reefs were exposed to. They make the existence of a *continuous* 505-foot stratum of coral limestone underneath the tufa of Diamond Head the more remarkable.

The artesian wells made within the limits of the city of Honolulu might be expected to throw light on the history of Punchbowl.

1. A well in "Thomas Square," just south of Punchbowl, afforded the following section.

Soil 6 feet, with 6 of black sand and "clay" 4	16 ft.	---
White coral rock	200	216 ft.
Brown clay	44	260
Coral rock	10	270
Brown clay	60	330
White coral rock	50	380
Brown clay	80	460
Bed rock or lava, penetrated	49	509

2. In "Mr. Ward's well," below Thomas Square, on King street, there were at the top 15 feet of loam and sand, then 180 feet of "hard coral rock," carrying the depth to 195 feet; again 24 feet of coral and shells above the 219-foot level; and

then, underneath 109 feet of "yellow clay" which may be Punchbowl tufa, 23 feet of coral rock above the 393-foot level, and 107 feet of white and yellow sand below it; with the bottom lava at 508 feet covered by 4 feet of quicksand. An abundant flow of water was obtained.

3. South of the last, in the "Kewalo well," begun near the sea-level, beneath 6 feet of black volcanic sand, there were 50 feet of coral rock over a 40-foot layer of hard lava; then 190 feet of coral, divided in two by an intercalated 30-foot layer of "clay," over the 350-foot level; with the bottom lava-bed at 620 feet.

4. Section from a well in the Palace yard:

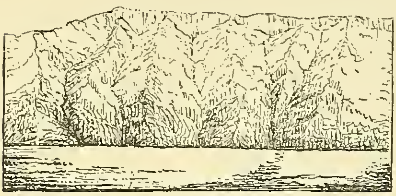
Soil 4 feet, black sand 4	8 feet.	---
Coral rock	64	72 feet.
Hard lava	6	78
White coral rock	60	138
Clay	240	378
Coral rock	75	452
Clay and gravel	254	707
Lava or bed rock penetrated	55	762

Of the above sections 1, 2 and 3 have a thick bed of clay on the 260-foot to 280-foot level; 1, 2 and 4 on the 330-foot, 370-foot and 378-foot levels; 1 and 2 and 3 on 460-foot, 500-foot and 535-foot levels; and No. 4, a layer 254 feet thick on the 707-foot level or the bottom rock. It is possible that one or more of these of "clay" may be decomposed tufa of Punchbowl origin. But to refer all to this source would make the period of eruption of very improbable length. The "black sand" below the soil in Honolulu is naturally referred to this source. But more investigation is required for a decision. There is no evidence that Diamond Head and Punchbowl were of simultaneous origin.

5. *West Oahu.*—The mountains of West Oahu cover at the present time a much smaller area than those of East Oahu. Their original dimensions we have no data for estimating. The highest peak, Kaala, in the northeast part of the group of summits, has a height, according to the government survey, of 3586 feet—which is 681 feet greater than that of Konahuinui; and besides this, there are, in the southeastern part, peaks of 3105 and 3110 feet. These elevations, and the deep and open valleys divided off by sharp ridges, are sufficient evidence that the mountain range is but a small remnant of the once great volcanic mountain, probably a loftier mountain than that of East Oahu. Denudation has had a far longer time for its dissecting work, and has done much to diminish the area it covers. Whether great loss has resulted also from subsidence is not ascertained.

The fact that the volcano of East Oahu was in full action long after the extension of the western cone, is shown (as I first observed in 1840 and again in 1887) by the encroachment of the eastern lava-streams over its base, and the burial in part of the valleys. The accompanying sketch is a view, looking westward from the plain made by the encroaching lavas, showing how the lavas dammed up the already made valleys of West Oahu, and forced the drainage waters to take a north or south direction, nearly parallel with the base of the mountain, in order to reach the sea. The courses of these streams are shown on the map. The depth of burial by the East Oahu lavas was probably some hundreds of feet.

1.

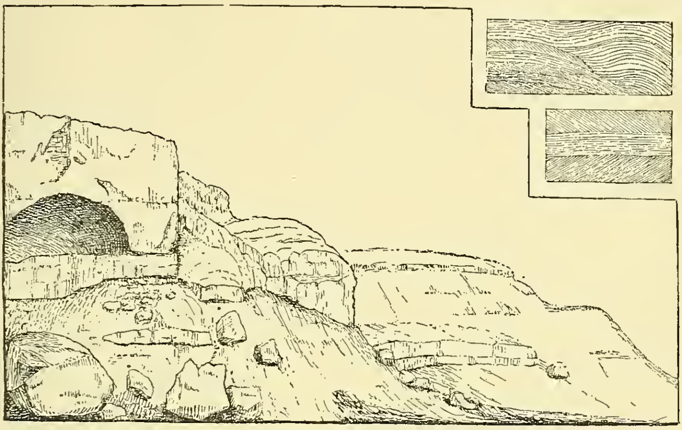


2. *Evidence of recent change of level.*

1. *Elevation.*—Evidence of recent upward change of level is afforded by the elevated coral reef along the sea-border. The dotted line on the map (Plate 4) has already been pointed to as approximately the inner limit of the raised reef; the small dotted areas about Kahuku Point, the prominent north cape of the island, and in Laie, the district next southeastward, besides others west of Waimanalo, are the positions of hills or bluffs made of the reef rock and consolidated drift sands. The rock is in some parts a beautiful white, fine-grained building stone; but generally it has sudden transitions in texture and firmness, and much of it is a consolidated mass of broken corals, or else of standing corals made compact or nearly so with coral sand. Along southern or southwestern Oahu the height of the reef is fifteen to thirty feet; and I estimated the amount of elevation indicated by it in 1840 at 30 to 40 feet.

At the Kahuku bluffs, which I visited anew in 1887 (see figure 2), the solid coral reef rock extends up in some places to a height by estimate of fifty to sixty feet above tide level; and this is surmounted by drift-sand rock, made of beach coral sands that were drifted into hills on the coast when the reef-rock was submerged, adding twenty feet or more to the height. There are large caverns in the bluffs, which are mostly within the upper layer of the coral reef-rock and have the drift-sand rock as the roof. In the sketch, a faint horizontal line may be seen passing by the top of the cavern; it separates the beds of different origin. The coral reef-rock consists mostly of cemented masses and branches of corals of the kinds common in the modern reef, and also has often the corals in the positions of growth. But the wind-drift beds show the quaquaversal or variously-striking dip common in wind-made drifts, as represented in the two sections below.

2.



Kahuku bluffs of coral rock and drift-sands, with two sections of the drift-sand rock.

The change of level along northern Oahu, according to the facts from Kahuku, appears to have been at least sixty feet, or twenty feet greater than on its southern side. Even with an accurate measurement of the height of the reef-rock about Oahu the amount of elevation would remain doubtful because the coral reefs off the island are at present nowhere up to low-tide level; and this may or may not have been the fact before the change of level took place.

The surface of the elevated reef of Oahu is exceedingly uneven from unequal construction and erosion, and its interior has in some places large and winding caverns, so that an overlying formation, were there one, would afford an example of *unconformability by denudation.* It is obvious that with greater elevation, the unevenness would be as much greater, large enough to get the credit, perhaps, of representing an interval of many thousands of years, although results of the "modern" period in geology. Denudation works rapidly among limestones and especially so when the limestones have just left the water, with the usual irregularities of upper surface and texture.

2. *Subsidence.*—A gradual subsidence of the island is apparently indicated by the coral reefs, through the depth to which they have been found to extend in Artesian borings. In these borings, described on page 96, a depth of 700 to 800 feet was

found for the coral rock, and more than 1,000 for broken corals; and over 700 is reported by Mr. McCandless from a well in the Eua district, about five miles west of Honolulu. The facts lead to the inference that the subsidence amounted to at least 800 feet, and that it corresponds to the coral-reef subsidence which Darwin's theory requires. Mr. McCandless informed me that fragments of corals like those of the modern reefs were brought up from the various levels.

This evidence of subsidence to the amount stated is not, however, complete. Doubt remains because the corals brought up in fragments have not been examined by any one competent to decide on their actual identity with existing species; I could not find that any of them had been preserved. The importance of their preservation and careful study is now understood, and we may hope before long to have the doubt removed. As the case stands, the *probability* is that the limestone is to the bottom true coral-reef rock and that the depth to which it extends is, therefore, a measure of actual subsidence.

Darwin's Coral Island theory.—In the above statements the present condition of Darwin's theory of Coral Islands, is fully and fairly recognized. Much has been recently written about the theory's having been set aside or proved to be without foundation. But in truth, no facts have been published that prove the theory false, or set aside the arguments in its favor. The facts and arguments from Tahiti brought out by Mr. Murray I have shown, in my review of the subject in this Journal in 1885* (published also at the same time in the London Philosophical Magazine), to have no weight and more than this, to sustain Darwin's theory, instead of opposing it. The idea of the excavation of the lagoon-basins of coral islands by sea-waters I have also proved in the same paper to be not a possibility.

The only suggestion of real importance that has been presented is not against Darwin's explanation, but simply in favor of a possible substitute. Mr. A. Agassiz and others have suggested that deep-sea organisms may build up limestone over the sea-bottom, and thus raise the rock to the level where reef-forming corals may grow, or within 100 to 150 feet of the surface; and that, in this way, coral reefs and islands *may* have been formed without subsidence. Mr. Guppy has shown that some coral-made limestone, in the southwest Pacific, actually has a base of limestone that had been made by other life than that of reef-corals. This is all the foundation for setting aside Darwin's conclusions. It is good ground for doubting, and a good reason for investigating the nature of the coral limestone in the various coral-reef regions of the Pacific at

* Volume xxx, pp. 89 and 169.

depths below the level of 100 to 150 feet—as I state in the article referred to, where I propose that deep borings should be made, under government authority, on a sufficient scale to settle the question. The borings have been made on Oahu; but, as I say above, the fossils of the reef-rock passed through below the coral-growing limit have not been examined and the subsidence therefore is not positively proved. There are many collateral arguments in favor of the Pacific coral-island subsidence reviewed in my paper which still remain strong; but they may be held in abeyance until the borings have been satisfactorily made. These and other points are discussed at length in the paper to which I have above referred.

I took no part in the controversy with reference to the statements of the dogmatic Duke of Argyll, knowing that the subject was in good hands. But I may here say that the charge which he made that no one had dared to bring forward and discuss the facts and views published by Mr. Murray and others against Darwin's theory was the more inexcusable that my paper had appeared as recently as in 1885 in the London Philosophical Magazine. The charge was based on ignorance of the facts on all sides, and on incapacity to appreciate the spirit actuating men of true science.

One other paper—on the question *whether volcanic action is a cause or not of trough-making over the Ocean's bottom, with a review of the ocean's depths illustrated by a new bathymetric chart*—will close this series with the exception of the promised paper on the rocks of the islands by E. S. Dana.

ART. XI.—*An Experiment bearing upon the Question of the Direction and Velocity of the Electric Current;** by EDWARD L. NICHOLS and WILLIAM S. FRANKLIN.

[Contributions from the Physical Laboratory of Cornell University, No. III.]

IN one of his recent articles in the *Annalen der Physik und Chemie*, Fœppl† has described an experiment in which the deflection of the galvanometer needle under the influence of a stationary coil of wire carrying an electric current, was compared with the deflection produced when the coil was given a high velocity of rotation; the axis of the coil being the axis of revolution. If the current traversing the coil had possessed direction and a finite velocity, a change in the de-

* Read before the American Association for the Advancement of Science; Cleveland meeting; August, 1888.

† A. Fœppl; Wiedemann's Annalen, Bd. 27, p. 410.

flection of the needle might have been looked for as the result of the revolution of the coil; the deflection being greater when the coil was revolving in the direction in which the current was flowing than when at rest, and less when the direction of the current was opposed to that of the coil. The result of the experiment was a negative one, the deflection of the needle being just the same when the coil was at rest as when it was in rapid rotation.

Fœppl's apparatus was inadequate to the end in view, for had the current consisted in a motion of translation of a single fluid, its velocity need not have greatly exceeded 300,000 centimeters per second to have rendered the difference between the deflections due to the stationary and to the rotating coil indistinguishable. The method is, however, capable of very much greater refinement than that attained in his experiment, and while modern views of the nature of the electric current are such as to lead us to look for a negative result, whatever the delicacy of the apparatus, the present condition of electrical theory is not such as to render a repetition of the experiment under improved conditions devoid of interest.

The present writers, by whom the details of a similar method had been developed before they became acquainted with Fœppl's work, have repeated his experiment with an apparatus capable of indicating the direction and velocity of the current, supposing it to have direction, even though that velocity were very large indeed.

A flat bobbin of hard rubber was carefully turned upon a lathe. It was $8{\cdot}25^{cm}$ in diameter and $1{\cdot}6^{cm}$ in thickness. The periphery was provided with a groove of rectangular cross-section. This groove was wound differentially with sixty-four turns of insulated copper wire. The winding was very compact and the wire was held in place within the groove by means of a brass tire or collar. Brass discs of slightly smaller diameter than the bobbin were screwed to the faces of the latter and well centered steel axles were inserted in these discs. Two brass supports, fastened to a hard rubber block which served as a base for the apparatus, carried bearings of Babbitt metal in which the steel axles of the bobbin rested. Each of the supports likewise bore two brushes of spring brass which could be so adjusted as to make contact with brass collars upon the axle of the coil. When the supports were connected with the terminals of a storage battery or other source of current, the circuit was completed through the coil; the current passing from one support to the axle upon that side by means of the bearing and brushes, thence to the brass disc upon the same side of the bobbin. From this disc, with which one terminal of the coil made contact, the current traversed the windings and made exit through the opposite disc, axle and support.

The coil thus mounted was driven by a belt. It could be given a very high velocity of rotation and could be supplied with current equally well whether at rest or in motion. In some preliminary trials to determine the rate at which it could be driven with safety the source of power was a small high-speed water-motor. It was found that four hundred revolutions per second could be readily obtained and that such a velocity could be maintained without undue heating of the bearings. Upon one occasion a speed of nearly six hundred revolutions was reached, when the brass retaining band parted with a loud report and the bobbin was instantly stripped of every vestige of wire. The coil was then rewound and balanced anew, and the rate of four hundred revolutions per second, already determined as lying well within the limits of safety, was not exceeded during the remainder of the investigation.

The rate of revolution was readily and accurately determined from the pitch of the note emitted by the revolving coil, this determination being verified from time to time by two independent methods; namely from the siren-like note uttered by four screw-holes situated 90° apart upon one of the brass discs attached to the bobbin, and by estimating the velocity of the driving belt.

The needle, by means of which variations in the magnetic moment of the coil were to be detected, was placed immediately above the latter and as near to the windings as possible. It consisted of a steel wire, about 1^{cm} long and 1 millimeter in diameter, hardened and magnetized. It was suspended within a cylinder of copper and was rigidly connected with a precisely similar needle, by means of an aluminium support, the two needles being parallel, in the same vertical plane and about 5^{cm} apart, their poles in opposition. The aluminium support also carried a plane mirror and was suspended in the usual manner by a silken fibre. The astatic pair thus mounted was completely neutral and it was necessary to give it directive force by means of a governing magnet, the position of which was so selected as to give the system a fixed zero point and at the same time a very high degree of delicacy. Deflections were noted by use of a telescope and scale. The figure of merit of the apparatus was determined by substituting a coil of direct windings and known area, for the differentially wound coil, and reading the deflection due to ·00001 ampères of current.

Since, for the effect in question, the figure of merit was the same as though the revolving coil also were directly wound, it could then be derived from a comparison of the total areas of the two coils.

The most serious defect of this apparatus lay in the imperfect balancing of the differential windings. The position of the needle when a current traversed the coil always differed considerably from that which it assumed when the current was broken, and with one ampère of current the deflection amounted to several centimeters. The difficulty was however not of a nature to interfere altogether with the progress of the investigation and a series of readings were accordingly made with coil at rest and in motion. The rate of revolution during the determinations was 380 turns per second. The direction of the current through the coil and the direction of rotation of the latter were repeatedly reversed while the position of the needle was under observation. The result was an entirely negative one, no measurable effect upon the needle resulting from the motion of the coil. The current traversing the coil was measured upon a Moler's "swinging-arm" galvanometer. During a portion of the time it exceeded one ampère. A determination of the figure of merit of the apparatus made immediately after the conclusion of the series of observations gave as a result:

$$1^{mm} \text{ deflection} = 0{\cdot}0000164 \text{ ampères.}$$

When one ampère of current traversed the coil, therefore, a change in the apparent magnetic moment of the latter (due to rotation), in the ratio $1:1\pm{\cdot}0000164$ would have shown itself in a change of deflection amounting to 1^{mm}. Such a variation could not have escaped notice.

The mean circumference of the windings of the coil was $23{\cdot}939^{cm}$, so that at 380 revolutions per second the wire had an average velocity, in the direction of its own length, of $9096{\cdot}82^{cm}$.

If we suppose the current to consist in the movement of electricity along the wire in a given direction, the velocity, relative to the conductor, being the same whether the coil is at rest or in motion, and the deflection of the needle to be due to the translatory movement of electricity with reference to the needle and proportional to that movement, it is easy to calculate the change in deflection, for any assumed current-velocity, which will be produced by a given rate of rotation of the coil.

Let V_w be the linear velocity of the conductor,
V_c the velocity of the current,
C_1 the current traversing the conductor,
C_2 the current necessary to produce a given deflection when traversing a directly wound coil of the same total area.

$$\text{Then } V_c = \frac{V_w C_1}{C_2},$$

In the case in question, a current-velocity of $554,680,000^{cm}$ per second would have been indicated by 1^{mm} change of deflection when the coil reached 380 revolutions per second. In these preliminary measurements, the highest degree of sensibility attainable by the method in question had been approached only in so far as the velocity of the revolving coil was concerned. It was evident that the number of ampère-turns in the revolving coil could be greatly increased without corresponding loss of speed, and that the question of further increasing the sensitiveness of the astatic pair, depended only upon our power to eliminate the disturbance due to the lack of complete balance in the differential windings of the coil.

To meet these ends a new coil was made for us by Mr. F. C. Fowler, the mechanician of the department of Physics, to whose skillful workmanship the excellent performance of the coils already described was due. This new coil was of the same diameter as the original one, and it was constructed in the same general manner. It was wound upon a box-wood spool, however, which was thick enough, axially, to admit of 390 turns of wire without changing the mean area of the windings. To avoid the very great difficulty of constructing a differentially wound coil so perfect that when carrying large currents, its effect upon the delicate astatic needle should be negligible, we resolved upon a modification in our method which should make the complete electrical balancing of the coil unnecessary. For the current from the storage battery used in our preliminary observations we substituted that generated by a small alternating-current dynamo giving 40,000 reversals a minute. The advantages of this change were very great, for there was no appreciable effect upon the needle, even when a much heavier current than we had attempted to use in our first experiment was traversing the coil. Under these conditions the sensitiveness of the astatic pair could be increased to the highest degree compatible with the maintenance of a permanent zero point, and the current traversing the coil was limited only by the heating of the wires.

The current from the alternating-current machine was measured by its heating effect upon a phosphor-bronze wire about fifty centimeters long, stretched vertically within a cylinder surrounded by a water-jacket. The elongation of the wire was made to move a small mirror by means of a simple device which need not be described here, and the angular movement of the mirror was read with a telescope and scale. This wire had been previously subjected to extended investigation and its reliability as an indicator of current was well established.* It

* See the Thesis of P. P. Barton and F. R. Jones: "The Measurement of Alternating Currents." MS. in the Library of Cornell University.

had been found that its indications when heated by an alternating current of the character used in our experiments agreed very closely indeed with those obtained by calibration with continuous currents of known intensity. Such a calibration was made in the present case, covering deflections from zero to 300 scale-divisions, which last-named reading corresponded to 5·00 ampères.

The new coil of 390 turns was now driven at 380 revolutions per second, the circuit being opened and closed and the current direction through the coil being repeatedly reversed, as in the former experiments. The amount of current traversing the coil was increased from time to time until the stretched wire indicated 4·26 ampères of alternating current, which was the largest quantity which it was deemed safe to permit the coils to carry, even for the few seconds necessary to the completion of an observation. The direction in which the coil revolved was likewise reversed from time to time. No change in the position of the needle due to the motion of the coil, nor to a reversal of the direction of the coil, nor to a reversal of the direction of the current within the coil could be detected, although the sensitiveness of the needle had been increased, about eight times, the current more than four times and the number of turns in the ratio of 390 to 64.

A re-determination of the figure of merit of the apparatus showed that 1^{mm} deflection now corresponded to ·00000043 ampères. An effect of much less than 1^{mm} due to the revolution of the coil, would have been clearly observable under the conditions of the experiment. The absence of such an effect seemed to warrant us in the conclusion, that if *direction* be ascribed to the electric current, its velocity must be such that the quantity of electricity conveyed past a given point in a unit of time, when the direction of the current was that in which the coil was travelling, did not differ from that transferred when the current and coil were moving in opposite directions by as much as one part in ten million—even when the linear velocity of the wire, as in our experiment was 9096·8 centimeters.

Now the velocity at which such a current must needs have traveled, in order that the revolution of the coil should increase or diminish the quantity of electricity passing the needle by an amount corresponding to a deflection of 1^{mm}, or in the case of the reversal of the direction of the current within the moving coil, corresponding to 2^{mm}, is found as before by multiplying the current in the coil by the linear velocity of the latter and dividing the product by the figure of merit of the apparatus.

We thus have

$$\frac{9096{\cdot}8 \times 4{\cdot}26}{{\cdot}00000043} = 90{\cdot}1218 \times 10^9 \text{ centimeters.}$$

It is quite within safe limits to say therefore that we should have been able to detect a change of deflection due to the motion of the coil, even though the velocity of the current had been considerably in excess of one thousand million meters per second.

Physical Laboratory of Cornell University, August 1, 1888.

Art. XII.—*On the occurrence of Monazite as an accessory Element in Rocks*; by Orville A. Derby.

Some five or six years ago Mr. John Gordon, an American mining engineer now engaged in commerce in Rio de Janeiro, brought to my attention a peculiar heavy yellow sand which had been sent to him from the province of Bahia under the supposition that it was tin sand. This on examination proved to be monazite with the composition, according to an analysis by Prof. Henri Gorceix of the Ouro Preto Mining School (*Comptes Rendus*, 1885): Phosphoric acid 28·7 per cent, oxide of cerium 31·3 per cent, oxides of didymium and lanthanum (?) 39·9 = 99·9. Inquiries instituted by Mr. Gordon and myself in regard to the locality and mode of occurrence of this sand revealed the fact that it occurs in considerable patches on the sea beach near the little town of Alcobaça in the southern part of the province of Bahia, where it seems to have been accumulated by natural concentration through wave action.

Attention having been thus drawn to this mineral, Prof. Gorceix has since detected yellow grains in the diamond sands of several localities of the provinces of Minas Geraes and Bahia which from giving the didymium lines in the hand spectroscope have been referred to monazite, and I have myself identified it by the same process in gold sands from several points in the provinces of Minas, Rio de Janeiro and São Paulo. The wide distribution of the mineral in the sea and river-sands of Brazil was thus established, but under circumstances that gave no clue to its origin.

Recently Mr. Gordon informed me that in examining with a lens the sands of the beaches about Rio de Janeiro he found always yellow grains similar in appearance to the Bahia monazite and that on concentrating the sands in a copper miner's pan, he obtained a small quantity of white and yellow sand that hung to the bottom of the pan behind the black iron minerals. Under the microscope the white grains show the characteristic form of zircon while the yellow ones, aside from their physical resemblance to the Bahia mineral, give like that, the didymium band in the hand spectroscope and the microchemical tests for phosphoric acid and cerium, so that their identity with monazite seems clearly established.

As gneiss is the only rock that is at all abundant about Rio de Janeiro, it was natural to suppose that the mineral so widely distributed in the sands might have come from that rock. About the same time Prince Pedro Augusto de Saxe Coburg Gotha discovered in an apatite-bearing streak of the gneiss of the Serra de Tijuca a minute yellow crystal with the physical aspect of monazite, but too small for chemical tests. This suggested the idea that, notwithstanding the small proportion of the mineral and the microscopic size of the grains, it was not altogether hopeless to look for it in the rock itself, while Mr. Gordon's method of concentration by panning was naturally suggested as the simplest and readiest mode of investigating the question. Under Mr. Gordon's instruction I soon acquired sufficient facility in the use of the pan to make a satisfactory concentration and with his aid some scores of tests have been made of the rocks in the vicinity of Rio and from about a dozen points in the provinces of Rio de Janeiro, Minas Geraes and São Paulo. Where decomposed rock was obtainable the tests were made on this by washing a quantity equal to a heaped double handful, care being taken to obtain material decomposed *in situ* and carefully freed from any extraneous wash. Where decomposed material was not at hand pieces of sound rock were ground in a mortar, a fragment the size of the fist or even smaller proving sufficient for a satisfactory test.

All the tests made on gneiss, granite and syenite have given, in addition to zircon, a greater or less quantity of microscopic crystals of a heavy yellow mineral apparently identical with the Bahia monazite. As no crystallographic study could be made, the identification has been based on the general appearance of the grains, their high specific gravity, and microchemical tests for phosphoric acid and cerium. In some few cases the yellow grains are lighter in color and duller in luster than the Bahia mineral, but as they give the phosphoric acid and cerium reactions they are presumed to represent a variety of monazite, or perhaps some other cerium-bearing phosphate. Their high specific gravity is proved by their behavior in the pan where they remain with the zircon, behind the other minerals, so that, after extracting the magnetite with a magnet, it is possible by careful manipulation to obtain these two minerals nearly free from titaniferous iron and garnet when these are present. The separation of the zircon is presumably favored by the minute size of the grains and by their prismatic form as it remains behind minerals as heavy or even heavier than itself when, as is generally the case, these are in larger grains. The yellow mineral, however, is frequently in as large grains as the titaniferous iron and of a similar rounded form and appears to hang back in virtue of its greater specific gravity. A few tests were made with fused chloride of lead (sp. gr. 5), which on cooling showed the yellow grains at the bottom of the ingot while the zircon and titaniferous iron were near the top. A number of the samples were tested with the hand spectroscope giving the didymium band, but owing to the difficulty of bringing together a sufficient number of such minute grains to give a perfectly satisfactory test, this means of identification was abandoned in favor of microchemical processes. All of the samples have been tested by treatment with sulphuric acid and molybdate of ammonia. In some cases crystals appeared in the sulphuric and oxalic acid solutions, along with those referred to cerium, which probably represent some other elements. It is possible that a more complete chemical and crystallogical study of the yellow grains of these residues may prove some of them to belong to minerals other than monazite, but in the impossibility of making such investigations here, they are all referred provisionally to that species. Samples of rock and residue from the granite of the Serra do Tijuca in the outskirts of Rio de Janeiro, in which the yellow grains are particularly abundant, have been placed in the hands of Prof. George H. Williams of Baltimore, in the hope that he may find them of sufficient interest to make such studies as, from the lack of appliances and the necessary training, are out of the question here.

The gneisses examined were obtained from a score or more points in and about the city of Rio, including porphyritic, granulitic and schistose varieties; from Kilometer 78 (ascent of the Serra do Mar), on the Dom Pedro II. railroad, and the station of Barra do Piraley on the same line; the station of Socego on the União Mineira railroad in the province of Minas Geraes; and the towns of Cutia, Piedade, Santos and Iguape in the province of São Paulo representing an extension of about 300 miles along the axis of the great gneiss region of the maritime group of mountains of Brazil. In every case zircon and the yellow mineral were found there, proving to be the most constant accessories since; of the ordinary accessory elements, garnet, rutile and the iron minerals, magnetite and ilmenite—the first two were frequently absent, while rarely only one of the iron minerals seemed to be present. Rutile appears to be a comparatively rare element in these gneisses since the transparent red titaniferous grains referred to it were found only in two or three places in peculiar highly micaceous schistose layers, unusually rich in iron minerals. If, as is possible, these grains belong to some other mineral, then rutile is entirely lacking in the rocks examined. The gneiss from Socego and Cutia contains an abundance of sillimanite. All the gneisses examined belong to the class of biotite gneiss, except that from Santos which contains both muscovite and biotite and in this the yellow grains are rare in comparison with the zircon. No opportunity for examining a purely muscovite gneiss has yet been afforded. The relative proportions of zircon and the yellow mineral vary considerably in these tests, sometimes the one sometimes the other predominating. In the rock from Socego and from Kil. 78 D. Pedro II. railroad, the yellow mineral is particularly abundant.

A small number of granites have been examined with a similar result, that is to say, all of them give zircon with a heavy phosphate which in most cases appears to be identical with the Bahia monazite. The greater number of tests have been made on fine-grained biotite granites which give residues identical in appearance with those from the gneiss. The two specimens of muscovite granite examined from the station of Caieiras on the São Paulo railroad and from Sorocaba in the province of São Paulo gave a small quantity of lusterless whitish grains, quite different in appearance from those which we had become accustomed to refer to monazite, but on subjecting them to microchemical tests these also proved to be cerium-bearing phosphates. Yellow grains of the ordinary aspect are quite abundant in the small dykes of biotite granite in the gneiss about Rio and also in the larger masses of the Serra de Tijuca near Rio and at Pridade in the province of São Paulo, where Mr. Henry Bauer has kindly made a test for me. It is also abundant in uncommonly brilliant and perfect crystals in a small dyke in the gneiss of the Serra de Tingua, a peak of the Serra do Mar range near Rio. They are rare, in comparison with the zircon, in the large dykes near Campo Grande on the Santa Cruz branch of the Dom Pedro II. railroad, and near Bassa do Pirahy on the main line of the same roads, and in a small dyke at a place called Boa Vista on the Ribeira river in the Iguape region. It is interesting to note that the first two of these rocks carry cerium as a silicate in the form of orthite. The Tijuca granite is one of the richest rocks yet examined in the yellow mineral and a rough quantitative test was made on it as follows: A quantity of the rock disintegrated but not completely decomposed was dried in the sun and ground in a mortar to pass through a sieve containing ·45 holes to the linear inch. As the decayed feldspar and mica, which may be presumed to carry the rarer and first formed minerals of this rock, went much finer than this, it was assumed that all of these were set free. From 1906 grams of the ground rock 0·557 grams or 0·029 per cent of residue consisting mainly of the yellow grains were obtained. As the small quantity of zircon and ilmenite in this residue is, probably, but little if any in excess of the loss in washing, the proportion of the yellow mineral can be safely put down as from 0·02–0·03 per cent of the entire mass of this rock.

A red syenite from the Serra do Stauba in the province of Bahia gave the yellow mineral in comparatively large grains, but these were few in number in comparison with the zircon. A mass of clay from the station of Sãn Joãs on the Sorocaba railroad in the province of São Paulo which is presumed to represent the syenitic rock of the vicinity, but which may be from gneiss, gave, with abundant zircons, a mineral giving the same reactions as those from the other rocks but lighter in color and duller in aspect than is usual.

The basic eruptives thus far examined, representing diabase, quartz-diorite mica-diorite and minette have afforded no trace of the yellow mineral.

It should be mentioned that in all these tests care has been taken to select samples representing the principal mass of the rock free from veins and mineral aggregates. In the course of these investigations grains which appear to represent several other rare minerals have been met with, but these have not yet been fully examined.

Since the above was written, a test has been made on a rock richer in monazite than any hitherto examined. This is a fine grained granitite exposed in a large dyke in the road from Engenho Noro to Jacarepagua in the outskirts of Rio de Janeiro. After thorough drying in the sun 3002 grams of the clay resulting from the decomposition of the rock was washed and the residue cleaned by the use of a heavy solution (sp. gr. 3·5), and of the electro-magnet. The residue weighing 2·24 grams, or 0·0746 per cent of the entire mass, consists principally of monazite in exceedingly fine grains with a small amount of zircon and a much smaller amount of other impurities that could not be completely separated without loss of material. The mixed monazite and zircon can safely be put down as 0·07 per cent of the rock.

In a recent excursion to the Argentine Republic Mr. Gordon obtained residues of zircon and monazite from the river-sands at Buenos Ayres and from gneiss and granite decomposed *in situ* at Cordoba.

ART. XIII.—*On the use of Steam in Spectrum Analysis;* by JOHN TROWBRIDGE and W. C. SABINE.

AMONG the difficulties with which the investigator in spectrum analysis must contend is that of obtaining a source of light which is free from constituents other than those which are under examination; and at the same time sufficiently powerful to enable him to photograph the spectra of the latter. The voltaic arc gives a sufficiently strong light to enable one to photograph throughout the visible spectrum; the electric carbons, however, are full of impurities, and it is difficult to interpret the spectra obtained by these means. Moreover, it is not easy to employ the arc spectrum for researches in the ultra violet portion of the spectrum. On the other hand the spark from a Ruhmkorff coil taken between terminals of metals, the spectrum of which we wish to examine, gives us in general spectra comparatively free from impurities, but its light is very feeble compared with that of the electric arc, and even when the spark is obtained by means of a powerful coil which is excited by an alternating dynamo machine an hour is necessary to obtain with a concave grating of 21 feet radius of curvature, on the most sensitive dry plate a photograph of the ultra violet spectra of copper at the wave length 2100.

It becomes an important question then to ascertain whether the time of exposure of the sensitive plate can be shortened by any process; for the outlay in obtaining one photograph in the ultra violet by the means hitherto at our command is very large, involving as we have said the running of an engine of at least two horse power for an hour. In our experiments with a jet of steam we find that the time of exposure of the sensitive plate can be shortened to at least one-third.

We were led to employ steam for the purpose of obtaining the spectra of oxygen and hydrogen with a more powerful electrical excitation than is possible in Geissler tubes. During the winter of 1886, when engaged upon the subject of oxygen in the sun, one of us in connection with Mr. C. C. Hutchins tried to obtain a powerful electric spark in an atmosphere of steam, but the experiments were unsatisfactory. The difficulties were chiefly in the way of proper insulation. Experiments showed that no containing vessel could be employed for the sides of the vessel conducting the electricty from one terminal of the Ruhmkorff coil to the other. No spark could be obtained, and the experiments were abandoned. During the present winter the experiments were renewed. The containing vessel was abandoned and the jet of steam was allowed to impinge directly upon the spark. No effect could be perceived when there were no condensers in the secondary circuit, and with the introduction of small condensers the effect was not marked; but when the number of Leyden jar condensers was increased to four the effect of the jet of steam upon the electric spark was surprising. Its light immediately became comparable with that of the electric arc, enabling us to see the metallic spectra with the naked eye upon the ground glass of the photographic camera without the use of an eye piece. The chamber in which the spark and steam jet were placed became rosy red from the hydrogen arising from the dissociation of the steam. The hydrogen and oxygen lines in the air spectra became very much strengthened, a continuous spectrum showed itself in the neighborhood of the C line and also in the yellow, and a photograph of the air line and metallic line of the terminals employed could be taken in a third of the time which was necessary when the steam jet was not employed.

The apparatus consists merely of a tin box which is placed opposite the slit of the spectroscope. Steam enters at one side and is blown across the terminals of the Ruhmkorff coil which are placed in the box opposite the slit, an outlet on the side opposite from the place of entrance of the steam allows the waste steam to escape into the outer air.

The change of color of the spark is undoubtedly due to hydrogen. The light filling the box above referred to is decidedly red, and the hydrogen line C flashes out with great brilliancy in the midst of a continuous band of red in the spectrum. The metallic line from the terminals are greatly strengthened. The light from iron terminals is especially brilliant. Without the steam the spark between iron terminals seemed to consist of a single line of discharge. When the steam was turned on a great bundle of sparks appeared in the midst of a flaring light and the noise of the spark was greatly increased. This effect can undoubtedly be traced to increased conduction of the air space between the terminals of the Ruhmkorff coil.

The appearance of the spectra led us to examine the question of the spectrum of the Aurora Borealis and its connection with that of aqueous vapor. We believe that the theory that the shifting nature of the northern lights may be due to electrical discharges following strata of air more or less laden with aqueous vapor has been advocated. The appearance of the spectra of the electric spark in steam certainly leads one at first to favor this hypothesis. We have spoken of the marked brilliancy of the hydrogen line and of a continuous red band near this line. The continuous spectrum in the yellow is no less prominent. The observations which have been made on the northern lights do not enable one to make exact comparisons.

The lines given by different observers, however, do not appear to coincide with the prominent lines and bands observed in the air spectrum heightened by steam.

Other observers, among them Professors Liveing and Dewar, have employed steam to obtain steam lines, but we have been unable to find any reference to the remarkable economy in time and in waste of apparatus which results in the use of a jet of steam in spectrum analysis, when the spark method of obtaining the spectra of metals is employed.

Jefferson Physical Laboratory.

Art. XIV.—*A New Personal Equation Machine, for use with the Meridian-Circle;* by A. G. Winterhalter, Lieut., U. S. Navy.

Doctor Walter F. Wislicenus, in charge of the meridian-circle at the Strassburg Observatory, has lately given an account of his investigations, by means of an apparatus devised by himself, of his personal error in recording transit observations. The salient features of the machine are its attachment directly to the meridian-circle and the capability of using it in almost any position of the telescope. These warrant a brief exposition of the contents of Dr. Wislicenus's paper.*

The idea of determining the personal error in transit observations by means of an apparatus appears to have been first enunciated by Professor Kaiser in 1851 in the 5th volume of the Tijdsschrift voor de Wis- en Natuurkundige Wetenschappen. Prazmowski, in Warsaw, seems to have been the first to publish (in Cosmos, vol. iv, p. 445), in 1854, a scheme for a personal equation apparatus.

The author, after a more or less detailed study of the apparatus designed, successively, by Mitchel, Plantamour and Hirsch, C. Wolf, F. Kaiser, E. Kayser, Harkness, Hilgard and Suess, Eastman, R. Wolf, Bredichin, Christie, has arrived at the conclusion that in all previous instruments the disadvantage is presented of a horizontal position of the telescope used and, therefore, of an upright one of the observer, conditions not found in transit observations. From this and other considerations, the author lays down the following features to be complied with by such an apparatus :

1. The personal error should be determined with the same instrument with which observations are made.

*Untersuchungen über den absoluten persönlichen Fehler bei Durchgangsbeobachtungen. Von Dr. Walter F. Wislicenus, Privatdocent and Assistent an der Sternwarte zu Strassburg. Leipzig, 1888. Pp. 50, 9"x12"; one plate, with 3 figures. (Wilhelm Engelmann).

2. The apparatus should allow the error to be determined in various positions of the observer.

These two requisites are found in an apparatus arranged by Professor Bakhuyzen, but the second is secured by a disposition, which is not convenient and which requires much time for adjustment, i. e., for reflecting into the tube of the transit-circle telescope (placed at a determined elevation), the image of the artificial star by means of two mirrors, one of which is secured to the object-end of the telescope. Of the good points of the Leyden apparatus, as described by the author, I had the opportunity of satisfying myself on a recent visit to that observatory.

The task to be accomplished, according to the author, was the fulfillment of three conditions, viz :

1. The apparatus must be capable of application to a transit or meridian circle of the larger class.
2. It should not hinder the free movements of the telescope.
3. The artificial star should traverse the whole field and so imitate as faithfully as possible the motion of a true star.

The design of a machine of this character was facilitated by the fact that in the instrument used an artificial star was already present, namely, the small luminous image which is seen in telescopes with a central field-illumination, produced by the little mirror attached to the inner surface of the object glass. This method of illumining the field, now always used in the Repsold constructions, is, therefore, the first essential to the apparatus.

The machine designed was fitted to the Cauchoix transit of 132 millimeters aperture, an old instrument left by the French Faculty and later modernized for the Strassburg Observatory by the Repsolds. The apparent motion of the artificial star over the wires is secured by causing the ocular to slide laterally, when the image appears to move in the direction of motion of the ocular and is found in the center of its field. The machine's breaks are recorded as followed: On the ocular slide, insulated by a layer of caoutchouc, is a brass plate secured by two scews running into sockets of hard rubber. This bears, at right angles to the line of motion of the ocular, a steel spring having a small brass terminal, carrying a platinum-point, which touches another brass plate secured to the fixed ocular-head on top of an insulating layer. With an electric wire running to each of the insulated plates mentioned, the current is closed, when the platinum-point touches the brass underneath it. In the last-named brass plate a number of parallel lines, corresponding as accurately as possible to the position of the reticule-wires, have been drawn by a dividing engine and filled up with an insulating substance. The platinum-point in passing breaks the current successively for each artificial transit. It can be so set that the machine's break and the observer's break shall differ by a constant amount, allowing them to appear in succession on the chronograph sheet and be recorded by one pen.

The motor used was the clock-work of a Hipp chronograph. On one end of the horizontal axis of the telescope the two halves of a wheel are clamped. This wheel has a double row of teeth, one row gearing into the chronograph-train used as the motive power, the other into the connections for moving the ocular. At the latter, the arrangement contemplates, by means of the raising of a cam, the alternate engagement of a pinion in upper and lower racks for motions forward and backward. This change of direction can be made without the eye leaving the eye-piece. By combining wheels of different numbers of teeth, a large number of different speeds can be given to the clock-work.

I pass over a number of interesting experiments, such as those with a flat platinum-point for slow motions and a fine one for fast motions, experiments with various insulating substances for filling the grooves representing the wires, and will mention that the application of the apparatus to the Cauchoix instrument in question restricts the motion of the telescope through 116° of the 360° of a complete revolution, of which only about 26° are above the horizon. This facility of movement enables the observer to take up any desired position on or off the observing-couch. Designed for a new instrument, still more ample motion might be secured. The motive power should impart a regular motion and should be capable of regulation without the insertion of various wheels.

The author gives the results of numerous observations made for the determination of his personal error, using the equation

$$(1) \quad x = \frac{a+b}{2},$$

where x is the absolute personal error; a, the difference taken from the chronograph record between the machine's and the observer's breaks for motion in one direction; b, the same for motion in the opposite direction. All instrumental inaccuracies are eliminated, as may be seen from the two equations (a), (b), from which (1) is derived:

$$(a) \quad a = x + c \pm d + f, \text{ for forward motion ;}$$
$$(b) \quad b = x - c \mp d - f, \text{ for backward motion ;}$$

where, in seconds of time,

c is the error introduced by a slight eccentric displacement of the image produced by the motion of the ocular;

d, the time by which the machine's break occurs earlier or later than the transit;
f, the time by which the machine's break precedes the transit for all threads, by reason of the adjustment of the platinum-point;
$\pm$, prefixed according as the machine's break occurs $^{\text{earlier}}_{\text{later}}$ than the corresponding transit of the artificial star.

The time elapsing between a transit and the corresponding automatic break must be the same for both directions of the motion of the ocular, which must be assured by the use of a uniformly acting clock-work. A table is computed to show the small influence of irregularities in the performance of the driving clock, provided only the ratio $\frac{t}{T}$ is confined within narrow limits; in this, t represents the amount in seconds by which the automatic break precedes or follows the actual transit; T, the time, in seconds, occupied in the forward motion of the ocular, $T \pm d$ being the time for backward motion.

The observations made by the author with this apparatus are exhaustive and may be divided into two principal groups: the first, consisting of three divisions, in each of which the rate of motion of the star remained unchanged, while the telescope was made to assume five typical positions; the second, in which the position of the telescope and rate of motion were uniformly changed, so that the artificial star should have that speed of transit corresponding to the observation of an actual star in transit in that position of the telescope.

In observing, the artificial star was allowed to run over the whole field and the transits over 21 threads were noted, giving 21 values for the personal error, each depending on two transits, for forward and backward motions of the ocular. The means which I have collated below are formed from those of several series on a number (usually five) of days. The author uses in his notation the expression,

Actual transit − observed = personal equation.

So that the result is the correction and has the sign with which it is to be applied to an observation.

First Group.

1.	2.	3.	4.
+90°	−0ˢ·190	−0ˢ·013	+0ˢ·519
+45	−0 ·178	−0 ·020	+0 ·477
0	−0 ·207	−0 ·046	+0 ·323
−45	−0 ·127	+0 ·041	+0 ·410
−90	+0 ·140	+0 ·497	+1 ·772

In this table, the first column indicates the position of the telescope, counting from the horizon, + above it, − below;

the remaining columns give the personal equation with rates of motion of the star corresponding, respectively, to 11° 21′·0, 60° 8′·5 and 80° 19′·0 declination.

The general deduction is: In the author's personal equation a dependence is proved on the position of the telescope, i. e., on the corresponding position of the body.

Second Group.

1.	2.
−15° 45′	−0s ·115
+15 0	−0 ·096
+59 40 U. C.	+0 ·017
+82 40 L. C.	+0 ·463
+59 40 L. C.	+0 ·040

In this table, the first column gives the setting in declination as read off on the circle, with an indication of upper and lower culminations, the motion being, as stated, that of a star of that declination; the second column, the personal equation.

The general deduction is: the amount of the personal equation is algebraically increased and changes sign (becoming positive) for slow motions; this is also shown by the first group. Besides, the second group indicates, although not as plainly as the first, the dependence of the equation on the position of the observer.

The author finds also that in time his equation changes. For a star of equatorial motion, it was found

1886. Dec. 13–22 :	−0s ·178;
1887. May 23–27 :	−0 ·105;
1888. March 17 :	+0 ·148.

A comparison of the two groups with results obtained in Leyden in 1886 is interesting, but does not safely show a variation depending on varying positions of the telescope.

Physiological investigations were not attempted nor were generalizations for others, but the author draws two conclusions applicable to his own case.

The absolute personal error is with stars of a mean speed of transit a minimum, increases with an increase and decrease of the speed and, in the latter case, in general more rapidly than in the former.

The absolute personal error is, in general, dependent on the position of the telescope and the requisite position of the body of the observer, as also on the observed object,—star or limb.

An ingenious disposition of the apparatus permitted the author to examine his personal error in observing the limb of disks of various diameters. A brass ring was blackened and fastened to the cell of the eye-piece on the side nearest the reticule, leaving, however, the entire aperture free. On this ring a glass-plate, 0·1 millimeter thick, was secured with shellac. This plate had a circular opening in its center and was attached in such a position that the edge of the opening passed through the center of the ring. It is obvious that the illumination of the field was now divided into a bright and a somewhat darker part by an arc passing through the center of the field.

There is seen, then, a part of a bright disk on a half-bright ground, transiting the wires by the motion of the ocular, as before. By using plates of different-sized openings, disks were obtained corresponding to angular radii of

$$16' \, 2'', \; 11' \, 27'', \; 7' \, 27'', \; 1' \, 5'', \; 10''.$$

The motion in one direction gives the transit of either the preceding or the following limb; to get the same limb for the reversed motion, it would be necessary to turn the ocular through 180°. Owing to a limited time, the observations were made only so as to take the mean between errors of preceding and following limbs.

For a motion corresponding to that of a star of 11° 21′ declination, the personal equations in observing the limbs, in the order of angular radius above given, were:

$$+0^{s}\cdot089, \; +0^{s}\cdot259, \; +0^{s}\cdot213, \; +0^{s}\cdot183, \; +0^{s}\cdot157,$$

while for a star the equation in the same position of the telescope was found to be $+0^{s}\cdot148$. Forming the differences limb − star, in the same order, we have:

$$-0^{s}\cdot059, \; +0^{s}\cdot111, \; +0^{s}\cdot065, \; +0^{s}\cdot035, \; +0^{s}\cdot009.$$

The observations in this last investigation are not complete, but it seems to be established that the author's personal equation is different for observation of limb and of star, the difference generally increasing with the increase of the size of the disk observed.

The advantage of the author's apparatus remains in the fact that with it the circumstances of transit observations can be closely imitated, both as regards the position of the observer and the fulfillment of other desirable conditions. Objections of complication can scarcely be made, as it is not likely that an apparatus of an entirely simple character will be devised to permit a complete investigation of the peculiarities of the personal error.

ART. XV. — *The Subsidence of Fine Solid Particles in Liquids;** by CARL BARUS.

1. THROUGHOUT this paper the motion of the corpuscles through the liquid is of the kind premised in treating capillary transpiration: in both cases solid and liquid move relatively to each other under conditions by which eddies are excluded, and the whole kinetic energy is at once converted into molecular kinetic energy, or heat.

In my earlier work I endeavored to analyze the phenomenon of sedimentation into parts such that the conditions under which the subsidence is to be explained from a chemical, or from a physical, point of view, may be better discernible. To do this I first considered the question in its purely mechanical aspects.† If P be the resistance encountered by a solid spherule of radius r, moving through a viscous liquid at the rate x, and if k be the frictional coefficient, then $P=6\pi krx$. Again, the effective part of the weight of the particle is $P'=\frac{4}{3}\pi r^3(\rho-\rho')g$, where g is the acceleration of gravity and ρ and ρ' the density of solid particle and liquid, respectively. In case of uniform motion $P=P'$. Hence $x=\frac{2}{9k}r^2(\rho-\rho')g$ . . . . (1)

In any given case of thoroughly triturated material the particles vary in size from a very small to a relatively large value; but by far the greater number approach a certain mean figure and dimension. An example of this condition of things may be formulated. To avoid mathematical entanglement I will select $y=Ax^{\frac{3}{2}}e^{-x^2}$ . . . . . (2) where y is the probable occurrence of the rate of subsidence x. If now the turbidity of the liquid (avoiding optical considerations) be defined as proportional to the mass of solid material particles suspended in unit of volume of liquid, then the degree of turbity which the given

*The present article, being a continuation of Bulletin U. S. G. S., No. 36, 1886, is largely based the experimental evidence there tabulated. Mr. William Durham (Chem. News, xxx, p. 57, 1874; id. xxxvii, p. 47, 1878) was the first to give an incentive to this class of experiments. Much of our knowledge of the effect of precipitants is due to him. Moreover, the theoretical views at which he ultimately arrives may be regarded as a definite point of departure. In this country Prof. T. S. Hunt (Proc. Boston Soc. Nat. Hist., Feb., 1874), Prof. W. H. Brewer (National Acad. Sc., 1883; Am. Journal, (3), xxix, p. 1, 1885) and Prof. C. R. Stuntz (Cincinnati Soc. Nat. Hist., Feb., 1886) have occupied themselves with similar work. Prof. Stuntz's paper contains further references among others to Waldie's results (Journal Asiatic Soc., of Bengal, 1873; Chem. News, 1873). Meanwhile Mr. W. Hallock has made experiments on the subsidence of lampblack in connection with his work on the density of that substance (Cf. Bull. U. S. G. S., No. 42, p. 132, 1887). I may add that my own experiments were suggested by Prof. Brewer's memoir.

† Cf. G. Kirchhoff, Mathematische Physik, lecture 26, § 4, 1876.

ydx particles add to the liquid is, *caet. par.*, proportional to r^3ydx, where r is the mean radius. Hence the turbidity, T, at the outset of the experiment (immediately after shaking) is $T = T_0 \int_0^\infty r^3ydx = T_0$, where equations (1) and (2) have been incorporated.

If the plane at a depth d below the surface of the liquid be regarded, then at a time t after shaking the residual turbidity is

$$(3) \ldots\ldots \quad T_d = T_0 \int_0^{\frac{d}{t}} r^3ydx = T_0 \left(1 - \left(1 + \frac{d^2}{t^2}\right) e^{-\frac{d^2}{t^2}}\right).$$

The equation describes the observed occurrences fairly well. In proportion as the time of subsidence is greater, the tube shows opacity at the bottom, shading off gradually upward, through translucency, into clearness at the top. If instead of equation (2) there be introduced the condition of a more abrupt maximum, if in other words the particles be very nearly of the same size, then subsidence must take place in unbroken column capped by a plane surface which at the time zero coincided with the free surface of the liquid. Again suppose one-half of the particles of this column differ in some way uniformly from the other half. Then at the outset there are two continuous columns coinciding, or as it were interpenetrating throughout their extent. But the rate of subsidence of these two columns is necessarily different, since the particles, each for each, differ in density, radius and frictional qualities by given fixed amounts. Hence the two surfaces of demarcation which at the time zero coincided with the free surface. In general if there be n groups of particles uniformly distributed, then at the time zero n continuous columns interpenetrate and coincide throughout their extent. At the time t, the free surface will be represented by n consecutive surfaces of demarcation below it, each of which caps a column, the particles of which form a distinct group. This phenomenon is Prof. Brewer's stratified subsidence. In the case of particles which have undergone an earlier fractionated sedimentation either in nature or in the arts, the occurrence of groups possessing the distinctive characteristics here discussed is not improbable. On the other hand when during subsidence the surfaces of demarcation follow each other in regular succession, one is tempted to look for something more than an adventitious cause for the phenomenon. An orderly arrangement of groups of particles might for instance indicate successive stages of hydration. Cf. § 6. In case of stratified subsidence, it is convenient to speak of the planes of demarcation as orders of surfaces, numbering them from the top downward. Seven or even ten orders are not uncommon.

2. With these deductions as a point of departure, I then attempted to find relations between rates of subsidence, the viscous and capillary properties of the liquid, and its electrical behavior, under analogous conditions of concentration and of temperature. This general survey proved that the phenomenon of sedimentation is unique; that the frictional resistances encountered by the particles are apparently different from the viscosities of the liquids in which subsidence takes place; that many of the occurrences observed are closely allied to the electrolytic and the capillary properties of this liquid. Finally utilizing Prof. Brewer's stratified subsidence, which I obtained very clearly with certain kinds of tripoli, I commenced a series of more rigorously quantitative measurements showing that *caet. par.*, rate of subsidence is primarily dependent on the turbidity of the mixture.

In my experiments with tripoli, the observed rates of subsidence ($cm / (sec \times 10^6)$) in ether, alcohol, water, glycerine were 7500, 1300, 3, 0·09, respectively; but owing to the difference in character of the divers precipitates, these figures have no further signification than to emphasize the said difference in character. §§ 5,6. Let water and ether be mixed so that there shall be equal bulks of etherized water below, and aqueous ether above, and then let the dust (bole) be added. If now the mixture is violently shaken and then allowed to subside, the ether is washed clean of particles in a few minutes whereas the sediments remain suspended in water for weeks and even months. Here however the separation and subsidence is promoted by the surface energy of water.

On the other hand if dry tripoli be added to ether dried over $CaCl_2$, in a test tube, and if the tube be held obliquely after shaking, subsidence is so rapid that the upward current of ether along the upper line of the tube is almost tempestuous.

The close relation of the present phenomena to electrolytic phenomena appears at once by observing that so little as a single molecule of HCl (for instance) added to 10,000 or even 50,000 molecules of H_2O, produces appreciable increase of the rate of subsidence. Remembering that the arrangement is in three dimensions, and supposing the molecule HCl as large as the molecule H_2O, the effect of the molecule HCl must be appreciable at a distance of at least 30 times its own radius,* and extend much beyond this asymptotically. Quincke's radius

* The estimated diameter of H_2O (distance between centers of adjacent molecules $2\rho = 40/10^{9cm}$) I take from Kohlrausch (Wied. Ann., vi, p. 209, 1879). In how far the molecule of liquid water differs from H_2O remains to be seen. Indeed the underlying cause of continuous and of discontinuous fusion and vaporization, and the cause of allied phenomena such as retarded solidification, ebullition, etc., seems clearly to be some form of polymerization. Nevertheless the atomic theory in its present stage of development fails to suggest a satisfactory mechanism for these occurrences.

of capillary attraction, ·000005^{cm}, being at least 100 times the molecular radius H_2O, it appears that the striking effect of the molecule HCl in accelerating subsidence, is not an abnormal occurrence, at least from a physical point of view. Other relations are adduced in the Bulletin.

3. To account for these phenomena as a whole, Mr. Durham, in his second paper, proposes an hypothesis in virtue of which the scope of the action of affinity is enlarged, and suspension regarded as the lower limit of solution. This view is rapidly gaining ground; nevertheless without concise experimental reference to the density and size of the solid particles and the viscosity of the liquid, Mr. Durham's explanation contains no sufficient reason for the observed suspension, nor for changes of rate of subsidence. Prof. Brewer's ingenious hypothesis of colloidal hydrates so constituted that the particles may ultimately swell up and float something like gelatinous silica, or even like starch grains, is more direct; and before further reasons of the cause of suspension are sought the validity of this inference must be tested. This test is feasible, I think. If the phenomenal difference of rate with which the same particles subside in water and in ether is due to volume changes of the particles, then a marked difference in the density of the sediment (clay or tripoli) in water and in ether respectively, must be experimentally demonstrable. Cf. equation (1). I made these experiments with both solids, using two nearly identical density flasks, one for water and the other for ether, in the usual way. The powders were sampled and dried at 200° in an air bath for half a day, transferred to the pycnometers, dried and weighed when cold. They were then left in a dessicator for 18 hours and again weighed; and finally dried in vacuo and weighed. The results throughout were satisfactorily constant. By aid of an apparatus specially devised for the purpose, the two flasks were once more thoroughly exhausted (mercury air pump), and then filled with water and with ether respectively, in vacuo, over sulphuric acid. In both cases (the experiments were made consecutively), the vacuum ebullition was kept up for some time to give full assurance of the expulsion of air, etc. The density of the ether had been previously determined by the same flasks, once for each experiment.

Thus I obtained for tripoli,

$$\begin{cases} \text{In water, density } = \Delta_w = 2{\cdot}672, \\ \text{In ether, density } = \Delta_e = 2{\cdot}697. \end{cases}$$

Again, I obtained for white bole,

$$\begin{cases} \text{In water, } \Delta^w = 2{\cdot}639, \\ \text{In ether, } \Delta^e = 2{\cdot}663. \end{cases}$$

The manipulation being somewhat difficult, the observed differences of Δ_w and Δ_e are no larger than the many sources of error led me to anticipate, particularly in view of the fact that the two samples for ether and for water may not have been absolutely identical. The concentrated ether used was the same commercial reagent with which I obtained the subsidence phenomena. In consequence of the high but normal values of both Δ_w and Δ_e, I saw no need of specially purifying it. I add finally that after calcination, the dry tripoli lost 1·2 per cent in weight, and the dry bole about 11·4 per cent. In both cases this is probably water of constitution, the elimination of which was of course not permissible. In spite of differences of chemical composition, the bole and tripoli particles are about equally suspended before and after calcination, and the phenomena with ether dried over $CaCl_2$ are identical with the above.

4. These results show that the densities in the two cases (sediment in water and in ether respectively), are not essentially different. Moreover, the density of tripoli is so nearly that of quartz, and the density of bole so nearly that of kaolinite, as to leave the hydration hypothesis very seriously in the lurch, so far as favorable evidence is concerned. It is improbable that the addition of water to the dry powder is accompanied by sufficiently marked volume changes; it is certain that the enormous variation of rates of subsidence actually observed when the particles descend in water, in solutions, and in ether, must be referred to some general cause apart from the density of the particles and the viscosity of the liquids.

5. This premised, the explanation of sedimentation may be so made as to give emphasis to the following principle: If particles of comminuted solid are shaken up in a liquid, the distribution of parts after shaking will tend to take place in such a way that the potential energy of the system of solid particles and liquid, at every stage of subsidence, is the minimum compatible with the given conditions. In the case of solid particles and pure water the configuration answering this condition, is schematically,

Particle, water. . . . . Particle, water.

In the case of solid particles and ether, or of solid particles and solutions, this configuration is schematically,

Particle, particles. . . . . ether, ether.

For the exemplification of this inference my paper contains varied experimental evidence. The principle asserts that in case of water the sediment is graded and the suspended material granular, whereas in ether the sediment is apparently homogeneous, as I found; that the bulk of sediment is necessarily less in water than in ether, being compact in the first instance and of a microscopically arched or castellated internal structure in the second instance, as I found; that the effect of a precipitant is particularly marked when the mixture is densely turbid with relatively coarse particles, as I found; that finally the phenomena of sedimentation must be of a distinct and special kind, and by no means the immediate converse of capillary viscous transpiration. The inferences are thus based on equation (1) above, and follow at once when k and ρ are nearly constant. In the Bulletin, I computed the relative size (radii) of particle of tripoli subsiding in water, alcohol, ether, to be 1, 19 and 24 respectively.*

It is exceedingly curious to note in case of water, that despite the phenomenally large surface energy of the liquid, subsidence takes place in such a way that for a given mass of suspended sediment, the surfaces of separation are a maximum. On the other hand, in case of subsidence in ether, or in salt solutions, the solid particles behave much like the capillary spherules of a heavy liquid, shaken up in a lighter liquid with which it does not mix. In other words the tendency here is to reduce surfaces of separation to the least possible value, large particles growing in mass and bulk mechanically at the expense of smaller particles. Finally it is clear that the condition of stratified sedimentation is very slow subsidence of a granular precipitate.

The experimental evidence adduced bears directly on the size of the particles of any precipitate. A given mass of small solid particles presupposed, the observations of the foregoing paragraph make it probable that the potential energy of the system of solid particles and liquid increases with the radius of the particle. These observations also show that the potential energy of the system of solid particles alone, decreases as the size of the particles increases, a state of things due both to the immediate action between solid particles, and probably also to the surface energy of the liquid in which suspension takes

* This is the first of the hypotheses which I develop in detail in Bulletin No. 36, pp. 34, 35, 37. In a re-calculation since made with more accurate values of k (water 0° to 100°, Slotte in Wied. Ann., xx, p. 262, 1883; ethyl and methyl alcohol, Graham in Phil. Mag., (4), xxiv, p. 238, 1861; ether, Landolt and Boernstein's Tables, p. 153; glycerine estimated $\eta=10$ g cm^{-1} sec.$^{-1}$), the radii of the particles in water, ethyl alcohol, methyl alcohol, ether and glycerine are found to be $r=0{\cdot}000009^{cm}$, $0{\cdot}00019^{cm}$, $0{\cdot}00018^{cm}$, $0{\cdot}00020^{cm}$ and $0{\cdot}00005^{cm}$ respectively. In case of bole suspended in water at 15° and 100°, the radii were approximately $< 0{\cdot}000010^{cm}$ and $> 0{\cdot}000020^{cm}$. § 6 points out, that whereas these dimensions may be called in question when considered absolutely, the relative values of r are probably true.

The fact that particles so extremely light descend at all is a result showing the almost marvelous delicacy of these experiments. In case of tripoli-water, for instance, the estimated weight of particle is only $1/10^{11}$ milligrams; being invisible microscopically it must have weighed less than $1/10^{10}$ milligram.

place. Under these conflicting conditions it is probable that there is a critical shell, within which the energy solid-liquid decreases less rapidly than the energy solid-solid; and beyond which shell the energy solid-liquid increases more rapidly than the energy solid-solid. This critical shell, being compatible with the conditions of minimum potential energy of the subsiding system as a whole, is the size of the precipitated particles: for any change of the radius of a particle bounded by the critical shell, implies an expenditure of work, which under the usual conditions of precipitation is not available.

6. I have finally to endeavor to assign some value to the radius of the critical shell for the case of the above water suspensions. In my experiments with tripoli, rates of subsidence, x, in *cm* (*sec.* $\times 10^6$), varied from $x = 1$ to $x = 20$, according as higher orders of surfaces or turbidities of lower degree, were chosen. Taking the more usual value, $x = 3$, the radius of the particles subsiding was probably not less than 400 times the molecular radius of water. The bole particles under analogous conditions of suspension in H_2O, were smaller, probably only 100 water radii. In Prof. Brewer's indefinitely suspended clays the limit of comminution can not be estimated at all, except perhaps from purely optical considerations.* Whether in this extreme case colloidal hydration with concomitant volume changes is still demonstrably absent, remains to be seen. To test it, a sufficient quantity of the extremely fine material would have to be collected and dried by low temperature evaporation.

Again in Bulletin No. 35 (p. 21), I point out at some length that "when the particles decrease (in size) from some estimable mean value indefinitely," liquid viscosity, being at least partially if not largely kinetic in character, can no longer be considered constant as regards time; that therefore a particle may descend, or in other words the continuous and constant action of gravity produce an effect even when the weight of the particle is below the mean or physically measurable value of the friction encountered; that the limits of time-variation of viscosity will increase as the radius of the circumscribed space decreases. In such a case the particle to be stationary must weigh less than the lower limit of the variable viscosity—a quantity which may be reasonably conceived to approach zero very nearly. I carried these inferences one step further by supposing, rationally, I think,

* The optical properties of light reflected from particles small in comparison with the wave length of light are discussed by Stokes (Phil. Trans., 1852, p. 530). How large a particle may be without interfering with optical clearness, I can not say. It is well to bear in mind that the suspension of corpuscles consisting of a small number, say ten molecules per critical shell, would bear the outward characteristics of solution.

that the limits within which this *elementary* viscosity (say) varies, will increase with the degree of molecular agitation of the liquid. On the basis of this postulate I then endeavored to explain sedimentation kinetically, both in its relations to temperature and the effect of precipitants.

One point which antagonizes this hypothesis must not be lost sight of: Two or more particles sufficiently near together will tend to screen each other; and receiving impact mainly on their outer surfaces will be brought to permanent coherence so long as the conditions of pronounced molecular agitation last. This is actually observed in water suspensions at 100°, in solution-suspensions, in ether suspensions, etc. In these instances there seems to be difficulty in preserving the granular state (Bull. 36, p. 38).

To pass judgment on the validity of such explanation, it is necessary to have in hand better statistics of the size of the particles relatively to the water molecule, than are now available. Inasmuch as the particles in pure water are individualized and granular, it is apparantly at once permissible to infer the size of the particles from the observed rates of subsidence. But my observations show that the said rate decreases in marked degree with the turbidity of the mixture. Hence the known formulæ for single particles are not rigorously applicable, though it cannot be asserted whether the cause of discrepancy is physical or mathematical in kind. It follows that special deductions must be made for the subsidence of stated groups of particles before an estimate of their mean size can fairly be obtained.

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Art. XVI.—*A Comparison of the Electric Theory of Light and Sir William Thomson's Theory of a Quasi-labile Ether;* by J. Willard Gibbs.

A remarkable paper by Sir William Thomson, in the November number of the *Philosophical Magazine*, has opened a new vista in the possibilities of the theory of an elastic ether. Since the general theory of elasticity gives three waves characterized by different directions of displacement for a single wave-plane, while the phenomena of optics show but two, the first point in accomodating any theory to observation, is to get rid (absolutely or sensibly) of the third wave. For this end, it has been common to make the ether incompressible, or, as it is sometimes expressed, to make the velocity of the third wave infinite. The velocity of the wave of compression becomes in fact infinite as the compressibility vanishes. Of course it has not escaped the notice of physicists that we may also get rid of the third wave by making its velocity zero, as may be done by giving certain values to the constants which express the elastic properties of the medium, but such values have appeared impossible, as involving an unstable state of the medium. The condition of incompressibility, absolute or approximate, has therefore appeared necessary.* This question of instability has now, however, been subjected to a more searching examination, with the result that the instability does not really exist "*provided we either suppose the medium to extend all through boundless space, or give it a fixed containing vessel as its boundary.*" This renders possible a very simple theory of light, which has been shown to give Fresnel's laws for the intensities of reflected and refracted light and for double refraction, so far as concerns the phenomena which can be directly observed. The displacement in an aeolotropic medium is in the same plane passing through the wave-normal as was supposed by Fresnel, but its position in that plane is different, being perpendicular to the ray instead of to the wave-normal.†

It is the object of this paper to compare this new theory with the electric theory of light. In the limiting cases, that is, when we regard the velocity of the missing wave in the elastic theory as zero, and in the electric theory as infinite, we shall find a remarkable correspondence between the two theories, the motions of monochromatic light within isotropic or aeolotropic media of any degree of transparency or opacity, and at the boundary between two such media, being represented by equations absolutely identical, except that the symbols which denote displacement in one theory denote force in the other, and *vice versâ*.‡ In order to exhibit this correspondence completely and clearly, it is necessary that the fundamental principles of the two theories should be treated with the same generality, and, so far as possible, by the same method. The immediate consequences of the new theory will therefore be deduced with the same generality and essentially by the same method which has been used with reference to the electric theory in a former volume of this Journal (vol. xxv, p. 107).

* It was under this impression that the paper entitled "A Comparison of the Elastic and the Electric Theories of Light with respect to the Law of Double refraction and the dispersion of colors," in the June number of this Journal, was written. The conclusions of that paper, except so far as respects the dispersion of colors, will not apply to the new theory.

† Sir William Thomson, *loc. citat.* R. T. Glazebrook, *Phil. Mag.*, December, 1888.

‡ In giving us a new interpretation of the equations of the electric theory, the author of the new theory has in fact enriched the mathematical theory of physics with something which may be compared to the celebrated *principle of duality* in geometry.

The elastic properties of the ether, according to the new theory, *in its limiting case*, may be very simply expressed by means of a vector operator, for which we shall use Maxwell's designation. The *curl* of a vector is defined to be another vector so derived from the first that if u, v, w be the rectangular components of the first, and u', v', w', those of its curl,

$$u' = \frac{dw}{dy} - \frac{dv}{dz}, \quad v' = \frac{du}{dz} - \frac{dw}{dx}, \quad w' = \frac{dv}{dx} - \frac{du}{dy}, \qquad (1)$$

where x, y, z are rectangular coördinates. With this understanding, if the displacement of the ether is represented by the vector $\mathfrak{E}$, the force exerted upon any element by the surrounding ether will be

$$-\ \mathrm{B}\ \mathrm{curl}\ \mathrm{curl}\ \mathfrak{E}\ dx\ dy\ dz, \qquad (2)$$

where B is a scalar (the so-called *rigidity* of the ether) having the same constant value throughout all space, whether ponderable matter is present or not.

Where there is no ponderable matter, this force must be equated to the reaction of the inertia of the ether. This gives, with omission of the common factor $dx\ dy\ dz$,

$$\mathrm{A}\ddot{\mathfrak{E}} = -\ \mathrm{B}\ \mathrm{curl}\ \mathrm{curl}\ \mathfrak{E}, \qquad (3)$$

where A denotes the density of the ether.

The presence of ponderable matter disturbs the motions of the ether, and renders them too complicated for us to follow in detail. Nor is this necessary, for the quantities which occur in the equations of optics represent average values, taken over spaces large enough to smooth out the irregularities due to the ponderable particles, although very small as measured by a wave-length.* Now the general principles of harmonic motion† show that to maintain in any element of volume the motion represented by

$$\mathfrak{E} = \mathfrak{A} e^{2\pi\iota\frac{t}{p}}, \qquad (4)$$

$\mathfrak{A}$ being a complex vector constant, will require a force from outside represented by a complex linear vector function of $\mathfrak{E}$, that is, the three components of the force will be complex

* This is in no respect different from what is always tacitly understood in the theory of sound, where the displacements, velocities, densities considered are always such average values. But in the theory of light, it is desirable to have the fact clearly in mind on account of the two interpenetrating media (imponderable and ponderable), the laws of light not being in all respects the same as they would be for a single homogeneous medium.

† See Lord Rayleigh's *Theory of Sound*, vol i, chapters iv, v.

linear functions of the three components of $\mathfrak{E}$. We shall represent this force by

$$\mathrm{B}\,\Psi\ddot{\mathfrak{E}}\,dx\,dy\,dz, \qquad (5)$$

where Ψ represents a complex linear vector function.*

If we now equate the force required to maintain the motion in any element to that exerted upon the element by the surrounding ether, we have the equation

$$\Psi\ddot{\mathfrak{E}} = -\,\mathrm{curl\ curl}\ \mathfrak{E}, \qquad (6)$$

which expresses the general law for the motion of monochromatic light within any sensibly homogeneous medium, and may be regarded as implicitly including the conditions relating to the boundary of two such media, which are necessary for determining the intensities of reflected and refracted light.

For let $u,\ v,\ w$ be the components of $\mathfrak{E}$,
$u',\ v',\ w'$ " " curl $\mathfrak{E}$,
$u'',\ v'',\ w''$ " " curl curl $\mathfrak{E}$;

so that

$$u' = \frac{dw}{dy} - \frac{dv}{dz}, \quad v' = \frac{du}{dz} - \frac{dw}{dx}, \quad w' = \frac{dv}{dx} - \frac{du}{dy},$$

$$u'' = \frac{dw'}{dy} - \frac{dv'}{dz}, \quad v'' = \frac{du'}{dz} - \frac{dw'}{dx}, \quad w'' = \frac{dv'}{dx} - \frac{du'}{dy};$$

and let the interface be perpendicular to the axis of Z. It is evident that if u' or v' is discontinuous at the interface, the value of u'' or v'' becomes in a sense infinite, *i. e.*, curl curl $\mathfrak{E}$, and therefore by (6) $\Psi\ddot{\mathfrak{E}}$, will be infinite. Now both $\mathfrak{E}$ and Ψ are discontinuous at the interface, but infinite values for $\Psi\ddot{\mathfrak{E}}$ are not admissible. Therefore u' and v' are continuous. Again, if u or v is discontinuous, u' or v' will become infinite, and therefore u'' or v''. Therefore u and v are continuous. These conditions may be expressed in the most general manner by saying that the components of $\mathfrak{E}$ and curl $\mathfrak{E}$ parallel to the interface are continuous. This gives four complex scalar conditions, or in all eight scalar conditions, for the motion at the interface, which are sufficient to determine the amplitude and

* It amounts essentially to the same thing, whether we regard the force as a linear vector function of $\mathfrak{E}$ or of $\ddot{\mathfrak{E}}$, since these differ only by the constant factor $-\frac{4\pi^2}{p^2}$. But there are some advantages in expressing the force as a function of $\ddot{\mathfrak{E}}$, because the greater part of the force, in the most important cases, is required to overcome the inertia of the ether, and is thus more immediately connected with $\ddot{\mathfrak{E}}$.

phase of the two reflected and the two refracted rays in the most general case. It is easy, however, to deduce from these four complex conditions, two others, which are interesting and sometimes convenient. It is evident from the definitions of w' and w'' that if u, v, u', and v' are continuous at the interface w' and w'' will also be continuous. Now $-w''$ is equal to the component of $\Psi\ddot{\mathfrak{E}}$ normal to the interface. The following quantities are therefore continuous at the interface:

$$\left.\begin{array}{ll}\text{the components parallel to the interface of} & \mathfrak{E},\\ \text{the component normal to the interface of} & \Psi\mathfrak{E},\\ \text{all components of} & \text{curl}\,\mathfrak{E}.\end{array}\right\} \qquad (7)$$

To compare these results with those derived from the electrical theory, we may take the general equation of monochromatic light on the electrical hypothesis from a paper in a former volume of this Journal. This equation, which with an unessential difference of notation may be written*

$$-\text{Pot}\,\ddot{\mathfrak{F}} - \nabla Q = 4\pi\Phi\mathfrak{F}, \qquad (8)$$

was established by a method and considerations similar to those which have been used to establish equation (6), except that the ordinary law of electro-dynamic induction had the place of the new law of elasticity. $\mathfrak{F}$ is a complex vector representing the electrical displacement as a harmonic function of the time; Φ is a complex linear vector operator, such that $4\pi\Phi\,\mathfrak{F}$ represents the electromotive force necessary to keep up the vibration $\mathfrak{F}$. Q is a complex scalar representing the electrostatic potential, ∇Q the vector of which the three components are

$$\frac{dQ}{dx},\quad \frac{dQ}{dy},\quad \frac{dQ}{dz}.$$

Pot denotes the operation by which in the theory of gravitation the potential is calculated from the density of matter.† When it is applied as here to a vector, the three components of the result are to be calculated separately from the three components of the operand. $-\nabla Q$ is therefore the electrostatic force, and $-\text{Pot}\,\ddot{\mathfrak{F}}$ the electrodynamic force. In establishing the equation, it was not assumed that the electrical motions are *solenoidal*, or such as to satisfy the so-called "equation of continuity." We may now, however, make this assumption,

* See this Journal, vol. xxv, p. 114, equation (12).

† The symbol $-$Pot is therefore equivalent to $4\pi\nabla^{-2}$, as used by Sir William Thomson (with a happy economy of symbols) at the last meeting of British Association to express the same law of electrodynamic induction, except that the symbol is here used as a vector operator. See Nature, vol. xxxviii, p. 571, *sub. init.*

since it is the extreme case of the electric theory which we are to compare with the extreme case of the elastic.

It results from the definitions of *curl* and ∇ that curl ∇Q=0. We may therefore eliminate Q from equation (8) by taking the curl. This gives

$$-\text{curl Pot } \ddot{\mathfrak{F}} = 4\pi \text{ curl } \Phi\mathfrak{F}, \tag{9}$$

Since curl curl and $\frac{1}{4\pi}$ Pot are inverse operators for solenoidal vectors, we may get rid of the symbol Pot by taking the curl again. We thus get

$$-\ddot{\mathfrak{F}} = \text{curl curl } \Phi\mathfrak{F}. \tag{10}$$

The conditions for the motion at the boundary between different media are easily obtained from the following considerations. Pot $\ddot{\mathfrak{F}}$ and Q are evidently continuous at the interface. Therefore the components parallel to the interface of ∇Q, and by (8) of $\Phi\mathfrak{F}$, will be continuous. Again, curl Pot $\ddot{\mathfrak{F}}$ is continuous at the interface, as appears from the consideration that curl Pot $\dot{\mathfrak{F}}$ is the magnetic force due to the electrical motions $\dot{\mathfrak{F}}$. Therefore, by (9), curl $\Phi\mathfrak{F}$ is continuous. The solenoidal condition requires that the component of $\mathfrak{F}$ normal to the interface shall be continuous.

The following quantities are therefore continuous at the interface:

$$\left.\begin{array}{ll} \text{the components parallel to the interface of} & \Phi\mathfrak{F}, \\ \text{the component normal to the interface of} & \mathfrak{F}, \\ \text{all components of} & \text{curl } \Phi\mathfrak{F}. \end{array}\right\} \tag{11}$$

Of these conditions, the two relating to the normal components of $\mathfrak{F}$ and curl $\Phi\mathfrak{F}$ are easily shown to result from the other four conditions, as in the analogous case in the elastic theory.

If we now compare in the two theories the differential equations of the motion of monochromatic light for the interior of a sensibly homogeneous medium, (6) and (10), and the special conditions for the boundary between two such media as represented by the continuity of the quantities (7) and (11), we find that these equations and conditions become identical, if

$$\mathfrak{F} = \Psi\mathfrak{E}, \tag{12}$$

$$\mathfrak{E} = \Phi\mathfrak{F}, \tag{13}$$

$$\Psi = \Phi^{-1}. \tag{14}$$

In other words, the displacements in either theory are subject to the same general and surface conditions as the forces required to maintain the vibrations in an element of volume in the other theory.

To fix our ideas in regard to the signification of Ψ and Φ, we may consider the case of isotropic media, in which these operators reduce to ordinary algebraic quantities, simple or complex. Now the *curl* of any vector necessarily satisfies the solenoidal condition (the so-called 'equation of continuity'), therefore by (6) $\Psi\mathfrak{E}$ and $\mathfrak{E}$ will be solenoidal. So also will $\mathfrak{F}$ and $\Phi\mathfrak{F}$ in the electrical theory. Now for solenoidal vectors

$$-\text{curl curl} = \frac{d^2}{dx^2} + \frac{d^2}{dy^2} + \frac{d^2}{dz^2}, \qquad (15)$$

so that the equations (6) and (10) reduce to

$$\Psi\ddot{\mathfrak{E}} = \left(\frac{d^2}{dx^2} + \frac{d^2}{dy^2} + \frac{d^2}{dz^2}\right)\mathfrak{E}, \qquad (16)$$

$$\ddot{\mathfrak{F}} = \left(\frac{d^2}{dx^2} + \frac{d^2}{dy^2} + \frac{d^2}{dz^2}\right)\Phi\mathfrak{F} \qquad (17)$$

For a simple train of waves, the displacement, in either theory, may be represented by a constant multiplied by

$$e^{\iota(gt + ax + by + cz)} \qquad (18)$$

Our equations then reduce again to

$$g^2\,\Psi\mathfrak{E} = (a^2 + b^2 + c^2)\mathfrak{E}, \qquad (19)$$

$$g^2\mathfrak{F} = (a^2 + b^2 + c^2)\,\Phi\mathfrak{F}. \qquad (20)$$

Hence,

$$\Psi^{-1} = \Phi = \frac{g^2}{a^2 + b^2 + c^2}. \qquad (21)$$

The last member of this equation, when real, evidently expresses the square of the velocity of light. If we set

$$n^2 = k^2\frac{a^2 + b^2 + c^2}{g^2}, \qquad (22)$$

k denoting the velocity of light *in vacuo*, we have

$$n^2 = k^2\,\Psi = k^2\,\Phi^{-1}. \qquad (23)$$

When n^2 is positive, which is the case of perfectly transparent bodies, the positive root of n^2 is called the index of refraction of the medium. In the most general case, it would be appropriate to call n—or perhaps that root of n^2 of which the real part is positive—the (complex) index of refraction, although the terminology is hardly settled in this respect. A negative value of n^2 would represent a body from which light would be totally reflected at all angles of incidence. No such cases have been observed. Values of n^2 in which the coefficient of ι is negative, indicate media in which light is absorbed. Values in which the coefficient of ι is positive would represent media in which the opposite phenomenon took place.*

It is no part of the object of this paper to go into the details by which we may derive, so far as observable phenomena are concerned, Fresnel's law of double refraction for transparent bodies, as well as the more general law of the same character which relates to aeolotropic bodies of more or less opacity, and which differs from Fresnel's only in that certain quantities become complex, or Fresnel's laws for the intensities of reflected and refracted light at the boundary of transparent isotropic media, with the more general laws for the case of bodies aeolotropic or opaque or both. The principal cases have already been discussed on the new elastic theory in the *Philosophical Magazine*† and a farther discussion is promised. For the electrical theory, the case of double refraction in perfectly transparent media has been discussed quite in detail in this Journal,‡ and the intensities of reflected and refracted light have been abundantly deduced from the above conditions by various authors.§ So far as all these laws are concerned, the object of this paper will be attained, if it has been made clear, that the two theories, in their extreme cases, give identical results. The greater or less degree of elegance, or completeness, or perspicuity, with which these laws may be developed by different authors, should weigh nothing in favor of either theory.

The non-magnetic rotation of the plane of polarization, with the allied phenomena in aeolotropic bodies, lie in a certain sense outside of the above laws, as depending on minute quantities which have been neglected in this discussion. The manner in which these minute quantities affect the equations of motion on the electrical theory has been shown in a former paper,‖ where these phenomena in transparent bodies are treated quite at length. For the new theory, a discussion of this subject is promised by Mr. Glazebrook.

But the magnetic rotation of the plane of polarization, with the allied phenomena when an aeolotropic body is subjected to magnetic influence, fall entirely within the scope of the above equations and surface-conditions. The characteristic of this

* But ι might have been introduced into the equations in such a way that a positive coefficient in the value of n^2 would indicate absorption, and a negative coefficient the impossible case.

† Sir William Thomson, *loc. citat.* R. T. Glazebrook, *loc. citat.*

‡ Vol. xxiii, p. 262.

§ Lorentz, Schlömilch's Zeitschrift, vol. xxii, pp. 1–30 and 205–219; vol. xxiii, pp. 197–210; Fitzgerald, Phil. Trans., vol. clxxi, p. 691; J. J. Thomson, Phil. Mag. (V), vol. ix, p. 284; Rayleigh, Phil. Mag. (V), vol. xii, p. 81. Glazebrook, Proc. Cambr. Phil. Soc., vol. iv, p. 155.

‖ This Journal, vol. xxiii, p. 460.

case is that Ψ and Φ are not self-conjugate.* This is what we might expect on the electric theory from the experiments of Dr. Hall, which show that the operators expressing the relation between electro-motive force and current are not in general self-conjugate in this case.

In the preceding comparison, we have considered only the limiting cases of the two theories. With respect to the sense in which the limiting case is admissible, the two theories do not stand on quite the same footing. In the electric theory, or in any in which the velocity of the missing wave is very great, if we are satisfied that the compressibility is so small as to produce no appreciable results, we may set it equal to zero in our mathematical theory, even if we do not regard this as expressing the actual facts with absolute accuracy. But the case is not so simple with an elastic theory in which the forces resisting certain kinds of motion vanish, so far, at least, as they are proportional to the strains. The first requisite for any sort of optical theory is that the forces shall be proportional to the displacements. This is easily obtained in general by supposing the displacements very small. But if the resistance to one kind of distortion vanishes, there will be a tendency for this kind of distortion to appear at some places in an exaggerated form, and even to an infinite degree, however small the displacements may be in other parts of the field. In the case before us, if we suppose the velocity of the missing wave to be absolutely zero, there will be infinite condensations and rarefactions at a surface where ordinary waves are reflected. That is, a certain volume of ether will be condensed to a surface, and *vice versâ*. This prevents any treatment of the extreme case, which is at once simple and satisfactory. The difficulty has been noticed by Sir William Thomson, who observes that it may be avoided if we suppose the displacements infinitely small in comparison with the wave-length of the wave of compression. This implies a finite velocity for that wave. A similar difficulty would probably be found to exist (in the extreme case) with regard to the deformation of the ether by the molecules of ponderable matter, as the ether oscillates among them. If the statical resistance to irrotational motions is zero, it is not at all evident that the statical forces evoked by the disturbance caused by the molecules would be proportional to the motions. But this difficulty would be obviated by the same hypothesis as the first.

These circumstances render the elastic theory somewhat less convenient as a working hypothesis than the electric. They do not necessarily involve any complication of the equations of optics. For it may still be possible that this velocity of the

* See this Journal, vol. xxv, p. 113.

missing wave is so small that the quantities on which it depends may be set equal to zero in the equations which represent the phenomena of optics. But the mental processes by which we satisfy ourselves of the validity of our results (if we do not work out the whole problem in the general case of no assumption in regard to the velocity of the missing wave) certainly involve conceptions of a higher degree of difficulty on account of the circumstances mentioned. Perhaps this ought not to affect our judgment with respect to the question of the truth of the hypothesis.

Although the two theories give laws of exactly the same form for monochromatic light in the limiting case, their deviations from this limit are in opposite directions, so that if the phenomena of optics differed in any marked degree from what we would have in the limiting case, it would be easy to find an *experimentum crucis* to decide between the two theories. A little consideration will make it evident, that when the principal indices of refraction of a crystal are given, the intermediate values for oblique wave-planes will be less if the velocity of the missing wave is small but finite, than if it is infinitesimal, and will be greater if the velocity of the missing wave is very great but finite than if it is infinite.* Hence, if the velocity of the missing wave is small but finite, the intermediate values of the indices of refraction will be less than are given by Fresnel's law, but if the velocity of the missing wave is very great but finite, the intermediate values of the indices of refraction will be greater than are given by Fresnel's law. But the recent experiments of Professor Hastings on the law of double refraction in Iceland spar do not encourage us to look in this direction for the decision of the question.†

In a simple train of waves in a transparent medium, the potential energy, on the elastic theory, may be divided into two parts, of which one is due to that general deformation of the ether which is represented by the equations of wave-motion, and the other to those deformations which are caused by the interference of the ponderable particles with the wave-motion, and to such displacements of the ponderable matter as may be caused, in some cases at least, by the motion of the ether. If we write h for the amplitude, l for the wave-length, and p for the period, these two parts of the statical energy (esti-

* This may be more clear if we consider the stationary waves formed by two trains of waves moving in opposite directions. The case then comes under the following theorem:

"If the system undergo such a change that the potential energy of a given configuration is diminished, while the kinetic energy of a given motion is unaltered, the periods of the free vibrations are all increased, and conversely." See Lord Rayleigh's *Theory of Sound*, vol. i, p. 85.

† This Journal, vol. xxxiii, p. 60.

mated per unit of volume for a space including many wave-lengths) may be represented respectively by

$$\frac{\pi^2 B h^2}{l^2} \text{ and } \frac{b h^2}{4}.$$

The sum of these may be equated to the kinetic energy, giving an equation of the form

$$\frac{\pi^2 B h^2}{l^2} + \frac{b h^2}{4} = \frac{\pi^2 A' h^2}{p^2}. \qquad (24)$$

B is an absolute constant (the rigidity of the ether, previously represented by the same letter), A′ and b will be constant (for the same medium and the same direction of the wave-normal) except so far as the type of the motion changes, *i. e.*, except so far as the manner in which the motion of the ether distributes itself between the ponderable molecules, and the degree in which these take part in the motion, may undergo a change. When the period of vibration varies, the type of motion will vary more or less, and A′ and b will vary more or less.

In a manner entirely analogous,* the *kinetic* energy, on the electrical theory, may be divided into two parts, of which one is due to those general fluxes which are represented by the equations of wave-motions, and the other to those irregularities in the fluxes which are caused by the presence of the ponderable molecules, as well as to such motions of the ponderable particles themselves, as may sometimes occur. These parts of the kinetic energy may be represented respectively by

$$\frac{\pi F l^2 h^2}{p^2} \text{ and } \frac{\pi^2 f h^2}{p^2}.$$

Their sum equated to the potential energy gives

$$\frac{\pi F l^2 h^2}{p^2} + \frac{\pi^2 f h^2}{p^2} = \frac{G h^2}{4}. \qquad (25)$$

Here F is the constant of electrodynamic induction, which is unity if we use the electromagnetic system of units, f and G (like A′ and b) vary only so far as the type of motion varies.

We have the means of forming a very exact numerical estimate of the ratio of the two parts into which the statical energy is thus divided on the elastic theory, or the kinetic energy on the electric theory. The means for this estimate is afforded by the principle that the period of a natural vibration is stationary when its type is infinitesimally altered by any constraint.† Let us consider a case of simple wave motion, and suppose the period to be infinitesimally varied, the wave-

* See this Journal, vol. xxii, p. 262.

† See Lord Rayleigh's *Theory of Sound*, vol. i, p. 84. The application of the principle is most simple in the case of stationary waves.

length will also vary, and presumably to some extent the type of vibration. But, by the principle just stated, if the ether or the electricity could be constrained to vibrate in the original type, the variations of l and p would be the same as in the actual case. Therefore, in finding the differential equation between l and p, we may treat b and A′ in (24) and f and G in (25) as constant, as well as B and F. These equations may be written

$$4\pi^2 B \frac{p^2}{l^2} + bp^2 = 4\pi^2 A',$$

$$\pi F \frac{l^2}{p^2} + \frac{\pi^2 f}{p^2} = \tfrac{1}{4} G.$$

Differentiating, we get

$$4\pi^2 B\, d\frac{p^2}{l^2} = -\, b\, d(p^2),$$

$$\pi F\, d\frac{l^2}{p^2} = -\, \pi^2 f\, d(p^{-2});$$

or

$$4\pi^2 B \frac{p^2}{l^2}\, d \log \frac{p^2}{l^2} = -\, b\, p^2\, d \log p^2,$$

$$\pi F \frac{l^2}{p^2}\, d \log \frac{l^2}{p^2} = -\, \frac{\pi^2 f}{p^2}\, d \log p^{-2}.$$

Hence, if we write V for the wave-velocity (l/p), n for the index of refraction, and λ for the wave-length *in vacuo*, we have for the ratio of the two parts into which we have divided the potential energy on the elastic theory,

$$\frac{bh^2}{4} \div \frac{\pi^2 B h^2}{l^2} = \frac{d \log V}{d \log p} = -\, \frac{d \log n}{d \log \lambda}, \tag{26}$$

and for the ratio of the two parts into which we have divided the kinetic energy on the electrical theory,

$$\pi^2 \frac{fh^2}{p^2} \div \frac{\pi F l^2 h^2}{p^2} = \frac{d \log V}{d \log p} = -\, \frac{d \log n}{d \log \lambda}. \tag{27}$$

It is interesting to see that these ratios have the same value. This value may be expressed in another form, which is suggestive of some important relations. If we write U for what Lord Rayleigh has called the velocity of a group of waves,*

$$\frac{U}{V} = 1 - \frac{d \log V}{d \log l},$$

$$\frac{d \log V}{d \log l} = \frac{V - U}{V},$$

$$\frac{d \log V}{d \log p} = \frac{V - U}{U}. \tag{28}$$

* See his *Note on Progressive Waves*, Proc. Lond. Math. Soc., vol. ix, No. 125, reprinted in his *Theory of Sound*, vol. ii, p. 297.

It appears, therefore, that in the elastic theory that part of the potential energy which depends on the deformation expressed by the equations of wave-motion, bears to the whole potential energy the same ratio which the velocity of a group of waves bears to the wave-velocity. In the electrical theory, that part of the kinetic energy which depends on the motions expressed by the equations of wave-motion bears to the whole kinetic energy the same ratio.

Returning to the consideration of equations (26) and (27), we observe that in transparent bodies the last member of these equations represents a quantity which is small compared with unity, at least in the visible spectrum, and diminishes rapidly as the wave-length increases. This is just what we should expect of the first member of equation (27). But when we pass to equation (26), which relates to the elastic theory, the case is entirely different. The fact that the kinetic energy is affected by the presence of the ponderable matter, and affected differently in different directions, shows that the motion of the ether is considerably modified. This implies a distortion, superposed upon the distortion represented by the equations of wave-motion, and very much greater, since the body is very fine-grained as measured by a wave-length. With any other law of elasticity, we should suppose that the energy of this superposed distortion would enormously exceed that of the regular distortion represented by the equations of wave-motion. But it is the peculiarity of this new law of elasticity that there is one kind of distortion, of which the energy is very small, and which is therefore peculiarly likely to occur. Now if we can suppose the distortion caused by the ponderable molecules to be almost entirely of this kind, we may be able to account for the smallness of its energy. We should still expect the first member of (26) to increase with the wave-length, on account of the factor l^2, instead of diminishing, as the last member of the equation shows that it does. We are obliged to suppose that b, and therefore the type of the vibrations, varies very rapidly with the wave-length, even in those cases which appear farthest removed from anything like selective absorption.

The electrical theory furnishes a relation between the refractive power of a body and its specific dielectric capacity, which is commonly expressed by saying that the latter is equal to the square of the index of refraction for waves of infinite length. No objection can be made to this statement, but the great uncertainty in determining the index for waves of infinite length by extrapolation prevents it from furnishing any very rigorous test of the theory. Yet, as the results of extrapolation in some cases agree strikingly with the specific dielectric capacity, although in other cases they are quite different, the correspondence is generally regarded as corroborative, in some degree, of the theory. But the relation between refractive power and dielectric capacity may be expressed in a form which will furnish a more rigorous test, as not involving extrapolation.

We have seen on page 140 how we may determine numerically the ratio of the two first terms of equation (25). We thus easily get the ratio of the first and last term, which gives

$$\frac{Gh^2}{4} = \frac{d \log l}{d \log \lambda} \frac{\pi F l^2 h^2}{p^2}. \tag{29}$$

In the corresponding equation for a train of waves of the same amplitude and period *in vacuo*, l becomes λ, F remains the same and for G we may write G′. This gives

$$\frac{G'h^2}{4} = \frac{\pi F \lambda^2 h^2}{p^2}. \tag{30}$$

Dividing, we get

$$\frac{G}{G'} = \frac{d \log l}{d \log \lambda} \frac{l^2}{\lambda^2} = \frac{d\,(l^2)}{d\,(\lambda^2)}. \tag{31}$$

Now G′ is the dielectric elasticity of pure ether. If K is the specific dielectric capacity of the body which we are considering, G′/K is the dielectric elasticity of the body and G′/2K is the potential energy of the body (per unit of volume), due to a unit of ordinary electrostatic displacement. But $Gh^2/4$ is the potential energy in a train of waves of amplitude h. Since the average square of the displacement is $h^2/2$, the potential energy of a unit displacement such as occurs in a train of waves is G/2. Now in the electrostatic experiment the displacement distributes itself among the molecules so as to make the energy a minimum. But in the case of light the distribution of the displacement is not determined entirely by statical considerations. Hence

$$\frac{G}{2} \geqq \frac{G'}{2K}, \tag{32}$$

$$K \geqq \frac{G'}{G},$$

and

$$K \geqq \frac{d\,(\lambda^2)}{d\,(l^2)}. \tag{33}$$

It is to be observed that if we should assume for a dispersion-formula

$$n^{-2} = a - b\lambda^{-2}, \tag{34}$$

$1/a$, which is the square of the index of refraction for an infinite wave-length, would be identical with the second member of (33).

Another similarity between the electrical and optical properties of bodies consists in the relation between conductivity and opacity. Bodies in which electrical fluxes are attended with absorption of energy absorb likewise the energy of the motions which constitute light. This is strikingly true of the metals. But the analogy does not stop here. To fix our ideas, let us consider the case of an isotropic body and circularly polarized light, which is geometrically the simplest case, although its analytical expression is not so simple as that of plane-polarized light. The displacement at any point may be symbolized by the rotation of a point in a circle. The external force necessary to maintain the displacement $\mathfrak{F}$ is represented by $n^{-2}\mathfrak{F}$. In transparent bodies, for which n^{-2} is a positive number, the force is radial and in the direction of the displacement, being principally employed in counterbalancing the dielectric elasticity, which tends to diminish the displacement. In a conductor n^{-2} becomes complex, which indicates a component of the force in the direction of $\dot{\mathfrak{F}}$, that is, tangential to the circle. This is only the analytical expression of the fact above mentioned. But there is another optical peculiarity of metals, which has caused much remark, viz: that the real part of n^2 (and therefore of n^{-2}) is negative, i. e., the radial component of the force is directed towards the center. This inwardly directed force, which evidently opposes the electrodynamic induction of the irregular part of the motion, is small compared with the outward force which is found in transparent bodies, but increases rapidly as the period diminishes. We may say, therefore, that metals exhibit a second optical peculiarity,—that the dielectric elasticity is not prominent as in transparent bodies. This is like the electrical behavior of the metals, in which we do not observe any elastic resistance to the motion of electricity. We see, therefore, that the complex indices of metals, both in the real and the imaginary part of their inverse squares, exhibit properties corresponding to the electrical behavior of the metals.

The case is quite different in the elastic theory. Here the force from outside necessary to maintain in any element of volume the displacement $\mathfrak{E}$ is represented by $n^2\ddot{\mathfrak{E}}$. In transparent bodies, therefore, it is directed toward the center. In metals, there is a component in the direction of the motion $\dot{\mathfrak{E}}$, while the radial part of the force changes its direction and is often many times greater than the opposite force in transparent bodies. This indicates that in metals the displacement of the ether is resisted by a strong elastic force, quite enormous compared to anything of the kind in transparent bodies, where it indeed exists, but is so small that it has been neglected by most writers, except when treating of dispersion. We can make these suppositions, but they do not correspond to anything which we know independently of optical experiment.

It is evident that the electrical theory of light has a serious rival, in a sense in which, perhaps, one did not exist before the publication of Sir William Thomson's paper in November last.* Nevertheless, neither surprise at the results which have been achieved, nor admiration for that happy audacity of genius, which, seeking the solution of the problem precisely where no one else would have ventured to look for it, has turned half a century of defeat into victory, should blind us to the actual state of the question.

It may still be said for the electrical theory, that it is not obliged to invent hypotheses,† but only to apply the laws furnished by the science of electricity, and that it is difficult to account for the coincidences between the electrical and optical properties of media, unless we regard the motions of light as electrical. But if the electrical character of light is conceded, the optical problem is very different from anything which existed in the time of Fresnel, Cauchy, and Green. The third wave, for example, is no longer something to be gotten rid of *quocunque modo*, but something which we must dispose of in accordance with the laws of electricity. This would seem to rule out the possibility of a relatively small velocity for the third wave.

* "Since the first publication of Cauchy's work on the subject in 1830, and of Green's in 1837, many attempts have been made by many workers to find a dynamical foundation for Fresnel's laws of reflexion and refraction of light, but all hitherto ineffectually." Sir William Thomson, *loc. citat.*

"So far as I am aware, the electric theory of Maxwell is the only one satisfying these conditions [of explaining at once Fresnel's laws of double refraction in crystals and those governing the intensity of reflexion when light passes from one isotropic medium to another]." Lord Rayleigh, *Phil. Mag.*, September, 1888.

† Electrical motions in air, since the recent experiments of Professor Hertz, seem to be no longer a matter of hypothesis. We can hardly suppose that the case is essentially different with the so-called vacuum. The theorem that the electrical motions of light are solenoidal, although it is convenient to assume it as a hypothesis and show that the results agree with experiment, need not occupy any such fundamental position in the theory. It is in fact only another way of saying that two of the constants of electrical science have a certain ratio (infinity). It would be easy to commence without assuming this value, and to show in the course of the development of the subject that experiment requires it, not of course as an abstract proposition, but in the sense in which experiment can be said to require any values of any constants, that is, to a certain degree of approximation.

ART. XVII.—*The Geology of Fernando de Noronha.* Part I; by JOHN C. BRANNER. With a map, Plate V.

THE island of Fernando de Noronha has never attracted much attention, owing to its small area, its want of commercial importance, and its somewhat forbidding character as a landing place, and partly also to its having long been used as a place of exile and punishment for criminals. Prior to the visit of the writer the geologic observations made upon the island of Fernando were very few; the only ones worthy of especial notice being those of Charles Darwin in 1832, made while on the voyage of the Beagle and published in his Geological Observations in 1844, and a few observations made, along with the collection of specimens, when the Challenger touched here in 1873. A careful survey would have been made by the Challenger party had permission been given by the Brazilian officers in charge; but owing to the care exercised in the supervision of the convicts and to a misapprehension of the objects of the survey, this permission was unfortunately withheld.

In 1876 I visited Fernando as a member of the Imperial Geological Survey of Brazil, and the following brief notes are the first to be published giving any of the results of my observations upon its geology.

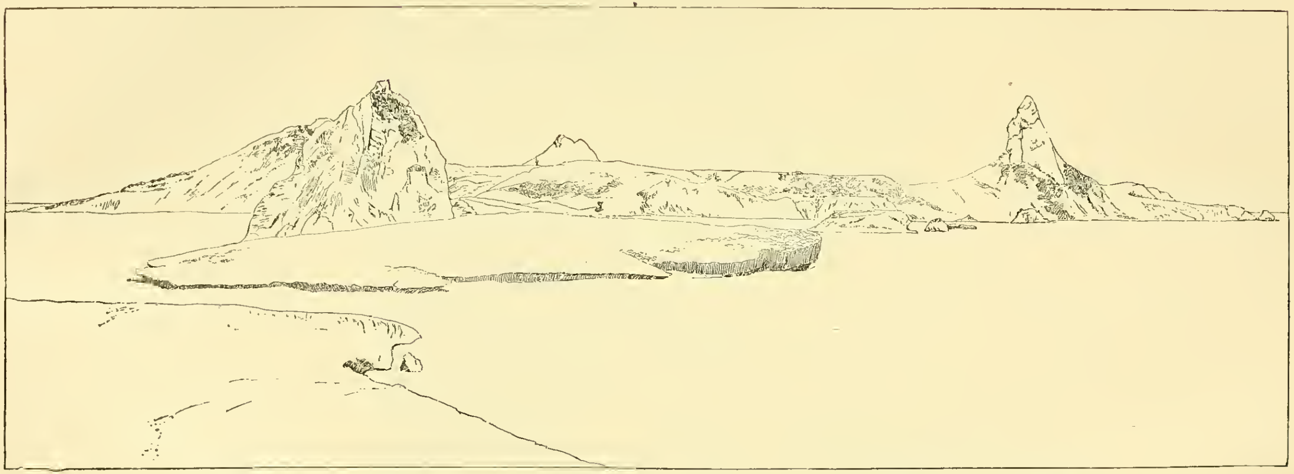
With the accompanying map the reader will scarcely need any observations upon the geography of this group of islands, while the illustrations will convey a sufficiently clear idea of the surface features of the place to dispense with detailed descriptions of topography.

The form of the ocean's bottom around this island, however, is worthy of note as indicating the relations of the group to other islands and to the Brazilian mainland. For the facts bearing upon this subject we are indebted to the deep-sea soundings of the Challenger expedition. It was formerly supposed that Fernando was simply the original northeastern extremity of the South American continent, now separated from Cape St. Roque by a shallow channel. The deep sea soundings have shown, however, that the Fernando group is an isolated one, and that the channels separating it from the Rocas, from St. Paul's Rock and from the Brazilian mainland, are profound ones. The channel between Fernando and St. Paul's Rock is more than 14,000 feet deep, while between Fernando and the Brazilian mainland the depth is over 13,000 feet. To the northeast, six miles from the island, the sound ings show a depth of more than 6,000 feet, while to the southeast, at the same distance, the depth is 3150 feet, and at twelve miles, 4920 feet. This group of islands, therefore, rises abruptly from the ocean's floor. The currents and surf that strike it from the east are unchecked by shallows on that side, so that it receives the full force of the waves and is consequently being cut away at a rapid rate.

The island is of volcanic origin, there being no sedimentary rocks upon it. The volcano which once existed here ceased action long ago, and the powerful surf which constantly beats upon the island has since cut away the cone, and is now fast diminishing the remnants of the original island. Moreover, the usual chemical processes of disintegration, hastened and deepened here by a very great precipitation falling upon rocks highly heated by exposure to a tropical sun, has covered the interior of the island with a deep soil mingled with rock fragment which, together, obscure the geological details over the main body of the island. Its original lofty central portion has gradually yielded to these disintegrating influences till only the great Peak and its smaller companions remain to suggest the former elevation of the group. A large portion of the island is now under cultivation, and the loose blocks, which might otherwise have been of some service in suggesting, at least, the distribution of the rocks, have been gathered from the fields and built up in stacks or stone walls, or used to make roads or houses. The lands that formerly sloped at a low angle into the sea have been encroached upon, cut down and swept away by the ocean currents until the island is now walled in for the most part by high, precipitous cliffs; the ancient sandy beaches which at one time bordered its southeastern shores, and which were probably fringed by coral reefs, have been almost completely obliterated. The more rapid destruction along the shores and the slower weathering of the interior brings into close proximity two topographic types, and almost any view which includes both shore and inland topography shows the more graceful lines of the old topography in strong contrast with the newer, bolder, and more angular cliffs and escarpments made by the steady encroachments of the sea upon the land.

The best, and almost the only, good rock exposures are about the shores; but many of these are difficult or impossible of access on account of the lack of boating facilities at the island, and because of the violent surf which so generally prevails. In addition, the rocks are so broken, faulted, and thrown into confusion, that it must be confessed my study of the place was far from satisfactory. I endeavored especially to construct an accurate map of the island, and to collect typical rock speci-

1.



Morro Franeez. Sella á Gineta. Atalaia Grande. Sao José. The Peak.

Ilha Rapta. Ilha do Meio.

Sketch of the Island of Fernando de Noronha taken from Ilha Rapta.

mens. The results of these endeavors are to be seen in the map published herewith—which does not differ materially from the French map published in 1873—and in the petrographic work kindly done by Dr. George H. Williams. The drawings are made from sketches and photographs taken by the writer. Unfortunately the dry, sensitive plates so universally and successfully used nowadays for photography were not then to be had, and the clumsy apparatus I was obliged to use prevented my obtaining some very desirable views.

The work which has hitherto been done upon the rocks of Fernando will be referred to by Dr. Williams in his part of the present paper. I wish to add, however, that the statement made by Dr. Alexander Rattray* to the effect that granite forms part of the peak and of "other hills, headlands and rocks" is erroneous. There is no granite on the island, so far as I was able to discover.

Amphibole-trachyte occurs at the base of Atalaia Grande and to the west of it. The beds from which the specimen (No. 10) was taken are soft and appear to be decaying rapidly. The exposure has a northeast and southwest trend at this place. The same kind of rock (No. 121) occurs on the east side and about the base of the Morro Francez where it is traversed by dykes of hornblende-augite trachyte (?) (No. 129). The soft whitish and cream-colored amphibole-trachyte which occurs at the bases of some of the hills and notably about Atalaia Grande is called *tauá* by many of the inhabitants. This is a Tupi word however, meaning clay, and is the one given on the Brazilian mainland to clays of any kind, and is doubtless applied to these soft rocks on account of their slight resemblance to hard clays.

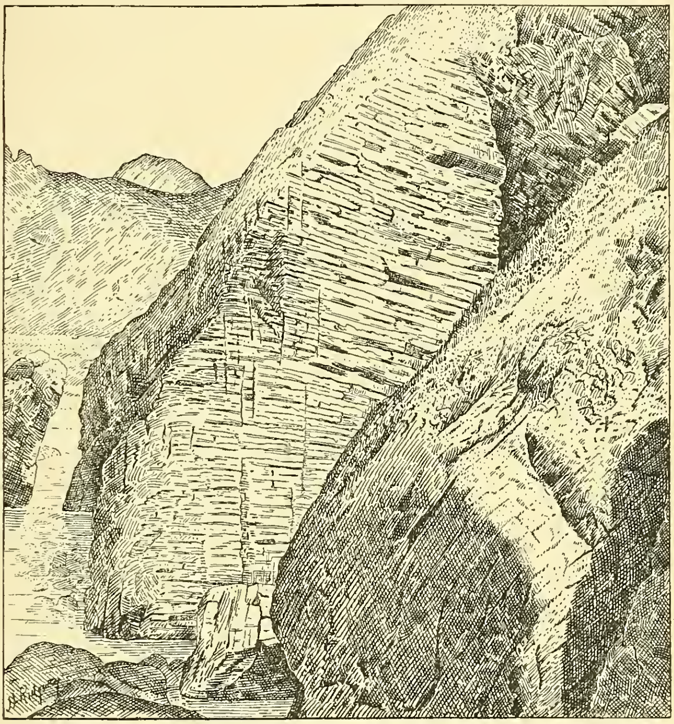
Hyalotrachyte occurs in several places. The principal localities are between the mouth of the stream flowing into the Bahia do Sueste and the old Fortaleza dos Leões. The rock (No. 19) is white and almost as soft as chalk, and breaks into irregular lumps. Here and there through the mass are lead-colored patches. It is supposed by the people on the island to be kaolin, and samples of it are said to have been taken to Europe to be tested for the manufacture of porcelain.

Phonolite.—Most of the isolated topographic prominences in the eastern portion of the island, with the exception of the Morro Francez, are composed either wholly or principally of phonolite, while its lower elevations are of some variety of basalt, loose fragments of nepheline-dolerite being of frequent occurrence about the fields on the plateau above the village. These prominences are the Peak and the southwestern prolongation of the hill from which it rises, the Pedra da Conceição,

* Jour. Roy. Geog. Soc., vol. xlii, 1872, p. 43.

a small peninsula northeast of the village, the Sella á Gineta,* the summit and southeast face of Atalaia Grande down to the water's edge, and to all appearances the Alatainha or Atalaia Piquena, and the Morro do Sueste. No phonolite was found in the western portion of the island. In all cases, excepting that of the Pedra da Conceição, these phonolites have the appearance of having been injected as dykes into older rocks.

2.



Phonolite columns of Atalaia Grande.

They seem to have cooled irregularly, but for the most part, from the sides. The older and more soluble surrounding rocks have, of course, been removed by denudation. Mr. Darwin says of such masses of phonolite that they have probably been formed by "the injection of fluid feldspathic lava into yielding strata."† In all the cases mentioned above, the rocks have a

* This island was not visited by the writer. As seen from Ilha Raza and Ilha Rapta, its rock had the appearance of phonolite and was so regarded. The examples collected by the Challenger party show beyond question that this supposition was correct.

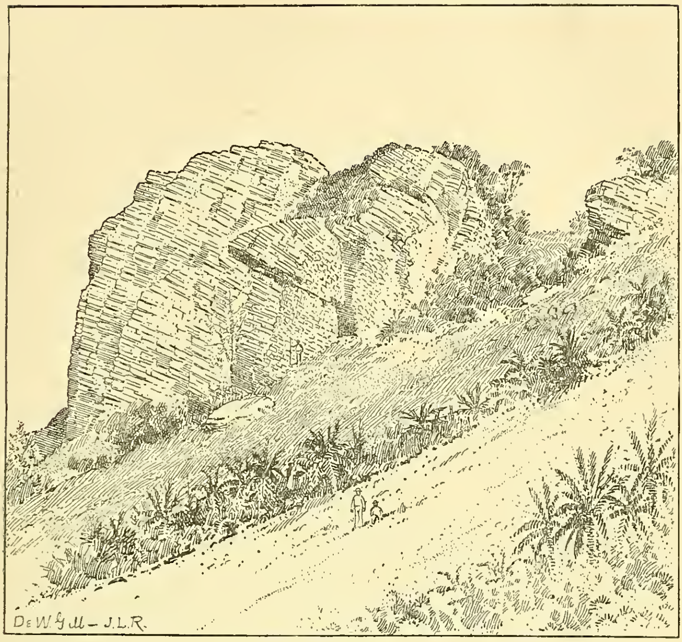
† Geological Observations, second edition p. 27.

columnar structure either very plainly or partially developed. The somewhat irregular columns lie for the most part horizontally, as is well shown in the dyke exposed at the Horta do Pico, southwest of the Peak. On the southeast side of the Atalaia Grande the columns are nearly horizontal, with a tendency to radiation from the center of the hill. Specimen No. 5 is from the nearly horizontal columns of phonolite exposed on the southwest side of the Atalaia Grande. Similar columns appear to form the whole south face of this peak, and are well exposed near its base where they are washed by the surf. As the peak is ascended the columns have a northward dip which increases toward the summit, so that a north-south section through the Atalaia Grande would expose the fan-like radiation of the columns above mentioned. The preceding cut, from a photograph of an exposure on the south side of Atalaia Grande, fig. 2, illustrates this point. No. 40 is from the summit of Atalaia Grande. Nos. 41 and 42 are from a loose block about 4×3×2 feet, found between Atalaia Grande and the Morro do Meio, the hill lying immediately north of it. This rock was not found in place on the island. It splits readily into slabs very like the phonolites from the Pedra da Conceição.

In the Sella á Gineta, fig. 4, the columns of phonolite are imperfect and vary somewhat in direction. Seen from São José some of the columns curve from a horizontal position on the left both upward and downward toward the right, radiating from a horizontal axis. In the Peak too, the direction of the columns varies in some cases as much as fifty degrees. The lowest rocks of the Peak exposed in place are the irregular columns upon its eastern side. The colums are here very nearly vertical; but higher up even upon this side, they twist and bend to the northeast and thus form the overhanging projection which is so remarkable a feature of this great rock. The curving of these columns prevents the falling of the most picturesque part of the Peak.* On its western side the columns stand at various angles with the meridian, and usually at a high angle with the horizon. Their direction and position, as well as the character of the rocks, leads to the conclusion that the Peak is part of a great dyke, the only remnants of which now exposed are the upper portions of the Peak itself, and the columns at the Horta do Pico, a short distance to the southwest. Specimens 51, 52 and 88 are from the highest accessible part of the Peak on its southwest

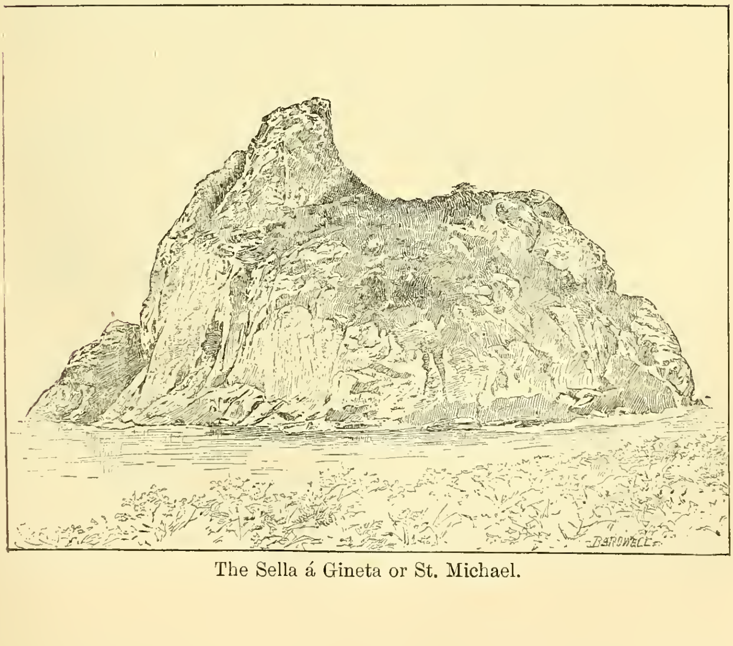
* Mr. Darwin calls attention to the disposition of phonolites to take on grotesque shapes. (Geological Observations, second ed., pp. 97–8). On Fernando these grotesque shapes of phonolite peaks are due to columnar structure when the axes of the columns change their directions. For a discussion of the curving and radiating of columns of igneous rocks see J. P. Iddings in Am. Jour. Sci., May, 1886, and Professor T. G. Bonney in Quart. Jour. Geol. Soc., vol. xxxii, 1876.

3.



Dyke of phonolite, near the Peak.

4



The Sella á Gineta or St. Michael.

side. The rocks of the summit are rudely columnar as is shown in the accompanying cut. The ledge just northwest of the Horta do Pico, fig. 3, shows the columnar structure of phonolite better perhaps than any other exposure upon the island. In most of these phonolites the metallic sound produced by striking with a hammer is very marked, especially when a somewhat thin slab is separated from the mass. From this peculiarity the Brazilians frequently call this rock "pedra de toque," which is the equivalent of our word "clinkstone."

The Peak is the most striking landmark in the South Atlantic ocean; it is 1000 feet high,* with the upper portion perpendicular or overhanging in such a manner as to make the summit quite inaccessible. The few drawings of this peak that have been published are taken from the same point—the anchorage—and even the best of them, that in the Challenger reports, conveys but a poor idea of its grandeur. Seen from other points it presents a striking variety of outlines.

It would be interesting to know whether this peak had undergone any marked changes since the discovery of the island in 1503, but unfortunately we have no detailed description of it as it appeared at that time, and the oldest drawing, that made by Ulloa in 1745, is clearly too imperfect to be trustworthy. It is evident, however, to one on the ground, that it is being slowly thrown down under the combined influence of sun and rain and the daily changes of temperature. Climbing up the accumulation of talus that slopes down from the base of the solid part of the peak to the seashore, it is noticeable that this material, loose as it is, stands at an angle of unstable equilibrium, and when disturbed in any way, miniature avalanches of loose stones slide down the slope, sometimes a hundred feet or more. Wherever this debris is stable there is sufficient soil upon it to support vegetation; and it is thus covered here and there with small tomato plants that have escaped from cultivation. In many places it was noticed that these plants were freshly broken and bruised by fragments that had fallen from the peak above.

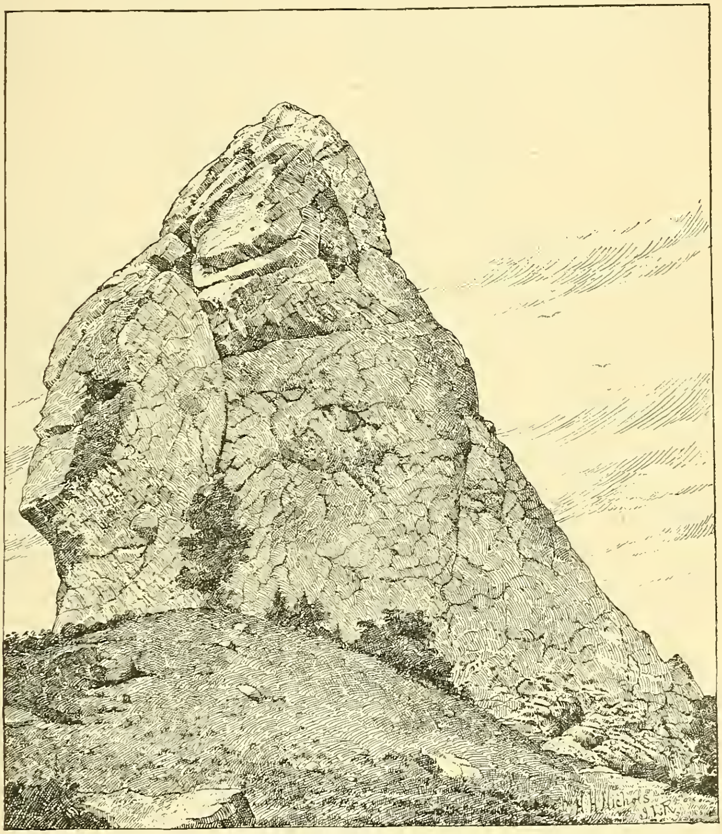
From top to bottom two great joints divide the Peak into three vertical sections. Into these crevices fall fragments of stone, which, heated and expanded during the day by the powerful rays of the sun, and cooled and contracted by the cool rains, or at night by radiation, wedge themselves deeper and deeper into the crevices and thus push off pieces large and small. Some years ago, no one seemed to know how many, the little fort near the base of the peak was almost completely demolished by a great mass of rock that fell from the Peak and rolled

* My own triangulation makes its height above tide 332 meters. Mouchez gives it at 305 meters.

down its sloping base. On another occasion, a convict, who had a little garden close under one side of the rock, found it one morning buried beneath a heap of stoues.

From the east or northeast the upper portion of the Peak presents the rude outlines of a human face. Fig. 5 is made from a photograph taken looking up from the beach.

5.



The Phonolite Peak of Fernando de Noronha, from the beach.

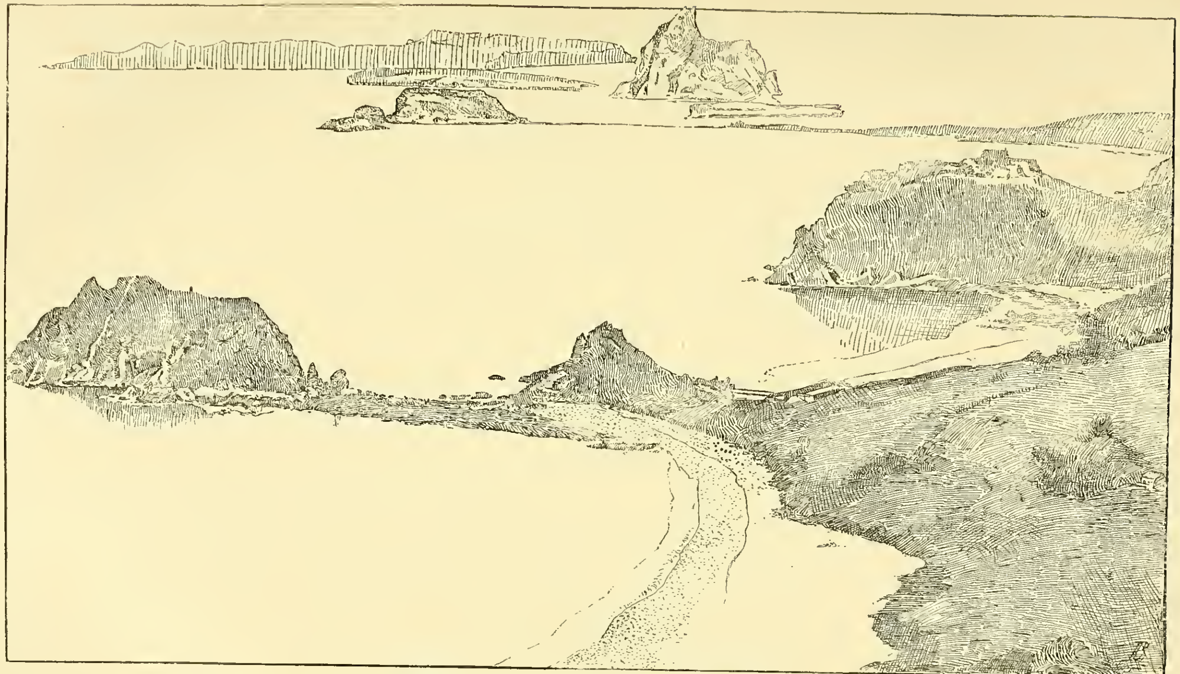
Slaty structure in phonolite.—The Pedra da Conceição is, at high tide, a small island of bare rock just west of the Praia do Cachorro, the landing place next the village; it has steep rugged sides and summit like a steep gothic roof. The place is shown in the left foreground of the following figure 6.

Most of the specimens collected at this locality were taken upon the south end or else upon the summit of this rock.

This locality is not included among those of the columnar phonolite. Mr. Darwin, in his "Geological Observations," remarks upon the occurrence near the base of the peak of slaty phonolite with cleavage. This peculiarity is very marked at the Pedra da Conceição, the rocks dipping sharply to the southwest, and having upon that side surfaces so flat and steep that I was able to hold my place only by clambering along its ridge. This is probably the locality to which Mr. Darwin refers. The rock splits readily into comparatively smooth slabs. A somewhat similar structure was observed in loose fragments found between the Morro do Meio and Atalaia Grande. (Nos. 40 and 42).

Basalts.—Rocks of a basaltic type form the great body of Fernando de Noronha. They occur in all portions of the island, and in masses of all shapes and sizes from thin veins to broad sheets. It was not observed, however, in any of the prominent isolated peaks, like the phonolite, yet nepheline-basalt was found on the summit of the Morro Francez, and augitite in the tuffs upon the east side of that hill. It occurs about the bases of the phonolite peaks, forming the body of Ilha Rapta, São José, Morro Redondo, and the cape near the phonolite peak of the Sella á Gineta. Rocks of basaltic type (limburgite) occur about the base of the Atalaia Grande and along the shores west of the peak. The Dois Irmãos appear to be made up of basalt, and so also the Laja Cape between the Atalainha and Morro Branco. In none of these cases, however, was I able to determine satisfactorily the relations of the basalt and phonolite to each other. Perhaps the most striking exposures of these rocks are to be seen upon the island of São José. The surf has here removed all the débris and uncovered columns of extremely hard nepheline-basanite (No. 31), which are best exposed upon the north side of the island, where a length of about fifty feet may be seen. This rock forms the greater part of São José and the two small adjoining islands, Pedra Furada and Ilha Redonda. In each case the columnar basalt forms the lower part of the island, and massive basalt the upper, while São José is further capped by a bed of the calcareous sandstone like that of which Ilha Raza is made. The columns of São José are usually bent. They vary in size and shape, as well as in position, but are usually hexagonal and about one foot in diameter, and break off in sections from one to four feet in length. The best exposure of the columns is on the eastern side of the island, where they are visible, however, only from the water. Many of them contain irregular masses of peridotite (No. 34) almost as large as one's fist. The broken columns are rolled by the surf upon the beach where they eventually form great black cobbles.

6.



Pedra da Conceiçao. Ilha Rapta. Ilha do Meio. Sao José. Sella à Gineta. Ilha Raza. Remedios.

Looking north-east from the base of the Peak.

Ilha Rapta, the most northeastern of this group of islands, appears to be made up for the most part of basalt, these rocks forming its highest portion and its eastern and western extremities. At its east end the basalt is rudely columnar along steep shores 120 feet high; but generally there is a broken slope to the sea, covered, above the reach of the waves, with talus and earth. The western point, about the Espigão, is composed of nepheline-basalt (No. 72.)

The slender neck forming the northeastern promonotory of the main island, appears to be of basalt. The weathering of the rocks at the exposures upon this neck, and especially upon the southeast side, is characterized by extensive exfoliation and a consequent disintegration of the body of the rock walls into great, black, approximately round bowlders. As these masses lie in place they have the appearance of a gigantic rude stone wall built of black bowlders of various sizes. When they fall and come within the reach of the waves, though excessively hard, they are soon smoothed and rounded. The beach on the north side of this neck is covered by vast numbers of these black rounded stones, here facetiously known as "*corações de negro*"—negro hearts. Large blocks of nepheline-basalt (No. 45) cover the summit of the Morro Francez.

It seems probable that, with a few exceptions, the basaltic rocks are continuous from the extreme northeast point of the main island along its eastern and southern side to the bay next east of the Atalaia Grande, though but few of the specimens collected upon this portion of the island seem to have been preserved. It should be mentioned, however, that the great deposit of tuff which forms the higher portions of the shore, just east of the Morro Francez, contains loosely consolidated fragments of many varieties of rocks, among which are augitite (No. 115). The next extensive exposure of basalt (nepheline-basalt) is in the horizontal beds which form the southwest shore of the island from the cape at the Laja just west of the Bahia do Sueste to the Morro Branco, a distance of more than a mile. These basalts have the appearance, from a distance, of being horizontally stratified sedimentary rocks. The uppermost bed along this escarpment is of nepheline-basalt (No. 27), while the underlying beds resemble this in gross structure. (Nos. 28, 29, 30). The lower beds contain amygdaloidal cavities, as do also some of the basalts about the eastern extremity of the main island, notably at the mouth of the stream called Cuyeira.

Some of the rocks of the basaltic type occur next the base of Atalaia Grande on the south side, but on account of the soil which covers this part of the island it was not possible to determine satisfactorily their relations to the phonolites which make up the body of the hill. The limburgite (No. 14) of the west base of Atalaia Grande forms a dyke either in, or west of and adjacent to, the amphibole trachyte (No. 10) mentioned elsewhere. Inasmuch as the eastern side of Atalaia Grande is exposed in one place down to the water's edge and is seen to be composed entirely of phonolite, these dykes of trachyte and limburgite are probably exterior to the body of the hill. Limburgite (No. 65) was found also in the peak of volcanic tuff which rises upon the narrow neck connecting the Sapato with the island. It there occurs associated with travertine (No. 66) and volcanic bombs. (Nos. 3 and 58). The two small isolated rocks known as the "Dois Irmãos" are not accessible, but as seen from the main island they have the appearance of being composed entirely of rudely columnar basalt.

Volcanic bombs (No. 48) occur in situ on the northern and near the summit of the Morro Francez. The east side of this hill, where it slopes down to the sea, is much checkered by dykes varying in thickness from two feet to eight, which cross each other at all angles. The bench of hard rock which skirts the base of the hill, and which is uncovered at low tide, varies in width from zero to three hundred and fifty feet. On its outer margin it is bordered by calcareous formations. On this bench the dykes are beautifully displayed at low tide. Immediately east of Capim Azul, a cliff more than 300 feet high is composed almost entirely of volcanic bombs and tuffs in beds dipping to the south at a high angle, and capped by jointed basalt. In size these bombs vary from that of a pin's head to the size of a bushel. Volcanic bombs occur also in the tuffs about the western end of the island, but they are nowhere so abundant or of such size as at the cliffs of Capim Azul.

Tuffs.—Tuffs occur about the northern and eastern sides of the Morro Francez, but are especially abundant about the western end of the island, where some of the beds are more than one hundred and fifty feet thick.

From the east side of the Morro Francez near the Pontinha are heavy beds of loosely consolidated tuff (No. 118), consisting of a mixture of angular fragments of rocks of many kinds which vary in size up to that of a millstone and larger; the beds slope down to the immediate beach of solid rock. This loose material is unlike the basaltic tuff of the western end of the island; it is greenish gray and without any appearance of stratification, while that of the Sapato and Capim Azul is more or less stratified and brownish.

The cliffs about Barro Vermelho and for some distance along the south side of the island, extending from the bed of volcanic bombs at Capim Azul to or near the Portão, are of some form of tuff (No. 62). The rock is soft and reddish, and forms upon decomposition a deep red earth which gives name to this part of the island—"Barro Vermelho," red mud.

The Portão.—The extreme western portion of the island lying west of the Portão Grande is known as the Sapato (the shoe). This is one of the most interesting and impressive places on Fernando. The waves have cut away the soft beds

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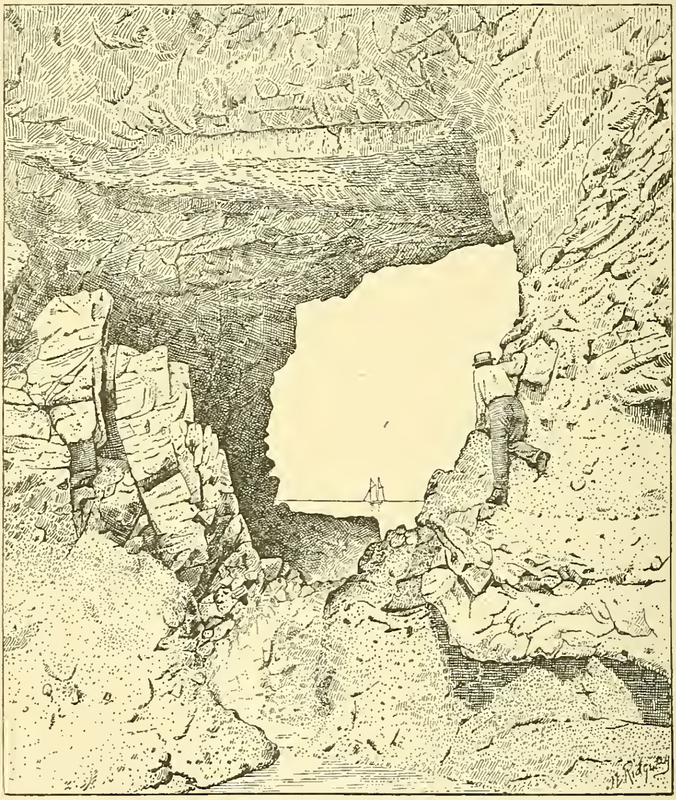

The Portão.

of dark brown basaltic tuff which here form the greater part of the strata of the island, until there remains little more than a narrow neck of steep and rugged cliffs, some of them eighty meters high, at whose breccia-covered foot breaks a ceaseless and violent surf. At one place an opening or tunnel has penetrated the isthmus; and this is the Portão Grande of the inhabitants of Fernando—"the hole in the wall" of English sailors.

The Portão beds of tuff (No. 54) are more homogeneous than those at Capim Azul. The individual fragments into which it breaks upon disintegration are seldom more than two inches in diameter, and the weathered surface of the beds has a lumpy rough appearance. The beds are regularly stratified, the dark brown material being streaked with lighter and darker bands. They dip southwest and southeast at an angle of nearly 45°, the opening being cut in a kind of syncline whose axis dips to the south. Overlying the tuff is a bed of hard rock containing many rectangular crystals, specimens of which unfortunately have not been preserved. This hard but much jointed rock fills the little depression, or syncline, in the tuff, and forms a nearly horizontal roof for this natural tunnel. The triangular gap between the tuff and its overlying bed is filled with irregularly stratified fragments which could not be examined.

The rock walls of the Portão from one face to the other are a little less than one hundred feet in thickness; the roof is about forty feet above the water at mean tide, and the opening is about forty feet in width. At the time of my visit the water did not have free passage through the opening, the northern entrance being barred by a narrow dyke of very hard basalt, about fifteen feet high, traversing the tuff and standing nearly square across its front.

The process by which the great opening has been made beneath this isthmus is not without interest. The surf about the Sapato is always violent, and especially so upon its south side. The excavation has all been done upon this south side, the character and dip of the rocks contributing largely to the result. If the waves breaking against the southwest dip of the excavated rock were carried up its slope, they were promptly checked by the hard overlying rock which forms the tunnel's roof. When, in the course of time, the wall was pierced, the waves struck the small basaltic dyke referred to above and this has ever since barred their progress. A gap, however, has been made through this dyke where it receives the full force of the waves. The dip of the dyke is toward the south and when the incoming waves plunge through the opening they strike this wall and are thrown off at a tangent, leap high in the air and fall in overwhelming volume and in spray upon the shingle of the northern beach. The swells and less violent waves occasionally lift their great volumes of water and pour intermittent cataracts over the gap on the little dyke, and down the channel which is opened to the left through the tuff between the wall and the overhanging cliffs.

The lowest beds exposed at the extreme western end of the Sapato are of basaltic tuff. The rock is reddish brown, soft and somewhat granular and contains an abundance of included fragments of a great variety of other rocks. The sea has carved out at the base of its cliffs a beautiful and regular bench from twenty to forty feet in width, which runs across the whole western end of the Sapato midway between high and low tides. The beds here dip westward at an angle of about 25 degrees. At the northwestern corner of this exposure a stratum of compact rock (basalt?) about fifteen feet in thickness overlies the tuff and dips 40° to the eastward. Above this is a bed of very hard but much shattered rock which continues to and beyond the Portão of which it forms the roof.

Basaltic tuffs, very similar to or perhaps identical with those in which the Portão opening is excavated continue along the north shore of the island for at least half a mile east of the Portão. The cliffs of this material are usually vertical and capped by a bed of some more resisting rock From the promontory called Portãozinho, looking northeast along the trend of the island's north coast, one sees rising abruptly from the water a lofty vertical cliff of what appears to be rudely columnar basalt. This exposure was not examined near at hand. Both east and west of this exposure are others of reddish brown rocks resembling in general appearance, and at a distance, the soft reddish palagonite of Barro Vermelho (No. 62). The cliffs of this material have their bases deeply underscored by wave action.

Calcareous sandstone.—Besides the rocks of igneous origin, a calcareous sandstone occurs along some shores. It covers about one-third of Ilha Rapta, a part of São José, and small areas of the main island near the Lancha on the northeast, the high shore west of Atalaia Grande, the shore along the southwest side of the Sueste Bay, and forms Ilha Raza, Ilha do Meio and the Chapeo at the mouth of Bahia do Sueste. The material of the sand-rocks was originally deposited in the form of sand dunes and the bedding shows that it must have been blown by the winds chiefly from a southern or southeastern direction. The deposits are all on eastern or southeastern shores and have no connection with the existing beach. On Ilha Raza, it makes a perpendicular bluff forty feet or more in height; on Ilha Rapta it rises about forty feet above the water, while south of Atalaia Grande it stands at an elevation of at least a hundred feet above the sea. A microscopic examination shows that it has been consolidated by the deposit of lime carbonate dissolved from the uppermost layers by the waters of the rains aided possibly by the spray of the surf. The grains are fragments of shells, corals, sea urchins, foraminifers and other calcareous growths of the shores.

Where these sandstones rise from the ocean, as they do on Ilha do Meio, Ilha Raza, Ilha Rapta and Chapeo, the wind


Pedra da
Conçeicão
Morro d
Village
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Peak
M. do Meio
Atal
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do
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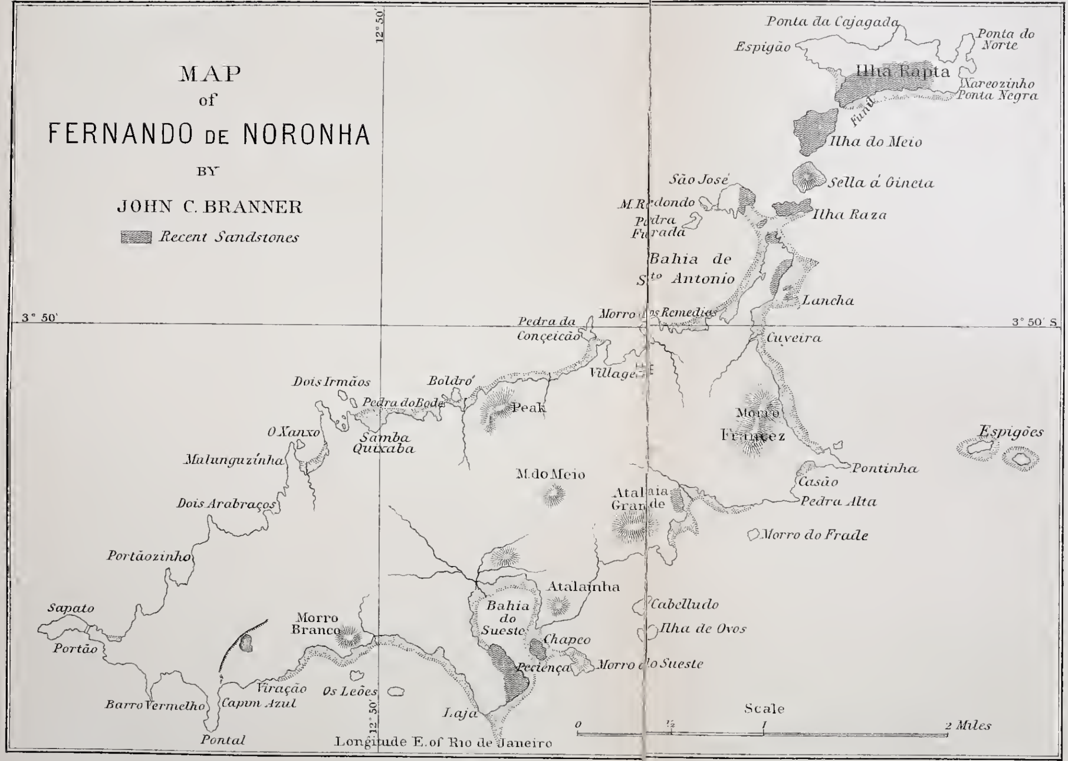
Bahia de Antonio
Ilha Raza
Sella á Gineta
Ilha do Meio
Ilha Rapta
Ponta Negra
Espigão
Ponta da Cajagada
Ponta do Norte
Morro do Frade
Pedra Alta
Pontinha
Espigões
Cuyeira
Lancha
São José
Ilha de Ovos
Cabelludo


MAP
of
FERNANDO DE NORONHA
BY
JOHN C. BRANNER
Recent Sandstones
Ponta da Cajagada
Espigão
Ponta do Norte
Ilha Rapta
Xareozinho
Ponta Negra
Funil
Ilha do Meio
São José
Sella á Gineta
M. Redondo
Ilha Raza
Pedra Furada
Bahia de Sto Antonio
Lancha
3° 50'
3° 50' S
12° 50'
Pedra da Conceição
Morro dos Remedios
Cuveira
Village
Dois Irmãos
Boldró
Pedra do Bode
Peak
Morro Francez
Espigões
O Xanxo
Samba
Quixaba
Malunguzinha
M. do Meio
Pontinha
Casão
Atalaia Grande
Pedra Alta
Dois Arabraços
Morro do Frade
Portãozinho
Atalainha
Cabelludo
Sapato
Bahia do Sueste
Ilha de Ovos
Morro Branco
Chapeo
Portão
Pecienca
Morro do Sueste
Viração
Os Leões
Barro Vermelho
Capim Azul
Laja
Scale
0
½
1
2 Miles
Pontal
Longitude E. of Rio de Janeiro

bedding is found to extend beneath the water,* indicating that the island once stood at a higher elevation. It should be noted, however, that the isolated remnant of sandstone near São José known as the Chapeo, and the western ends of Ilha Raza and Ilha Rapta stand upon waterworn shingle. Inasmuch as the cobbles must have been worn before they were covered by sand, the island must have stood at a level as low or somewhat lower than its present one while the cobbles were being made, and as the wind bedding could not be produced below the surface of the water or in sand to which the waves had access, the island must have been elevated somewhat before the dunes were blown over and deposited upon the shingle-covered beaches.

That they were blown up from the south or southeast is shown by the geographic positions of the various beds, by the absence of such rocks at corresponding elevations on the opposite sides of the islands, and by the internal structure of the rocks themselves, the steeper face of the dune always being toward the north or northeast. But as there is now no beach from which this sand could have been derived, we must conclude that the island was, not long ago, wider to the southeast, and that there were upon that side of it sandy shores, upon which an abundance of organic remains was thrown and ground to sand. These sands were then blown across the island to and upon the opposite shore, burying the former bowlder-covered beach near São José beneath 15 or 20 feet of sand, and piling it up considerably higher than the highest parts of the existing sand-rock. They joined into one what are now the separate islands and places marked as sandstone upon the map.

* See also the voyage of the Challenger, by Sir C. Wyville Thomson, vol. ii, p. 100, et seq.

Note upon the Map.—The names given upon the map and in this paper are those used by the inhabitants of the island. Other names have been used by visitors and navigators, especially by English and French-speaking persons who knew but little or nothing of the Portuguese language, or who have had no opportunity of learning the correct names. Inasmuch as these English and French names are not the ones known and used at Fernando de Noronha they cannot be regarded as correct. That there may be no misunderstanding, however, about some of the more important points mentioned in this paper and by others who have visited this island, I give a few of the names erroneously used with the correct Portuguese names.

Ilha Rapta has been called *Rat Island* by the English, and *Ile aux Rats* by the French. The word *rapta* is the participle of the verb *raptar*, Eng. *rape.* It is supposed to have been given on account of the place once having been occupied by Dutch pirates.

Sella à Gineta (horned saddle), so named on account of its resemblance to a horned saddle, is called St. Michael's Mount by English and French.

Morro do Frade (friar's hill), so called on account of its resemblance to a monk's cowl, is called *Le Clocher* by the French. *Ilha Raza* (flat island), has been named Egg Island, and *Ilha do Meio* (middle island), has been called Booby Island.

Miscellaneous Scientific Intelligence.

1. *American Geological Society.*—The American Geological Society was formally organized at Ithaca, N. Y., on December 27th, 1888. The report of the Committee of Organization showed that 98 Geologists belonging to the American Association for the Advancement of Science had become Original Fellows; and that ballots received from 74 Fellows had elected the 17 candidates for admission to the Society. The names of 19 new candidates were presented and were referred to the Executive Council.

A committee was appointed to prepare a permanent Constitution; and another to take into consideration the whole matter of publications; both committees to report at the next meeting of the Society.

The officers for 1889 are: President, James Hall; 1st Vice-President, James D. Dana; 2nd Vice-President, Alex. Winchell; Secretary, John J. Stevenson; Treasurer, Henry S. Williams; Members of the Council, John S. Newberry, J. W. Powell, Chas. H. Hitchcock.

The Society adjourned to meet in Toronto on Wednesday, in August, 1889, immediately after the adjournment of Section E of the American Association for the Advancement of Science.

We are indebted for the above notes to the Secretary of the Society, Prof. J. J. Stevenson.

The Society, thus auspiciously inaugurated, promises, through the free interchange of views it will promote and in other ways, to be of great service to American Geology. No better choice for the position of President could have been made. Professor Hall began his labors early in the thirties, and, ever since, geology and paleontology have had his undivided attention. His works—making more than a dozen great volumes with over 700 plates of fossils—have laid the foundations of American Geology, and have been a chief source of its progress. J. D. D.

2. *Mineral Resources of the United States;* calendar year, 1887, David T. Day, Chief of division of Mining Statistics and Technology. 832 pp. 8vo. Washington, 1887 (U. S. Geol. Survey).—This, the fifth volume of the series, appears with most commendable promptness, and contains the usual large amount of valuable information in regard to the development of the mineral interests of the country during the calendar year 1887. The tabulated list of useful minerals, arranged according to states and territories, has been much improved by additions and general revision; this work has been in the hands of Albert Williams, Jr.

3. *Index der Krystallformen der Mineralien* von Dr. Victor Goldschmidt. Vol. II, Part 4, vol. III, Parts 2 and 3.—This continuation of Goldschmidt's important work on crystallography (see xxxi, 475; xxxii, 485; xxxv, 501) embraces the species, alphabetically arranged, from idocrase to kupfervitriol, and ralstonite to syngenite. The same exhaustive thoroughness is shown in these parts as in those before issued.

APPENDIX.

Art. XVIII.—*Restoration of Brontops robustus, from the Miocene of America;** by Professor O. C. Marsh. (With Plate VI.)

The largest mammals of the American Miocene were the huge *Brontotheridæ*, which lived in great numbers on the eastern flanks of the Rocky Mountains, and were entombed in the fresh-water lakes of that region. They were larger than the *Dinocerata* of the Eocene, and nearly equalled in size the existing elephant. They constitute a distinct family of perissodactyles, and were more nearly allied to the rhinoceros than to any other living forms.

The deposits in which their remains are found have been called by the author, the Brontotherium beds. They form a well-marked horizon at the base of the Miocene. These deposits are several hundred feet in thickness, and may be separated into different subdivisions, each marked by distinct genera or species of these gigantic mammals.

The author has made extensive explorations of these Miocene lake-basins, and has secured the remains of several hundred individuals of the *Brontotheridæ*, which will be fully described in a monograph, now well advanced towards completion, to be published by the United States Geological Survey. The atlas of sixty lithographic plates is already printed, and the author submitted a copy to the section. The last plate of this volume is devoted to a restoration of *Brontops robustus*, one-seventh natural size, and a diagram enlarged from this plate to natural size was also exhibited.†

* Abstract of a paper read before Section D, of the British Association for the Advancement of Science, at the Bath meeting, Sept. 7th, 1888.

† The present plate (VI), one twenty-fourth natural size, shows a reduced copy of the same restoration.

The skeleton represented in this restoration is by far the most complete of any of the group yet discovered. It was found by the author in Dakota, in 1874, and portions of it have been exhumed at different times since, some of the feet bones having been recovered during the past year. It is a typical example of the family, and shows well the characteristic features of the genus and species which it represents.

The most striking feature of the restoration here given, aside from the great size of the animal, is the skull. This is surmounted in front by a pair of massive prominences, or horn-cores, which are situated mainly on the frontal bones. The nasals contribute somewhat to their base, in front, and the maxillaries support the outer face. These elevations, or horn-cores, vary much in size and shape in the different genera and species. They are always very small in the females.

The general form of the skull and lower jaw is well shown in the figure. The prominent occipital crest, the widely-expanded zygomatic arches, and the projecting angle of the lower jaw, are all characteristic features. In general shape, the skull resembles that of *Brontotherium*, but may be readily distinguished from it by the dental formula, which is as follows:

Incisors $\frac{2}{1}$; canines $\frac{1}{1}$; premolars $\frac{4}{4}$; molars $\frac{3}{3}$.

The presence of four premolars in each ramus of the lower jaw is a distinctive feature in this genus. This character, with the single, well-developed lower incisor, marks both the known species.

The number of teeth varies in the different genera. The form of the teeth, especially in the molar series, is more like that in *Chalicotherium* and *Diplacodon* than in any other known forms. The teeth in the allied genus *Brontotherium* have already been figured and described by the author.

The vertebræ are somewhat similar to those of the existing rhinoceros. In the present genus, *Brontops*, the neural spines of the dorsal vertebræ are elevated and massive. There are four sacral vertebræ in this genus, and in the known species the tail is short and slender, as in the individual here described.

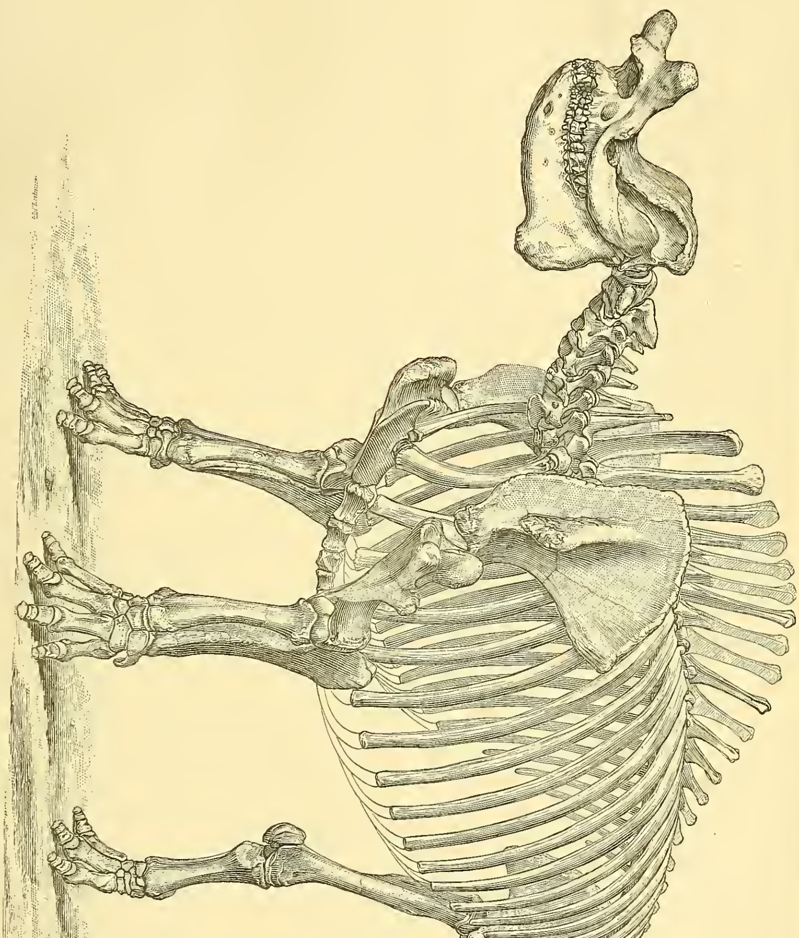
The ribs are strong and massive. The sternal bones are compressed transversely. The exact form of the first one is not known with certainty, and is here restored from the rhinoceros. This is the only important point left undetermined in the restoration.

The fore limbs are especially robust. The humerus has its tuberosities and ridges very strongly developed, and the radius and ulna have their axes nearly parallel. There are four well-developed digits in the manus, the first being entirely wanting.

The pelvis is very wide, and transversely expanded, as in the elephant. The femur is long, and has the third trochanter rudimentary. The tibia and fibula are quite short. The calcaneum is very long, and the astragalus is grooved above. There are only three digits in the pes, the first and fifth having entirely disappeared.

Diplacodon of the Upper Eocene is clearly an immediate ancestor of the *Brontotheridæ*, while *Palæosyops* and *Limnohyus* of the Middle Eocene are on the more remote ancestral line. The nearest related European form is the Miocene *Chalicotherium.* No descendents of the *Brontotheridæ* are known.

Menodus, *Megacerops*, *Brontotherium*, *Symborodon*, *Menops*, *Titanops*, and *Allops*, all belong to the family *Brontotheridæ*, and their relation to the genus here described, and to each other, will be fully discussed in the monograph, to which reference has already been made.



Restoration of BRONTOPS ROBUSTUS, Marsh; one twenty-fourth natural size.

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WITH PLATE VII.

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[THIRD SERIES.]

Art. XIX.—*Some Determinations of the Energy of the Light from Incandescent Lamps*;* by Ernest Merritt, M.E., Fellow in Physics at Cornell University.

[Contributions from the Physical Laboratory of Cornell University, No. IV.]

In the numerous experiments that have been made on the efficiency, life, etc., of incandescent lamps, the light from the lamp is always measured photometrically, and is expressed in candle powers. For most purposes this method is satisfactory, for it is the luminous effect of the light that is of practical importance. It is of some scientific interest, however, to determine what proportion of the energy supplied to a lamp is given off as light, and what proportion is wasted, practically, as dark heat. Photometric methods are evidently of no use in determinations of this kind. The candle power is rather a physiological than a physical unit; it measures the effect of light waves on the eye, and not the energy of these waves. It was necessary, therefore, on beginning the investigation to be described in this paper, to find some means of separating the visible from the invisible rays, and of measuring each in units of power.

The most exact method would probably have been to form a spectrum of the light to be tested with a rock salt prism, and to measure the energy of the visible and invisible portions by

* Read before the American Association for the Advancement of Science, Cleveland, August, 1888.

means of a bolometer. The elaborate character of the experimental preparation necessary to the successful carrying out of the bolometric method was, however, such as to necessitate its rejection, and recourse was had to a modification of the method first used by Melloni.* He separated the light from the dark heat by passing the radiations to be measured through a thin layer of water, or better still through a solution of alum in water. While the dark heat is almost entirely absorbed, the light nearly all passes through. The energy of the light can then be measured by a thermopile, and that of the dark heat by the rise in temperature of the water.

I. *Calorimetric Method.*

The first experiments which I shall describe were made by Mr. S. Ryder and myself in the spring of 1886. The lamp to be tested was placed in a large glass calorimeter, and maintained at the desired degree of incandescence. The greater part of the light escaped through the glass, but the dark heat was absorbed by the water and raised its temperature. The energy of the dark heat could thus be measured. Corrections were made for radiation, and for the absorption of light by the calorimeter. The total energy supplied to the lamp being determined by electrical measurements, the difference between this total energy and the energy of the dark heat gave the energy of the visible rays.

The calorimeter was cylindrical in form, being 22^{cm} in diameter and 38^{cm} high. It held about ten liters of water, and was supported by two narrow bars of iron, which offered a quite inappreciable obstruction to radiation.

During the progress of the experiment, distilled water was allowed to flow through the calorimeter in a steady stream, entering at the bottom through the glass tube E [fig. 1], and passing out at the top through the tube F. The temperature of the water when entering and leaving was determined by means of the thermometers C and W, placed in the entrance and exit tubes of the calorimeter.

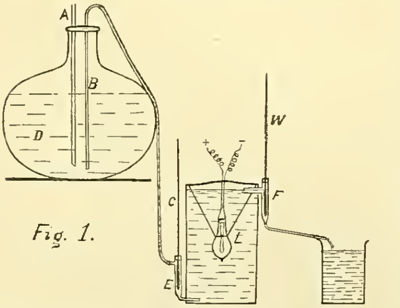


Fig. 1.

If the current in the lamp, and the rate of flow of the water, remain constant, then the difference in temperature between the water entering and that leaving

* Melloni: "La Thermochrose," Naples, 1850.

must also remain constant, and the heat absorbed by the water is measured by the product of this difference in temperature into the amount of water passing through the calorimeter.

Let t = time occupied by the experiment.
T_1 = temperature of water entering.
T_2 = " " leaving.
F = rate of flow of the water.
R = heat lost by radiation.

Then H, the heat absorbed by the water is:

$$H = [T_2 - T_1]Ft + R.$$

This method of determining the heat absorbed was adopted for several reasons. In the first place the correction for radiation was very small; we were always able to make the temperature of the air intermediate between T_1 and T_2 and of such value that the absorption of heat by the lower part of the calorimeter nearly balanced the radiation from the upper part. As it was impossible in our experiments to use a water jacket, or similar arrangement for reducing the radiation, this fact was of great importance. Then, if the ordinary form of calorimeter had been used, it would have been necessary to use a stirrer, which would have absorbed a considerable amount of light. Finally, by using this method we were enabled to take a number of readings of temperature and current instead of only one, and could continue the experiment as long as we wished.

The electrical energy supplied to the lamp was determined by measurements of current and resistance. The dynamo furnishing the current was allowed to run at its normal potential and to send a current of 10 or 15 Ampères through a dead resistance of heavy German silver wire. The lamp was connected so as to be in multiple with enough of this resistance to give the desired difference of potential. The resistance in multiple with the lamp, and the resistance of the lamp connections, were measured after the close of each experiment. The total current, and the lamp current, having been measured during the experiment, the resistance of the lamp was calculated from these data. The large tangent galvanometer in the Magnetic Observatory of Cornell University was used in measuring currents. For H the average value 0·1718 was used throughout the experiments.

The thermometers used were Baudin's "specific heat" thermometers, Nos. 10214 and 10294, graduated to 0°·02. They were read every minute by means of telescopes placed about two metres away and at the same height as the mercury in the tubes. After each experiment the two thermometers were compared to determine the difference in zero point. Curves were drawn after each test showing the variations of T_1, T_2, and of the lamp current C. The changes in T_2 were found to be slight and to correspond almost exactly with changes in the lamp current.

In calculating the rise of temperature it was necessary to allow for the time occupied by a particle of water in passing through the calorimeter. Since the rise in temperature of each particle is the difference between its temperature when entering and its temperature when leaving, T_1 must be observed before T_2. The exact difference in time depends on the rate of flow and the capacity of the calorimeter. The correction to be applied to T_1 was usually small.

The rate of flow, F, was kept constant by an arrangement similar to the "Mariotte's bottle" used in illustrating the laws of hydrostatics. D (fig. 1) is a large carboy filled with distilled water, and closed by an air-tight stopper. Through this stopper two glass tubes A and B pass down into the water, reaching nearly to the bottom of the carboy. The tube A is open to the air at the top, while B is connected by means of a rubber tube with the entrance tube, E. The carboy being air-tight except for the tube A, the rate of flow must depend on the difference in level between the surface of the water in the calorimeter and the lower end of A. The flow will therefore remain constant until the level of the water in the carboy has fallen below the bottom of the tube A. As a matter of fact F never varied more that 0·1 per cent in an hour or more. F was measured by weighing the water discharged in a known time.

The correction for radiation was complicated by the fact that the water in the calorimeter did not come quite to the top, but left a layer of air two or three centimeters thick between the lid and the surface of the water. For this reason the radiation coefficient for the lid was less than for the sides and bottom. The two coefficients were determined as follows: On a warm day, when the water in the carboy was several degrees cooler than the air, the water was allowed to flow through the calorimeter for two hours, and readings were taken of T_1 and T_2. The rate of flow was also determined in the usual way. Since the lamp was not running, the rise in temperature must have been due to absorption of heat from the air. This rise was only about 0°·3, while the difference between the temperature of the air and the mean temperature of the calorimeter was almost 5°. Hence it was not far wrong to say that the surface temperature of the calorimeter was the same at all points, and equal to the mean temperature of the water. This experiment then gave the sum of the two coefficients R_1 and R_2. The coefficient, R_1, for the lid was then determined separately. A thermometer was inserted through the lid of the calorimeter, (the flow being stopped) so that the bulb was just covered by the liquid. The water being about 4° warmer than the air, its gradual cooling was shown by the thermometer. Since the sides and bottom cooled more rapidly than the top, there were no convection currents, and the fall in temperature shown by the thermometer was due to the radiation from a layer of water at the top whose depth was equal to the length of the thermometer bulb. The greater part of this radiation must have been from the upper surface. Some heat escaped from the sides of the layer, but, since the sum $R_1 + R_2$ was known, this could be allowed for, and R_1 was determined. The radiation from the cylindrical surface of the calorimeter during an actual test, depended also on the mean *surface* temperature. After each experiment, therefore, the surface temperature was measured at seven different points by means of a thermometer let down into the calorimeter and placed as close to the sides as possible. A curve was then plotted showing the distribution of surface temperature. The mean ordinate of this curve gave the mean temperature of the cylindrical surface. The temperature of the bottom was taken as equal to that of the water entering, and the temperature of the top as equal to that of the water leaving.

To test the accuracy of the whole method we made several experiments with the lamp surrounded by a copper case, which allowed the water to circulate freely and yet shut off all the light. The heat given to the water should in this case be exactly equal to the electrical energy consumed. The mean of two determinations showed the agreement between the heat energy and electrical energy to be within 0·25 per cent.

In computing the results we used Lord Rayleigh's determination of the ohm, viz:

$$1 \text{ B A unit} = 0{\cdot}98677 \text{ true ohms}$$

and Rowland's value of the mechanical equivalent of heat:

$$1 \text{ calorie} = 4{\cdot}179\ 10^7 \text{ ergs, at } 20°.$$

The correction for the absorption of light by the calorimeter was determined photometrically. Curves were found connecting candle power and potential when the lamp was in the calorimeter and when outside. From these the absorption was calculated. It was found to vary from 25 per cent to 30 per cent.

Another needed correction was due to the fact that water does not absorb quite all of the dark heat from a highly heated source. It seems, as Tyndall first pointed out,* that the penetrating power of dark heat increases as the temperature of the

* "Contributions to Molecular Physics." Tyndall, p. 264.

source rises. The correction due to this fact was determined as follows: The radiations from the lamp, after passing through the water and glass of the calorimeter, were allowed to fall on the face of a delicate thermopile, and the deflection of the galvanometer in circuit was observed. A small cell containing an opaque solution of iodine in carbon disulphide was then placed between the pile and the lamp, and the deflection again observed. The iodine solution cut off the light entirely, but allowed the dark heat to pass through. The ratio of the second deflection to the first, therefore, gave the ratio of the dark heat escaping from the calorimeter to the total radiant energy that escaped. It was found that a little less than one-third of the energy that had passed through the glass and water of the colorimeter, was dark heat. This correction was determined for each particular candle power at which the lamp was run.

The lamp used in the experiments was an Edison "108 volt," 16 C. P. lamp with a cold resistance of 255 ohms. This lamp was perfectly new when the tests began. Determinations of the energy of the light were made at seven different candle powers; the results are given in the following table:

Lamp A. Edison.

E. M. F.	W	C. P.	L	$\frac{L}{W}$	$\frac{L}{C. P.}$
74·2	34·6	0·9	0·18	0·005	0·59
91·6	56·2	4·8	0·68	·012	0·14
97·3	64·6	7·3	1·13	·017	0·15
100·3	69·3	8·9	1·62	·023	0·18
107·6	81·6	14·6	2·97	·036	0·20
109·3	84·4	16·3	4·57	·054	0·28
124·1	115·4	38·2	7·46	·065	0·19

In this table W is the total energy, in Watts; L the energy of the light, also measured in Watts; and C. P. the candle-power.

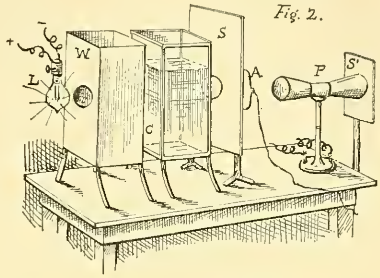
Some of these results are shown graphically in fig. 3. The curve A is found by taking as abscissæ the different values of W, and as ordinates the corresponding values of L. The vertical scale is about ten times the horizontal.

II. *Determinations made with the Thermopile.*

I returned to this subject in 1888 and continued the investigation by a somewhat different method. The calorimeter was abandoned, and for absorbing the dark heat a cell one decimeter thick containing a strong solution of alum was used. After passing through this cell the light was allowed to fall on a thermopile, and the deflection was observed. Then the alum cell was removed and the deflection corresponding to total radiation was observed. The ratio of the two deflections gave the ratio of the light energy to the total energy. The total energy being determined by electrical measurements, the energy of the light could be calculated.

Fig. 2 shows the arrangement of the apparatus. The lamp, L, was placed close behind the screen W. This was a metallic vessel of the form shown, and was filled with water. A cylindrical opening through the center allowed part of the light from the lamp to pass through. This screen prevented any heat from the supports of the lamp from reaching the pile. Beyond this water-screen was the cell C containing the solution of alum, and beyond C the large screen S of asbestus paper. There was a small opening in this screen, directly in line with the opening in W, and covered by a movable piece of asbestus paper A. The pile P was placed with its funnel-shaped tube about 5^{cm} from A. Close to the end of the other funnel of the pile was the asbestus screen S′, which served to protect the right-hand face from sudden changes of temperature. The total distance from the lamp to the pile was about two feet.

Fig. 2.



The pile contained 56 pairs with a total surface of about $2{\cdot}5^{sq\ cm}$. Wires led from it to a Thomson tripod galvanometer of about 0·3 ohms resistance. The galvanometer and scale were placed at some little distance from the pile, and the screen S was between the pile and the observer. The galvanometer was so delicate, that it was impossible to keep its zero point from drifting. As it took fully four minutes for the needle to reach its final deflection when the light was allowed to fall on the pile, and as the lamp current was not at all steady, this movement of the zero point made it difficult to obtain reliable deflections, but a peculiarity in the manner in which the needle reached its final position, simplified the matter greatly. The screen A could be suddenly drawn aside by means of a cord reaching to the observer, so as to allow the lamp to shine upon the pile. When this was done the spot of light which indicated the motion of the galvanometer needle, moved quickly to one side. But in two or three seconds it began to move more slowly, and in about five seconds stopped, moved backward a short distance, and then on again. Several of these maxima and minima could be noticed before the final deflection was reached. The needle *always* moved in this way, no matter whether the final deflection was large or small. Using a steady gas flame as a source of heat, and taking special precautions to avoid drafts of air, I determined the ratio of this first deflection to the final deflection throughout the range of deflections used in these experiments. The ratio was constant and equal to 32·6 per cent for deflections between 20 and 100 scale divisions. For deflections less than 20 the ratio rose rapidly to 50 per cent at 1·7 divisions. The curve found by plotting this ratio, and the first deflection, resembled an equilateral hyperbola with vertical and horizontal asymptotes.

In the experiments with incandescent lamps the first deflection alone was observed, and the value of the corresponding final deflection was calculated from the curve just described. As the first maximum was reached in about five seconds the error from change of zero point was very small.

The proportionality of deflections to heating effects was shown by plotting a curve for each lamp tested, in which ordinates represented deflections and abscissæ Watts expended in the lamp. In every case this curve was very nearly a straight line passing through the origin. What slight variation there was might be accounted for by the convection from the glass of the lamp.

In the actual tests the alum cell C was first removed and the deflection corresponding to total radiation was observed. Then the cell was placed in position, and the deflection due to the light was taken. Finally a cell containing an opaque iodine solution was placed between the alum cell and the pile, and the deflection again observed. This gave the correction for dark heat passing through the alum. In each case the correction due to any difference in temperature between the pile and the apparatus was determined by taking the deflections when the lamp was turned off. The correction for light absorbed was found in the same way as when the calorimeter was used. It varied from 25 per cent to 30 per cent as before. Only about 10 per cent, however, of the radiations passing through the alum, were dark heat. For low candle powers the percentage was much less even than this.

The lamp current was measured by a Thomson ammeter, calibrated from the large tangent galvanometer. With each lamp tested the curve between current and Watts was determined once for all by measurements with the galvanometer. The energy expended in the lamp could then be calculated from its current.

The results for the four lamps tested by this method are given below. As in table A, W is the total energy expended, measured in Watts; L is the energy of the light, also measured in Watts; and C. P. is the candle power.

Lamp B.

An Edison 16 C. P. Lamp. Resistance = 249 ohms.

E. M. F.	W.	C. P.	L.	$\frac{L}{W}$.	$\frac{L}{C.P.}$.
63·0	25·4	0·3	0·42	0·016	1·61
74·6	37·8	1·0	0·77	·021	0·79
85·4	52·5	2·5	1·96	·037	0·78
99·0	72·2	6·3	4·30	·059	0·68
116·0	102·0	15·2	7·38	·072	0 49

Lamp C.

Weston 16 C. P. Cold resistance = 402 ohms.

E. M. F.	W.	C. P.	L.	$\frac{L}{W}$.	$\frac{L}{C.P.}$.
72·0	21·6	0·4	0·46	0·021	1·27
87·4	33·5	1·5	1·10	·033	0·76
102·0	47·8	4·4	2·09	·044	0·48
117·0	66·1	10·7	3·19	·048	0·30

Lamp D.

Weston 16 C. P., 70 volt. Resistance = 152 ohms.

E. M. F.	W.	C. P.	L.	$\frac{L}{W}$.	$\frac{L}{C.P.}$.
43·0	25·8	0·5	0·53	0·021	1·06
50·7	36·0	1·6	0·97	·027	0·62
60·5	52·0	5·2	2·03	·039	0·39
67·5	65·5	11·0	3·95	·060	0·36

Lamp E.

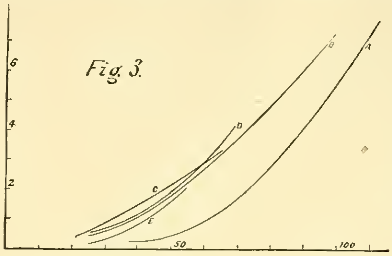
Bernstein 8 C. P. Resistance = 11·3 ohms.

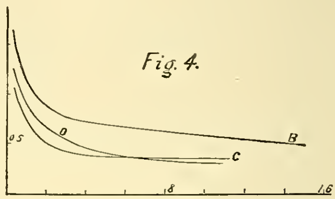
E. M. F.	W.	C. P.	L.	$\frac{L}{W}$.	$\frac{L}{C.P.}$.
12·2	25·2	0·2	0·20	0·008	1·00
13·4	30·8	0·5	0·41	·013	0·84
15·0	40·4	1·3	0·75	·018	0 57
16·4	53·2	4·1	2·03	·038	0·50

The curves of light energy, L, and total energy, W, for these four lamps are shown in fig. 3.

None of the lamps tested were of the most recent styles, all being made previous to 1886. All of the lamps, also, except lamp A, had been used a greater or less time before the tests were made. Lamps B and E especially had seen a great deal of use, and had their glass globes slightly blackened.

The curves in fig. 4 show the relation between candle power and light energy at different candle powers. Abscissæ are the candle powers at which the lamps are run, and ordinates measure the energy of the light per candle power, or, in other words, the mechanical equivalent of one candle power. The numerical values of the ordinates are given in the columns





headed $\frac{L}{C.P.}$ of the tables. It will be seen that the energy per candle power varies from 1·5 Watts at 0·5 C. P. to about 0·3 Watts at 16 C. P. In every case the *intensity* of the light, as measured by its candle power, increases more rapidly than the *energy* of the light.

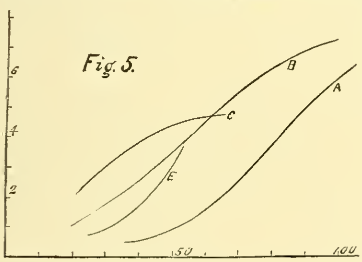
In this connection it is interesting to compare the value of the mechanical equivalent of a candle power of lamp light, found by Dr. J. Thomson some twenty years ago.* His method was similar to that used in these experiments. A cell of distilled water was used instead of an alum solution, and no correction was made for the dark heat passing through. To get absolute measurements of energy he standardized his thermopile by means of Leslie tubes. He found the energy of one candle power of light from an oil lamp to be 2·5 Watts, and for a gas flame and a standard candle the value was very nearly the same. This is considerably larger than the greatest value that I found. A part of the difference might be accounted for by the correction for dark heat passing through the water, which Dr. Thomson neglected; and the standards of light used in the two cases may have been different. It is hard to believe that the temperature of the incandescent matter in an oil flame is less than that of a lamp filament at 0·5 C. P. Recent spectrophotometric determinations by Dr. E. L. Nichols and Mr. W. S. Franklin† show that the light from a gas flame is of almost exactly the same quality as that from an incandescent lamp at 16 C. P. This would seem to indicate that the incandescent matter in a gas flame is at about the same temperature as the lamp filament.

* Julius Thomson. "Das mechanische Aequivalent des Lichtes;" Pogg. Ann. cxxv, p. 348.

† Proc. A. A. A. S., Cleveland meeting, 1888.

Some determinations of the radiation from incandescent lamps made by Capt. Abney and Col. Festing* are also of interest in this connection. The radiations from the lamp were dispersed by a prism, and the increase in the energy of each ray, as the candle power was raised, was measured by a thermopile. The curves found for different wave-lengths were approximately parabolas with vertical axes. The summation of a number of such curves should evidently give a curve similar to those found in my experiments.

There is another way of looking at the results of these experiments, which may be of some practical interest. An incandescent lamp, in fact any artificial source of illumination, may be considered as a machine for producing light. Energy in some form being supplied, the machine transforms a certain portion of this energy into luminous vibrations. Now the efficiency of any machine is the ratio of the useful work done by it to the energy expended. The efficiency of an incandescent lamp, therefore, is the ratio of the energy given off as light, to the total energy consumed. This efficiency, for the lamps tested, can be determined from the results already given by dividing the values of L by the corresponding values of W. The values of this quotient are given in the tables of results. The curves of efficiency and total energy are shown in Fig. 5. The largest value found for the efficiency was slightly over 7 per cent.



It will be noticed that this "luminous efficiency," as it might be called, does not correspond at all with the commercial efficiency of the lamp. Take for example the two Edison lamps A and B. A was new and fairly efficient, commercially, for lamps made at that time, giving 16 C. P. at about 80 Watts; B was old, and commercially very inefficient, giving 16 C. P. at something over 100 Watts. Yet the efficiency of A as a light machine was only 3·5 per cent at 16 C. P., while that of B was 7·4 per cent. ! The difference must be in the quality of the light.

Dr. Thomson, whose article on this subject has already been referred to, made several determinations of the efficiency of oil and gas flames. He found that about two per cent of the radiant energy was light. This low value of the efficiency is probably not due to the low temperature of the incandescent portion of the flame, but rather to the fact that the heated

* "Relation between Electric Energy and Radiation, in Incandescent Lamps." Capt. Abney and Col. Festing. Proc. Roy. Soc., vol. xxxvii, p. 157.

gases around the flame radiate a considerable amount of heat to the pile, and yet give off no light. Dr. Thomson also found that only about 15 per cent of the heat of combustion was radiated, the remaining 85 per cent being lost by convection. The true efficiency of an oil lamp as a light-making machine is therefore only about 0·3 per cent, or one-tenth that of an incandescent lamp.

It will thus be seen, as has already been pointed out by several writers, that the incandescent lamp, though an immense improvement on gas and oil lamps, is still far from being an efficient light-making machine. Whether a light machine will ever be found whose efficiency is much greater, it is of course impossible to say, but it is a question which merits the serious attention of investigators.

ART. XX.—*Geology of Fernando de Noronha.* Part II. *Petrography;* by GEORGE H. WILLIAMS.*

WHAT has heretofore been published in regard to the petrography of the island of Fernando de Noronha is inconsiderable, but this fact is due to the difficulty in obtaining access to the locality and the consequent rarity of material rather than to any lack of interest in the rocks themselves.

The volcanic nature of the island and the true character of its prevailing rock (phonolite) were recognized by Darwin in 1832.† The place was visited by the Challenger party in 1873, from one member of which (Willemoes-Suhm) Gümbel obtained a single specimen of the phonolite which he analyzed and examined microscopically in 1879.‡ Other specimens collected by Mr. J. Y. Buchannan, also a naturalist of the Challenger expedition in 1873, from islands of the Fernando group, although not from Fernando de Noronha itself were described by Abbé Renard in 1882.§ He figures and gives the microscopic characters of a phonolite from St. Michael's Mount (Sella á Gineta)‖ and of a nepheline basalt from Rat Island (Ilha Rapta) with an analysis of the latter. He also mentions a feldspar basalt from Platform Island (São José), and a calcareous

* For Part I, see page 145 of this volume.

† Geological Observations on Volcanic Islands, London, 1844, p. 23.

‡ Tschermak's Mineralogische und Petrographische Mittheilungen, ii, p. 188. 1879.

§ Notice sur les roches de l'ile de Fernando Noronha, Bull. d. l'Acad. roy. de Belg. (3) III, No. 4. 1882.

‖ It is probable that the phonolite specimen studied by Gümbel came from this locality, as the Challenger party appear not to have landed for scientific purposes on Fernando de Noronha itself. (Cf. Wyville Thompson's narrative, The Atlantic, II, p. 115, 1877.)

tuff containing fragments of basalt and palagonite, from both Platform and Rat Islands. At the Aberdeen meeting of the British Association in 1885, Renard made a further verbal communication on the Fernando rocks, and the complete results of his researches will be published in the Challenger reports.

The collection of Fernando rocks placed in my hands for examination numbers thirty-four specimens. They were selected as a representative suite from a much larger collection made by Professor Branner in 1876 and now deposited in the National Museum at Rio de Janeiro. Specimens from this same collection were also sent by Professor Derby to Professor Rosenbusch who mentions the following types: nephelinoid phonolite with inclusion of eleolite-syenite, nepheline basanite, nephelinite, and augitite.*

Mr. A. C. Gill, Fellow of the Johns Hopkins University, made a preliminary examination of the collection here described, identifying the following species: phonolite, nepheline-basanite, nepheline-basalt, nephelinite, basalt-glass and tuff.†

Another large collection of specimens appears to have been made by a party from the British Museum, who spent six weeks on the island of Fernando de Noronha in 1887, and from whom still further petrographical descriptions may be expected.‡

Of the thirty-four specimens in Professor Branner's collection, one (66) is travertine, and three others (18, 20 and 118), on account of their extremely altered and friable condition, were not particularly studied. In most of the remaining thirty nepheline is present, although in certain of the lightest colored and most acid rocks its presence could not be established, while in the more glassy of the basalts, if the requisite constituents for its formation exist in the base, they have not come to actual crystallization.

The specimens may be assigned to the following petrographical types:—

I. *Trachytes and Andesites.*

Hornblende trachyte	10, 121, and 129.
Hyalotrachyte	19.
Hornblende andesite	131.

II. *Phonolite.* 1, 5, 9, 35, 40, 41, 43, 51, 52, 88, 137.

* Die massigen Gesteine, 2d ed. 1887, pp. 91, 518, 624, 628, 769, 785, 802, 821.

† Petrographical notes on a rock collection from Fernando Noronha (preliminary notice.) Johns Hopkins University Circulars, VII, p. 71, No. 65. April, 1888.

‡ Rev. T. S. Lea: The island of Fernando de Noronha in 1887. Proc. Roy. Geogr. Soc., x. 424, 1888.

III. *Basalt in Rocks.*

Nepheline basanite	31, 34.
Nephelinite-dolerite	2.
Nepheline basalt	45, 72, 27.
Augitite	115.
Limburgite	14, 65.
Basalt bombs	3, 48, 58.
Basalt tuffs	54, 62.

I. *Trachyte.*

Darwin observed at the base of Fernando de Noronha beds of whitish tuff cut by dykes of trachyte,* and Professor Branner† states that these soft light-colored rocks have a very considerable development at low levels and at the base of certain of the eminences, notably Atalaia Grande and Morro Francez.

No. 121. Amphibole-Trachyte. East base of Morro Francez.—This rock is a very light greenish gray, homogeneous and comparatively compact mass, in which porphyritic crystals of sanidine and black hornblende are only rarely discernible. Under the microscope the thin section shows the same poverty in porphyritic crystals as the hand-specimen. Two or three sharply defined Carlsbad twins of sanidine and a single crystal of dark brown, intensely pleochroic hornblende are all that are present. The main mass of the rock is composed of a rather coarse-grained aggregate of feldspar crystals in two forms. The most abundant are short rectangular sections with well-defined outlines and a zonal structure, often more altered internally than at the periphery ("orthophyric feldspar" of Rosenbusch). The other feldspar is in narrow acicular or lath-shaped microliths ("trachytic feldspar" of Rosenbusch).‡ In this aggregate are further observable irregular patches of a brown globulitic glass; abundant sharp octahedrons of magnetite; minute brightly polarizing needles too small to be positively determined but doubtless pyroxene microliths with a very high extinction angle; small diamond-shaped crystals of titanite; and finally occasional minute, but very sharp dodecahedral (rarely octahedral) crystals which are transparent with a violet color and which may be perofskite, although their amount is too small in this specimen to allow of their certain identification.§ The general structure of this rock is such as is included by Rosenbusch under the Drachenfels-type. The powder of the rock is not materially attacked by strong chlorhydric acid

* Geological observations on Volcanic Islands, 1844, p. 23.

† Vid. ante, p. 9.

‡ Die massigen Gesteine, 2d ed., pp. 594–5.

§ In a letter from Professor Renard dated Jan. 30th, 1887 he announces to the writer his identification of perofskite and sodalite in the Fernando phonolite.

nor can the section be etched, except in the occasional patches of glass, by the same reagent. Mr. Gill determined by means of the Thoulet solution that all the powder of this rock, except its heaviest components (magnetite, hornblende, titanite, etc.), had a specific gravity between 2·557 and 2·455. All of these tests, as well as the general character and structure of the specimen seem to show conclusively that it contains no nepheline.

No. 129, from a dyke cutting the rock last described, possesses a somewhat anomalous character. The lack of a complete analysis, together with the altered condition of this specimen makes it difficult to define its exact position, but it probably belongs somewhere between the trachytes and andesites. A macroscopic examination is able to detect only a gray, somewhat vesicular groundmass, enclosing occasional needles of black hornblende. The vesicles are elongated in the direction of movement in the mass before its solidification and are coated with calcite and minute crystals of analcite.

The microscope discloses crystals of brown hornblende and purplish gray augite imbedded in a fine network of long, lath-shaped microliths. These latter when examined with a high power show a very weak double refraction, suggesting melilite or nepheline. Their habit, however, differs wholly from that of these minerals, while their resistance to the action of strong chlorhydric acid leaves little doubt that they are feldspar. These little microliths are often quite completely changed to calcite, and yet there is rarely visible the twinning striation characteristic of the members of the plagioclase series. A specific gravity determination yielded no satisfactory results on account of the alteration of the rock, the fineness of grain and intimate admixture of magnetite. There was a continual fall of the light-colored portions of the powder in the Thoulet solution between the limits of andesine and sanidine, but the presence of magnetite grains and zeolites prevented any conclusion being drawn from this fact. The only other original constituent observed was biotite, in very minute but sharply defined hexagonal plates. This is very abundant. The analcite of the vesicles shows between crossed Nicols its anomalous double refraction in great perfection. The percentage of silica in this rock was determined, by Mr. John White, Jr., as 50·1.

No. 10. Amphibole Trachyte, base of Atalaia Grande.—This specimen presents a pale gray lithoidal groundmass similar to the last, but the porphyritic constituents are here much more abundant. These consist of glassy idiomorphic sanidine crystals, black idiomorphic hornblende crystals, and rusty yellow spots where some mineral no longer determinable has weathered out. Under the microscope the sanidine appears quite fresh, although it is often surrounded by a rusty border probably the result of infiltration. The hornblende is dark brown with almost complete absorption ∥ c. It is surrounded by a border of magnetite and augite grains frequently associated with sphene crystals. The yellow spots macroscopically visible mark the position of some mineral rich in iron which has now wholly disappeared. They appear as a large yellow stain in which irregular bits of some opaque iron oxide or a group of sphene crystals are occasionally clustered. The whole groundmass of the rock is also everywhere spotted with similar, but much smaller yellow stains, which have resulted from the rusting of minute magnetite crystals. The groundmass itself consists of a felt-like network of minute slender feldspar microliths, with a large amount of non-polarizing interstitial matter (colorless glass). The same small brightly polarizing needles with high extinction angle, noticed in the last specimen, are also present in this. Strong chlorhydric acid attacks this rock to a certain extent, but this is due only to the presence of the glassy base. No indication was discovered of the presence of nepheline. It was determined by Mr. Coates to contain 55·6 per cent. of SiO_2.

No. 19. Hyalotrachyte, Bahia do Sueste.—This specimen and No. 20, which was not examined microscopically, present a soft chalky mass, of a white or cream color, and contain no porphyritic crystals. Under the microscope only microliths of sanidine are visible which show in their arrangement a decided flow-structure and are imbedded in a very large proportion of a somewhat globulitic glass. The structure of this rock is typically trachytic and quite porous.

No. 131. Hornblende andesite, loose pebbles from the beach.—This contains abundant large crystals of plagioclase and a few of brown hornblende scattered through a reddish, somewhat vesicular groundmass. No other porphyritic constituents are present. The groundmass is made up of plagioclase microliths showing flow structure, and occasional minute green augite grains, imbedded in a glassy matrix which is itself apparently colorless, but rendered nearly opaque by the amount of magnetite dust present in it.

II. *Phonolite.*

The eleven specimens of typical phonolite in Professor Branner's collection all come from the eastern half of the main island and were collected either along the north shore as far west as the Peak, or on the line joining this eminence with the one on the south shore called Atalaia Grande. All are representative nephelinoid phonolites, gelatinizing readily with acid and possessing the compact structure and somewhat oily luster characteristic of that rock. The specimens vary considerably in the relative abundance of their porphyritic crystals, range in color from dark green to pale grey, and differ in their microscopic composition and structure. No relation could, however, be discovered between these differences and the areal distribution of the rocks. The St. Michael's Mount (Sella á Gineta) phonolite described by Renard is not represented in this collection.

The distribution of the phonolite specimens (cf. map) is as follows: No. 137, N.E. corner of island, between the village and Bahia de Sto. Antonio. Professor Branner's notes say, "This is the rock most common east of the village along the north shore of the island." Nos. 1 and 35, Pedra da Conceiçao. Nos. 51, 52 and 88, Peak. Nos. 41 and 43 north of Atalaia Grande from loose blocks. Nos. 5, 9 and 40 Atalaia Grande.

The phonolites of Fernando de Noronha are remarkable for having a columnar parting more prominently developed than the separation into plates parallel to the cooling surface, so common in this rock.

With reference to their microscopic characters the specimens of phonolite at hand may be arranged as follows:

I. *Nepheline of the groundmass in distinct crystals ; green bisilicate in compact stout crystalloids.*

Grain fine, little brown hornblende, no hauyne	No. 41
Grain fine, black hauyne abundant, no hornblende	9
Grain very fine, hauyne and sphene, but no hornblende	40
Grain very fine, like last without hauyne	35

II. *Nepheline of the groundmass moderately distinct ; green bisilicate in more or less radiating ocellar sheaves.*

Ocellar sheaves very distinct	43
Sheaves less distinct ; nepheline crystals plainer	5

III. *Nepheline of the groundmass indistinct ; green bisilicate not prominent.*

Porphyritic nepheline, hauyne, sphene, flow structure	51
Porphyritic nepheline, hauyne, eutaxitic structure	88
Porphyritic nepheline, hauyne, brown hornblende, dull groundmass	137
Groundmass dull and opaque, hauyne, brown hornblende	1
Like last	52

The constituent minerals agree very closely with the diagnosis given by Professor Rosenbusch for the components of typical phonolite.

The sanidine is abundant in all specimens both as porphyritic crystals and in the groundmass. The former have a flat tabular habit parallel to their plane of symmetry, which, as a rule, lies parallel to the cleavage of the rock. Carlsbad twins are rather the rule than the exception. This mineral is younger than the hauyne but of about the same age or a little younger than the porphyritic nepheline. In some cases (No. 9) a continuation of the growth of an intratelluric crystal may be seen to have taken place during the final period of consolidation. The sanidine of the groundmass consists of lath-shaped microliths, which often exhibit in their arrangement a well marked flow structure. (No. 51.) Brown hornblende occurs only in sparsely disseminated porphyritic crystals; never in the groundmass. It is not present in all the thin sections, but this may be accidental as the hand specimens show no marked difference in this respect. Is is always surrounded by the magnetite corrosion-rim showing that it must have been wholly a product of intratelluric crystallization. Within this rim sphene is of frequent occurrence. Around the outside of the magnetite rim is a fringe of minute crystals of green pyroxene (ægirine). The hornblende is, in some cases at least, younger than the hauyne. Its pleochroism is as usual, but particularly strong.

Hauyne is abundant in many of the specimens. Its well defined crystal outline shows it to belong to the earliest secretions of the magma, as does also its inclusion in all the other constituents. It is in every instance colorless but filled with its characteristic opaque inclusions which in one section (No. 9) are so numerous as to make the mineral appear nearly black. Alteration to zeolites and to calcite are common; the latter being the ground for referring the mineral to hauyne rather than to nosean.

Nepheline is very frequent in porphyritic crystals which often possess a diameter of a millimeter or more. In this form it belongs to the oldest crystallizations of the magma. As a constituent of the groundmass it is sometimes very distinct in short stout crystals showing well defined hexagonal or rectangular outlines. In other cases it is poorly individualized and indistinct. The green bisilicate constituent of the Fernando phonolites is without doubt an alkaline pyroxene (ægirine), although its optical properties are so like those of hornblende that in minute individuals devoid of crystalline form, it is not strange that it should be confused with this mineral. As a porphyritic constituent it is rare and unimportant, the crystals being always comparatively small. These generally exhibit a zonal structure, with a gray or violet-colored center and a weak pleochroism. In the groundmass the ægirine occurs either as short stout crystalloids or in more or less radiating "ocellar" tufts crowded with small nepheline crystals. Its lack of well developed form indicates that it was a late product of crystallization. The late Prof. C. E. Wright determined the inclination of the axis of greatest elasticity ($\mathfrak{a}$) to the vertical axis ($\overset{|}{c}$) as between 7°·42′ and 16°; double refraction negative. Among the more compact crystalloids in the groundmass of No. 41 a few cross-sections were found which showed the prismatic development. These sections were hexagonal bounded by (110) and (100), while (010) is wanting. The pleochroism, which is often quite strong, is: $\bar{b}$ ($\mathfrak{b}$) green; $\overset{|}{c}$ ($\mathfrak{a}$ nearly) green; $\grave{a}$ ($\mathfrak{c}$) yellow; absorption. $\mathfrak{a} > \mathfrak{b} \gg \mathfrak{c}$. All of these determinations agree closely with those given by Rosenbusch.*

The other minerals observed were sphene, magnetite and very sparingly apatite, all of which present their character usual in the phonolites. Noticeable for the sphene is its frequent occurrence in the black corrosion rims around the hornblende.

A point of considerable interest with regard to the Fernando phonolites is the possible occurrence in them of inclusions of eleolite-syenite as mentioned by Prof. Rosenbusch.† The material in hand is not however sufficient to definitely decide this question. In a communication from Prof. Orville Derby of Rio de Janeiro, in whose hands the entire collection made by Professor Brauner formerly was and who still has charge of the greater part of it, he says that in this large amount of material only a single specimen showed any sign of such an inclusion. This was a pale gray and rather coarse grained phonolite from the Peak (No. 50) which contained a sharply defined inclusion, apparently of a typical eleolite-syenite about 3^{cm} square. Of this inclusion and a portion of the surrounding phonolite one fragment was sent by Prof. Derby to Prof. Rosenbusch and another to myself. Prof. Derby has also kindly furnished me with a photograph of this specimen. If the inclusion is really an eleolite-syenite it belongs to an exceptionally porphyritic type, inasmuch as more than one-half of its small area (3×3^{cm}) is occupied by a single crystal of a blue iridescent orthoclase ($2\times1\frac{1}{2}^{cm}$). Both Profs. Derby and Branner agree that inclusions of this sort must be of rare occurrence in the Fernando phonolites,‡ and in no way comparable to those so abundant in the tinguaites of the Rio de Janeiro neighborhood. Prof. Derby is inclined to regard this inclusion as an early and intratelluric secretion of the phonolite magma. This view§ may derive some support from the fact

* Die massigen Gesteine, 2d ed., p. 616.

† Die massigen Gesteine, 2d ed., pp. 91, 628 and 821.

‡ Quart. Jour. Geol. Soc., xliii. p. 459, 1887.

§ Opinion expressed in a letter to the writer (cf. reference just cited and Neues Jahrbuch für Min., etc., 1887, II, p. 258.)

that another phonolite specimen of this collection (No. 5) does undoubtedly contain such coarse-grained secretions composed of large crystals of nepheline and sanidine. The appearance of these is however undeniably different from that of the apparent inclusion; and, in the absence of more abundant material, the writer would refrain from expressing a decided opinion.

III. *Basaltic Rocks.*

No. 31. Nepheline-basanite, São José Island.—This is a very compact black rock in which minute crystals of olivine and augite are macroscopically visible. Under the microscope these two constituents are seen to be present in abundant well-formed crystals possessing their usual characters. The groundmass in which they are imbedded is a fine holocrystalline aggregate of augite and plagioclase microliths and magnetite grains. Some interstitial nepheline is also present, but this is of so small amount as to ally this rock to the feldspar basalts.

No. 34 is a fragment of a coarsely granular inclusion or secretion in the last described specimen. It is composed of perfectly fresh olivine and enstatite with hardly a trace of any other mineral, and is analogous to the so-called "olivine bombs," common in many basaltic rocks but whose origin is still a matter of discussion.

No. 2. Nephelinite-dolerite.—A dark gray, coarse grained rock collected in the N.E. part of the main island, but nowhere found *in situ*. Long black crystals of augite and small grains of olivine are macroscopically visible. The microscopic character of this rock agrees very exactly with Rosenbusch's description of the doleritic type of nephelinite;* and, in spite of its comparatively large amount of olivine, it is here assigned to this class on account of its close resemblance to the classic occurrences at Meiches and Löbau.

The structure of this rock is holocrystalline and granular (*hypidiomorph-körnig* in the sense of Rosenbusch†) like that of a plutonic mass. Its most prominent constituent is augite. whose jet black crystals are often a centimeter or more in length and impart to the hand-specimen a porphyritic appearance. Under the microscope these crystals have a brownish red color, a decided pleochroism and a distinct zonal structure. The colors of the different rays are $\mathfrak{c}$ and $\mathfrak{b}$ reddish brown; $\mathfrak{a}$ greenish yellow; absorption $\mathfrak{c} > \mathfrak{b} \gg \mathfrak{a}$. The outer zones are invariably more intensely colored (i. e. richer in ferric iron) than the inner and are hence more pleochroic. The hour-glass structure is also frequent as a form of zone growth. The ex-

* Die massigen Gesteine, 2d ed., p. 791.
† Ib., p. 11.

tinction angle is very high and twinning lamellæ intercalated parallel to the orthopinacoid (011) of common occurrence. To all appearances this augite is identical with that of the Kaiserstuhl basalts which has been studied by Knop and found by him to be titaniferous.*

The olivine of this rock is in some slides quite abundant; in others less so. It is very fresh and of a pale yellow color. It occurs commonly in small grains, but more rarely in sharp crystals.

The colorless component is for the most part nepheline in large crystals, easily recognized by negative uniaxial character, its parallel extinction, lack of cleavage and the ease with which it is attacked by acids. Its specific gravity is from 2·61 to 2·59.

An unstriated feldspar, probably sanidine, is present in small quantity,† and also occasionally particles of a striated feld-spar.

Sodalite in irregular patches is present in almost every section, its isotropic substance being penetrated in every direction by brightly polarizing needles of some zeolite which has resulted from its alteration.

Apatite is abundant in its characteristic forms. The iron ore is octahedral—probably a titaniferous magnetite. A small amount of the peculiar copper-colored and but slightly pleochroic mica, so common in nepheline rocks, is also present.

Nepheline-basalt is represented by three specimens in Prof. Branner's collection. One of these (No. 45) from Morro Francez agrees almost exactly with the figure and description given by Renard of a similar rock from Rat Island‡ (Ilha Rapta.) Its only porphyritic constituents is olivine in sharp crystals or irregular grains. These are surrounded by a yellow border of iron hydroxide and more or less opaque iron oxide resulting from decomposition, and appear in the compact black hand specimen as rusty yellow spots. The interior of these olivines is however shown by the microscope to be quite fresh and colorless. The groundmass is a fine aggregate of idiomorphic augite crystals, octahedrons of magnetite and nepheline, without any unindividualized base.

No. 72, from Ilha Rapta, differs from the last described specimen in having the porphyritic olivines nearly devoid of the yellow border and in possessing a slightly coarser groundmass. Within the latter may also be seen occasional flakes of a brown mica and transparent octahedral crystals which are without doubt perofskite.

* Zeitschrift für Krystallographie, x, p. 58, 1885.

† Knop has shown that a barium orthoclase is present in the closely allied nephelinite from Meiches in the Vogelsgebirge. Neues Jahrbuch für Min., etc., 1865, p. 687.

‡ Bull. d. Acad. roy. de Belge (3), III, No. 4, 1882.

No. 27 from a point on the south side of Fernando agrees closely with the last specimen except that it contains no perofskite.

No. 65 from Portão, at the west end of Fernando is a typical limburgite. In the hand-specimen it is of a dark gray color and filled with vesicular cavities of all sizes which are either coated or completely filled with zeolites. Small rusty yellow spots indicate the position of abundant olivine crystals which are the only constituent macroscopically visible. Under the microscope well-formed olivines surrounded by a yellow border are seen imbedded in a groundmass of augite microliths, magnetite octahedra and a colorless glass. Thus the rock is a limburgite of the second class in the sense of Bücking, which, as we might expect from the present association, is more nearly allied to the nepheline, than to the feldspar basalts.

No. 14, from Atalaia Grande, may also be classed as a limburgite, although from its poverty of olivine it is closely related to the augitites. The hand-specimen of this rock presents a striking contrast to the last, it being compact and black like the nepheline-basalts. Small, sharply-formed augite crystals and a few olivines are the only components visible. Under the microscope this specimen is seen to differ greatly from all the others. The olivines are few but very fresh. The augites are distinguished by their pronounced zonal structure, their interior being of a brilliant green and pleochroic, while the outer zone is reddish gray. Their extinction is very high. Smaller crystals of brown basaltic hornblende are also abundant. The groundmass consists of a brown glass somewhat devitrified with globulitic dust and occasional arborescent growth forms. This contains augite microliths, magnetite in octahedra and occasional crystals of blue hauyne. As a secondary product analcite occurs, either after the hauyne or in minute cavities.

No. 115, from Morro Francez, is a more typical augitite in being wholly free from olivine, although it approaches the nephelinites in containing nepheline, mostly in the form of porphyritic crystals. The hand-specimen shows abundant black porphyritic crystals which are in part hornblende and in part augite. The groundmass is mostly composed of a colorless glass containing augite microliths and magnetite. A little nepheline is also present in it. This mineral is, however, more abundantly present in crystals or grains of medium size imbedded in the groundmass.

Three specimens, No. 48 from Morro Francez, No. 3 from the S.W., and No. 58 from the W. corner (Japato) of Fernando, represent very scoriaceous ejected fragments (volcanic bombs) of basaltic rocks. The first is a mottled black and red vesicular glass containing abundant porphyritic olivines externally altered and sometimes completely changed to iron hydroxide. Small yellow augite crystals are also present. The second of these specimens (No. 3) is a porous black and almost opaque glass including sharp olivine crystals. Lath-shaped forms resembling feldspar microliths also occur here, but they are now wholly replaced by some isotropic substance. No. 58 is a pumiceous fragment of a reddish gray color. Under the microscope it is seen to be composed of a colorless glass filled with minute yellow augite crystals and iron oxide globulites. In this matrix are abundant olivine crystals, now however almost wholly replaced by iron hydroxide.

Basalt Tuffs—two specimens from the western end of the island of Fernando are composed of fragments of glassy basalts cemented by zeolites. No. 54 is of a brownish color speckled with white (zeolite) and shows its fragmental character very distinctly when examined with a lens. The microscope discloses angular or rounded fragments of a reddish or yellow glass. These are of various sizes and are very vesicular, containing altered olivine crystals, lath-shaped microliths and opaque octahedrons. In external aspect this specimen resembles palagonite but it is not wholly soluble in acids and contains too many crystalline components to be properly classed under this head.*

No. 62, collected near the last, is a rock of similar character, but of less pronounced fragmental appearance. It is of a brick-red color, compact in structure and also filled with zeolitic minerals. Under the microscope it is seen to possess a character quite like the one last described, except that the glass is a deeper red and more opaque.

Petrographical Laboratory, Johns Hopkins University, Dec., 1888.

ART. XXI.—*On the Ophiolite of Thurman, Warren Co., N. Y., with remarks on the Eozoon Canadense;* by GEORGE P. MERRILL.

THE Warren County Ophiolite or Verdantique Marble as seen in the limited amount put upon the market, consists in its typical development of an even granular admixture of white calcite and pale yellowish green serpentine in about equal proportions. The uniformity of texture is, however, often interrupted by large irregular blotches of deep lustrous green serpentine which, as shown in a large block in the National

* Renard mentions grains of palagonite in a fragmental rock collected by Buchanan on Rat Island, loc. cit., p. 11.

Museum collections, sometimes carry a white nucleus. The presence of this nucleal material, which may frequently be observed passing by imperceptible gradations into the green serpentinous material, suggested at once that here, too, the serpentine is a metasomatic product, as the writer has shown* is the case with that of Montville, New Jersey. Thin sections of the rock under the microscope confirm this suggestion. The white nucleal mineral is seen to be an aggregate of small monoclinic pyroxenes, quite colorless in the thin sections, without pleochroism, but polarizing brilliantly and giving extinctions on clinopinacoidal sections as high as 41°. Irregular canals of serpentinous matter cut through these aggregates following cleavage and fracture lines, and all stages of alteration can, as in the Montville stone, often be observed in a single section. In the more even-textured portions of the rocks the serpentine appears as rounded or oval granules with small enclosures of secondary calcite imbedded in the large original plates of the same material. Here, too, all stages of alteration are readily detected, some of the pyroxene granules being traversed by but a few wavy threads of the serpentinous matter, while in others not a trace of the original mineral longer remains. Were it not for these fresh remaining portions one would hesitate to pronounce them pyroxenic derivatives, since they in no case show crystal outlines, but are mere oval blebs or granules imbedded like shot in the white calcite in a manner quite similar to that of the chondrodite grains in the white limestone from Amity, Orange County, in the same state. The granules are not in all cases isolated but sometimes occur in groups, or connected by canals of serpentinous matter in a manner strikingly suggestive of the detached sections and groups of Eozoon chamberlets as figured by Dr. Dawson on pages 24 and 28 of his late paper.† Indeed I can but feel, since reading his resumè that, even at this late day, this serpentinization of pyroxene is destined to throw some light on the Eozoon problem. This idea is supported by the fact that the fragmental Eozoon has been reported from these same formations at Warren County, further by Dr. Dawson's statement that eozoonal masses often occur as "rounded or dome-shaped masses that seem to have grown on ridges or protuberances, now usually represented by nuclei of pyroxene."‡ While from the study of so limited an amount of the Warren County stone it may not be advisable to assert that the remarkably regular structures figured by Dr. Dawson are due wholly to alteration in situ of

* Proc. U. S. Nat. Mus., vol. xi, 1888, p. 105.

† Specimens of Eozoon Canadense and their Geological and other relations. Peter Redpath Museum. Notes on Specimens, Sept. 1888.

‡ Op-cit., p. 29.

pyroxene granules, I can but suggest that we have in this alteration the source of the serpentinous material and that the "mineral pyroxene of the white or colorless variety . . occurring often in the lower layers and filling some of the canals" of the Eozoon, is but the residual mineral which has escaped alteration. Further, that the structureless nodules of serpentine found in the eozoonal rocks, and to which often patches of Eozoon are attached or imbedded, are but patches in which the alteration is complete and the pyroxenic nucleus quite obliterated. Dr. Dawson, although recognizing the frequent accompaniment of a white pyroxene with the eozoonal structure, in no case mentions appearances indicating that the serpentine is an alteration product, but seems rather to regard it as an original injection,* following in this respect the well known teachings of Dr. Hunt.† Those conversant with the literature of the subject may recall that Messrs. King and Rowney‡ recognized also the presence of pyroxenes in these limestones and in insisting upon the inorganic nature of the eozoon, compared its structural forms to those assumed by chondrodite, coccolite, etc. in the limestones of New York, New Jersey and other localities. These authorities seem however to have regarded the serpentine as true "replacement pseudomorphs" after these minerals rather than alteration or metasomatic products.

In conclusion: The serpentine in the Warren County Ophiolite, Ophicalcite or Verdantique as it has been variously called is an alteration or metasomatic product after a mineral of the pyroxene group. The original rock would appear to have been simply a pyroxenic limestone, the pyroxene occurring either in scattering granules or in granular aggregates of considerable size. An examination of the Essex County Ophiolite reveals a somewhat similar, though more complicated condition of affairs. A portion of the serpentine here is also derived from a pyroxene, but another, and in cases a very large portion is apparently after a mineral which I have not as yet found sufficiently unchanged to be able to identify. The rock is as yet insufficiently studied, and must be made the subject of another paper. I am indebted to Mr. George F. Kunz for the Warren County material.

National Museum, Dec. 18, 1888.

* Op-cit., p. 16--22 et als.

† Quart. Jour. Geol. Soc. of London, vol. xxi, p. 67, Chem. and Geol. Essays, etc.

‡ Quart. Jour. Geol. Soc. of London, vol. xxv, p. 115: also Proc. Royal Irish Academy, vol. x, Part IV, 1870, p. 506.

ART. XXII.—*On the Origin of the deep troughs of the Oceanic depression: Are any of Volcanic origin?* by JAMES D. DANA, with a bathymetric map, Plate VII.

THE consideration of the question with regard to the origin of the ocean's deep troughs requires, as the first step, a general review of oceanic topography; for according to recent bathymetric investigations, the deep troughs are part of the system of topography, and its grander part. We need, for this purpose, an accurate map of the depths and heights through all the great area. Such a map will ultimately be made through the combined services of the Hydrographic Departments of the civilized nations. At the present time the lines of soundings over the oceans, especially over the Pacific and Indian, are few, and only some general conclusions are attainable. It is to be noticed that the system of features of the oceanic area are involved in the more general terrestrial system; but since the former comprises nearly three-fourths of the surface of the sphere, it is not a subordinate part in that system.

With reference to this discussion of the subject I have prepared the accompanying bathymetric map.

I. THE BATHYMETRIC MAP, AND THE GENERAL FEATURES OF THE OCEANIC DEPRESSION DISPLAYED BY IT.

1. *The Map.*—In the preparation of the bathymetric map I have used the recent charts of the Hydrographic Departments of the United States and Great Britain,* which contain all depths to date, and the lists of new soundings published in German and other geographical Journals. In order that the facts on which the bathymetric lines are based may be before the reader a large part of the depths are given, but in an abbreviated form, 100 fathoms being made the unit: 25 signifying 2500 fathoms or nearly (between 2460 and 2550); 2·3, about 230 fathoms, ·4, about 40 fathoms. Only for some deep points is the depth given in full. The addition of a plus sign (+) signifies no bottom reached by the sounding.†

* I am indebted to the Hydrographic Departments of Great Britain as well as the United States for copies of these charts.

† On the map the bathymetric lines for 1000, 2000, 3000 and 4000 fathoms, besides being distinguished in the usual way by number of dots, have been made to differ in breadth of line, the deeper being made quite heavy in order to exhibit plainly the positions of the areas without the use of colors. The line for 100 fathoms is, as usual, a simple dotted line. As the bathymetric map herewith

In the plotting of oceanic bathymetric lines from the few lines of soundings that have been made, the doubts which constantly rise have to be settled largely by a reference to the general features of the ocean, and here wide differences in judgment may exist in the use of the same facts; but through the depths stated on the map, the reader has the means of judging for himself. In the case of an island the lines about it may often have their courses determined by those of adjoining groups, or by its own trend; but in very many cases new soundings are needed for a satisfactory conclusion.

Some divergences on the map from other published bathymetric maps require a word of explanation. The northern half of the North Pacific is made, on other deep-sea maps, part of a great 3000-fathom area (between 3000 and 4000) stretching from the long and deep trough near Japan far enough eastward to include the soundings of 3000 fathoms and over in mid-ocean along the 35th parallel. It has seemed more reasonable, in view of present knowledge from soundings, to confine the deep-sea area off Japan to the border-region of the ocean, near the Kurile and Aleutian islands, and leave the area in mid-ocean to be enlarged as more soundings shall be obtained. Again in the South Pacific, west of Patagonia, the area of relatively shallow soundings (under 2000 fathoms) extending out from the coast, is on other maps bent southward at its outer western limit so as to include the area of similar soundings on the parallel of 40° and 50°, between 112° and 122° W. The prevailing trends of the ocean are opposed to such a bend, and more soundings are thought to be necessary before adopting it.

It may be added here that in the Antartic Atlantic, about the parallel of 66½° S. and the meridian of 13½° W., a large area of 3000 and 4000 fathoms has been located. It was based, as I have learned from the Hydrographic Department of the British Admiralty, on a sounding in 1842 by Capt. Ross, R. N., in which the lead ran out 4000 fathoms without finding bottom. The sounding was, therefore, made before the means

published is necessarily small, and none of the ordinary maps of the oceans give either deep-sea soundings or a correct idea of the trends of the oceanic ranges of islands, I state here that the charts of the U. S. Hydrographic Department for the Atlantic, Pacific, Indian and Arctic oceans may be purchased of dealers in charts in the larger sea-board cities for 50 cents a sheet and less according to size. (There are several large charts to each ocean). One of the firms selling them in New York City is that of T. S. & J. D. Negus, 140 Water st. The British Admiralty have published a map of the Pacific with its soundings on a single sheet, and for the Atlantic and Indian oceans with part of the Pacific, besides charts of the Antarctic and Arctic seas. The occasional bulletins from the Hydrographic Department and Petermann's Mittheilungen contain nearly all the new data issued for the perfecting of such a chart.

available were "sufficient to ensure the accuracy of such deep casts."*

2. *The Feature-lines of the oceanic and bordering lands.*—The courses of island-ranges and coast-lines have a bearing on the question relating to the courses of the deep-sea troughs, and, therefore, by way of introduction, they are here briefly reviewed.† The system of trends in feature-lines takes new significance from a bathymetric map, for the courses are no longer mere trends of islands or emerged mountain peaks; they are the trends of the great mountain ranges themselves; and, in the Pacific, these mountain courses are those of half a hemisphere. Some of the deductions from such a map are briefly as follows:

(1). Over the Pacific area there are *no* prominent north-and-south, or meridional, courses in its ranges, and none over the Atlantic, except the axial range of relatively shallow water in the South Atlantic. And, to this statement it may pertinently be added that there are none in the great ranges of Asia and Europe, excepting the Urals; none in North America; none in South America, excepting a part of those on its west side.

(2). The ranges in the Pacific ocean have a mean trend of not far from northwest-by-west, which is the course very nearly of the longer diameter of the ocean. One *tranverse* range crosses the middle South Pacific—the New Zealand—commencing to the south in New Zealand and the islands south of it, with the course N. 35° E., and continuing through the Kermadec Islands and the Tonga group, the latter trending about N. 22° E., and this is the nearest to north and south in the ocean, except toward its western border.

(3). The oceanic ranges are rarely straight, but instead, change gradually in trend through a large curve or a series of curves. For example, the chain of the central Pacific becomes to the westward, north-northwest; and the Aleutian range and others off the Asiatic coast, make a series of consecutive curves. Curves are the rule rather than the exception. Moreover, the intersections of crossing ranges, curved or not, are in general nearly rectangular.

(4). Approximate parallelisms exist between the distant ranges or feature-lines; as (1) between the trend of the New

* The communication received from the Admiralty Office adds that "Some of Ross's soundings up to 2660 fathoms have been proved correct, and hence the sounding in 68° S., referred to, has been retained on our charts until disproved." "Another sounding obtained by Ross in the Atlantic has had strong doubts thrown upon it by a sounding of 3000 fathoms obtained not very far from its position." See the accompanying map, near latitude 14° S.

† This subject of the system in the earth's feature-lines is presented at length, with a map, in my Expedition Geological report, pp. 11–23 and 414–424; and also more briefly in this Journal, II, ii, 381, 1846.

Zealand range and that of the east coast of North America; and also that of South America (which is continued across the ocean to Scandinavia); also (2) between the trend of the foot of the New Zealand boot with the Louisiade group and New Guinea farther west, and the mean trend of the islands of the central Pacific both south and north of the equator, and also that of the north shore of South America. These are a few examples out of many to be observed on the map.

(5). The relatively shallow-water area which stretches across the North Atlantic from Scandinavia to Greenland—the Scandinavian plateau, as it may well be called—is continued from these high latitude seas southwestward, in the direction of the axis of the North Atlantic (or parallel nearly to the coast of eastern North America and the opposite coast of Africa), and becomes the "Dolphin shoal."

It may be a correlate fact in the earth's system of features that a Patagonian plateau stretches out from the Patagonia coast, or from high southern latitudes, in the direction of the longer axis of the Pacific, and embraces the Paumotu and other archipelagos beyond.*

The above review of the Earth's physiognomy, if accompanied by a survey of the map, may suffice for the main purpose here in view: to illustrate the general truths—that system in the feature-lines is a fact; that the system is world-wide in its scope; and—since these feature-lines have been successively developed with the progress of geological history—that the system had its foundation in the beginning of the earth's genesis and was developed to full completion with its growth.

2. Facts Bearing on the Origin of the Deep-sea Troughs.

In treating of this subject, the facts from the vicinity of volcanic lands that favor a volcanic origin are *first* mentioned;

* As parallelisms may have importance that is not now apparent, I draw attention to one between the Mediterranean Sea that divides Europe from Africa, and the West India (or West Mediterranean) sea that divides North from South America. Both have an *eastern*, *middle* and *western* deep basin. Their depths (see map) in the East Mediterranean, are 2170, 2040 and 1585 fathoms; in the West Mediterranean (the three being the Caribbean, the West Caribbean or Cuban, and the Gulf of Mexico), 2804, 3428 and 2080 fathoms. Further, in each Mediterranean Sea, a shallow-water plateau extends from a prominent point on the south side, northward, to islands between the eastern and middle of the deep basins; one from the northeast angle of Tunis to Sicily, the other from the northeast angle of Honduras to Jamaica and Haiti, the two about the same in range of depth of water. And this last parallelism has its parallels through geological history, even to the Quaternary, when the great Mammals made migrations to the islands in each *from the continent to the South.*

secondly, those from similar regions that are not favorable to such an origin; *thirdly*, facts from other regions bearing on the question.

A. *Facts apparently favoring a volcanic origin.*

1. The Pacific soundings have made known the existence of two deep-sea depressions, if not a continuous trough, *within forty miles of the Hawaiian Islands;* one situated to the northeast of Oahu, or, north of Molokai, with a depth of 3023 fathoms, or 18,069 feet, and the other east of the east point of Hawaii, 2875 fathoms, or within 750 feet of 18,000 feet. Again, 450 miles northeast of Oahu, there is a trough in the ocean's bottom, over 800 miles long, which runs nearly parallel with the group and has a depth of 3000 to 3540 fathoms; and, as far south, another similar trough of probably greater length has afforded soundings of 3000 to 3100 fathoms. The depths about the more western part of the Hawaiian chain of islands have not yet been ascertained, and hence the limits of the deep areas are not known. Such depths, so close to a line of great volcanic mountains, the loftiest of the mountains not yet extinct, appear as if they might have resulted from a subsidence consequent on the volcanic action.

The subsidence might have taken place (1) either from underminings:—which the amount of matter thrown out and now constituting the mountain chain, with its peaks of 20,000 to 30,000 feet above the sea-bottom, shows may be large; or (2) from the gravitational pressure in the earth's crust, about a volcanic region which speculation makes a source of the ascensive force and of the upward rising of the lavas,—the subsiding crust following down the liquid surface beneath. In either case the mass of ejected material might be a measure more or less perfectly of the maximum amount of subsidence.

2. In the western part of the North Pacific, at the south end of the volcanic group of the Ladrones off the largest island of the group, Guam, the Challenger found a depth of 4475 fathoms, one of the two deepest spots yet known in the Pacific. The situation with reference to the group is like that off the east end of the Hawaiian group.

3. East of Japan and the Kuriles, a region of ranges of volcanoes, there is the longest and deepest trough of the ocean, the length 1800 miles, the depths 4000 to 4650 fathoms; and farther northeast, south of one of the Aleutian islands, a depth of 4000 fathoms occurs again; and depths of 3100 to 3664 fathoms also still farther east. It is probable that the 4000-line trough continues from the Kurile to this deep spot off the Aleutian volcanic range; and if so, the length of the trough

is over 2500 miles. The map is made to suggest its extension still farther eastward; but among the very few soundings made, none below 3664 fathoms have yet been obtained off the more eastern Aleutians.

Other similar facts may be found on the map; and still others may exist which are not now manifest owing to the sinking of oceanic areas and islands. But no cases can be pointed to which are more decisively in favor of volcanic origin.

B. *Facts from the vicinity of volcanic regions apparently not referable to a volcanic origin.*

1. The ocean off the western border of North and South America affords striking examples of the absence of deep troughs from the vicinity of regions eminently volcanic. The South American volcanoes are many and lofty; and still the ocean adjoining is mostly between 2000 and 2700 fathoms in depth: and just south of Valparaiso, it shallows to 1325 fathoms. The only exception yet observed is that of a short trough of 3000 to 3368 fathoms close by the Peruvian shore. It may, however, prove to be a long trough, although certainly stopping short of Valparaiso. The waters, however, of the Pacific border of America deepen abruptly compared with those of the Atlantic border; and the significance of this fact deserves consideration.

The facts off Central America are more remarkable than those off the coast to the south. The volcanoes are quite near to the Pacific coast, and still the depths are between 1500 and 2500 fathoms.

The condition is the same off the west coast of North America. Of the two areas of 3000 and over, nearest to the east coast of the North Pacific, one is 600 miles distant in the latitude of San Francisco, and the other is within ten degrees of the equator and twenty degrees of the coast; both too far away to be a consequence of volcanic action in California, Mexico or Central America.

In the North Atlantic the European side has its volcanoes and has had them since the Silurian era, and yet the non-volcanic North American side of the ocean has far the larger areas of deep water and much greater mean depth. The Azores or Western Islands, which are all volcanic, have depths around them of only 1000 to 2000 fathoms and no local troughs. Iceland, the land of Hecla, is in still shallower waters, with no evidence of local depressions off its shores. The Canaries are volcanic, but no deep trough is near them.

C. *Facts from regions not volcanic which are unfavorable to the idea of a volcanic origin.*

1. In the North Pacific, near its center, the area of 3000 or more fathoms about 35° N.; the two similar but smaller areas toward its eastern border; the areas north of the Carolines in the western part of the ocean; the broad equatorial area about the Phœnix Group; the area in the South Pacific in 170° W., east of Chatham Island, and another just south of Australia, are all so situated that no reason is apparent for referring them to a volcanic origin. Some of the areas are in the coral-island latitudes, and the supposed volcanic basis of coral-islands makes a volcanic origin possible, but their probable size and position appears to favor the idea of origin through some more fundamental cause. The area in the South Pacific, east of Chatham Island, is 450 miles distant from the land. The border of southern Australia, abreast of the deep-sea trough, has no known volcano.

2. *In the Atlantic, away from the West Indies*—The 3000-fathom areas of the North and South Atlantic, that is, the three in the North Atlantic, the two in the South Atlantic, and the two equatorial, one near the coast of Guinea and the other near that of South America, occupy positions that suggest no relation to volcanic conditions. The Cape Verdes, north of the equator, are partly encircled by one of the deep areas, somewhat like the eastern end of the Hawaiian group; but this bathymetric area appears to be too large to owe its origin directly to volcanic work in the group. The coast of Guinea near the 3000-fathom area has nothing volcanic about it, and the opposite coast of South America, near another, is free from volcanoes.

The only facts in the Atlantic that suggest a volcanic origin are the depression of 2445 fathoms within 40 miles of the west side of the volcanic Cape Verde Archipelago, and that of 2060 fathoms within 20 miles of Ascension Island; and a connection is possible.

3. *In and near the West Indies.*—The most remarkable of the depths of the Atlantic area are situated in and near the region of the West Indies, as is well illustrated and discussed by Mr. Alexander Agassiz in his instructive work on the "Three Cruises of the Blake." The deepest trough of the ocean, 4561 fathoms, occurs within seventy miles of Porto Rico; and yet this island has no great volcanic mountain, though having basaltic rocks. By the north side of the Bahama belt of coral reefs and islands, for 600 miles, as Mr. Agassiz well illustrates, the depth becomes 2700 to 3000 fathoms within twenty miles of the coast-line, and at one point 2990 within twelve miles, a pitch-down of 1 : 3·5; and nothing suggests a volcanic cause for

the abrupt descent. Cuba and Hayti are not volcanic, and look as if they were an extension of Florida, so that no grounds exist for assuming that the Bahamas rest on volcanic summits.

One of the strangest of 3000 fathom troughs is that which commences off the south shore of Eastern Cuba, having there a depth of 3000 to 3180 fathoms. It is within 20 miles of this non-volcanic shore, and nearly three times this distance from Jamaica. No sufficient reason appears at present for pronouncing its origin volcanic. It is continued in a west-by-south direction to a point beyond the meridian of 85° W. or over 700 miles, making it a very long trough, and the depths vary from 2700 to 3428 fathoms. The depression extends on into the Gulf of Honduras, carrying a depth of 2000 fathoms far toward its head, and in a small indentation of the coast it stops; for nothing of it appears in the outline of the Pacific coast or the depths off it, and nothing in the range of volcanic mountains on the coast. Against the three deepest parts of the trough there are, *first*, the Grand Cayman reef, 20 miles north of a spot 3428 fathoms deep; *second*, banks in 13 and 15 fathoms within 15 miles of a depth of 2982 fathoms; and *third*, Swan Island reef, 15 miles south of a depth of 3010 fathoms; the first of the three indicating a slope to the bottom of 1:5, and the last of 1:4·4. Why these greatest depths in the trough, so abrupt in depression, should be on one side of shoals or emerged coral reefs, it is not easy to explain; and the more so that the part of the trough south of Cuba has nothing volcanic near by in the adjoining mountain range, and the fact also that the westernmost end of the trough extends on for 175 miles, and there has a depth of 3048 fathoms, with 2000 fathoms either side and no coral reefs.

D. *Arrangement of the deep sea troughs in the two halves of the oceans, pointing to some other than a volcanic origin.*

The *western* half of the Atlantic and Pacific oceans contains much the larger part of the 3000-fathom areas and all the depths over 4000 fathoms. In the North Atlantic the areas of 3000 and over in the western half, or off the United States, are very large; and the bathymetric line of 2500 fathoms extends westward nearly to the 1000-fathom line. This important feature can be appreciated for both oceans from a look at the map without special explanations.

As a partial consequence of this arrangement, the Pacific, viewed as a whole, may be said to have a westward slope in its bottom, or from the South American coast toward Japan. This westward slope of the bottom exists even in the area between

New Zealand and Australia—the ocean in this area being shallow for a long distance out on the east side and deepening to 2500–2700 fathoms close to that non-volcanic land, New South Wales, in eastern Australia. In the Atlantic, the slope is in the direction of its northeast-southwest axis, either side of the Dolphin shoal, but especially the western side, rather than from east to west, it commencing in the Scandinavian plateau and ending in the great depths adjoining the West Indies.

Owing to the system in the Atlantic topography, the Dolphin Shoal—the site of the *Atlantis* of ancient and modern fable—is really an appendage to the eastern continent, that is to Europe, and is shut off by wide abyssal seas from the lands to the west that have been supposed to need its gravel for rock-making.

But the view that the west half of an oceanic basin is always the deepest becomes checked by finding in the Indian ocean that the only areas that are 3000 fathoms deep or over are in the *eastern* part of the ocean and off the northwest coast of Australia, and near western Java and Sumatra. The greatest depths in its western half or toward Africa, are 2400 to 2600 fathoms.*

3. CONCLUSIONS.

1. The facts reviewed lead far away from the idea that volcanic action has been predominant in determining the position of the deep-sea troughs. It has probably occasioned some deep depressions within a score or two of miles of the center of activity, but beyond this the great depths have probably had some other origin.

2. It is further evident that the deep-sea troughs are not a result of superficial causes of trough-making. Erosion over the ocean's bottom cannot excavate isolated troughs. The coldest water of the ocean stands in the deep holes or troughs instead of running, as the reader of Agassiz's volume has learned.

The superficial operation of weighting the earth's crust with sediment, or with coral or other organic-made limestone, and filling the depressions as fast as made, much appealed to in explanations of subsidence, has not produced the troughs; for filled depressions are not the kind under consideration. More-

* In the Arctic seas, going north from the Scandinavian plateau, the water deepens north of the latitude of Iceland, between Greenland and Spitzbergen, to 2000 fathoms, and farther north to 2650 fathoms, in the latitude nearly of Greenwich; and it is probable that the 2000-fathom area extends over the region of the North Pole. The continents of Europe (with Asia probably) and North America, are proved by the shallow soundings over the adjoining Arctic seas and the islands or emerged land, to extend to about 82½° N., which is about 450 miles from the pole.

over, the areas are out of the reach of continental sediments and too large and deep to come within the range of possibilities of organic sedimentation or accumulation. The existence of the troughs is sufficient proof of this. The deep troughs of the West Indian and adjoining seas are in a region of abundant pelagic and sea-border life, and yet the marvelous depths exist. And the depths of the open oceans are no less without explanation. Those close by the Bahamas extending down to 16,000 and 18,000 feet, are evidence of great subsidence from some cause; and the coral reefs for some reason have manifestly kept themselves at the surface in spite of it.*

3. If superficially acting causes are insufficient, we are led to look deeper, to the sources of the earth's energies, or its interior agencies of development, to which the comprehensive system in its structure and physiognomy points. Whatever there is of system in the greater feature-lines, whether marked in troughs or in mountain chains, or island ranges, must come primarily from systematic work within. The work may have been manifested in long lines of flexures or fractures as steps in the process, but the conditions which gave directions to the lines left them subject to local causes of variation, and between the two agencies, the resulting physiognomy has been evolved.

We have from the Pacific area one observation of a volcanic nature bearing on the comprehensiveness of the system of feature-lines in the oceans, and although I have already referred to it, I here reproduce the facts for use in this place.

If the ranges of volcanic islands were, in their origin, lines of fissures as a result of comprehensive movements, the lines should continue to be the courses of planes of weakness in the earth's crust. The New Zealand line, including the Kermadec Islands and the Tongan group, has been pointed to as one of these lines, and one of great prominence, since it is the chief northeastward range of the broad Pacific, and nearly axial to the ocean. The series of volcanoes along the axis of New Zealand is in the same line. It was noticed, at the Tarawera eruption of 1883, that *four or five days after* the outbreak, and three after it had subsided, White Island, in the Bay of Plenty, at the north end of the New Zealand series, became unusually active; and *two months later* there was a violent eruption in the Tonga group, on the Island of Niuafou. The close relation in time of the latter to the New Zealand erup-

* The migrations from South America alluded to in a note to page 195, proving an elevation of 2000 feet to make it possible, prove also that a large part of the West India seas *afterward* suffered subsidence in the Quaternary. How far the Bahama and Florida region participated in the subsidence is not known. That it did not participate in it has not been proved.

tion is referred to by Mr. C. Trotter, in Nature of 1886, Dec. 7.* May it not be that these disturbances were due to a slight shifting or movement along a series of old planes of fractures, taking place successively from south to north; and, hence, that even now changes of level may take place through the same comprehensive cause that determined the existence of the earth's feature lines? Owing to the long distance of the Tonga group from New Zealand an affirmative reply to the question cannot be positively made. But there is probability enough to give great interest to this branch of geological enquiry.

ART. XXIII.—*Description of a problematic organism from the Devonian at the Falls of the Ohio;* by F. H. KNOWLTON, U. S. National Museum.†

ON May 2, 1887, the Smithsonian Institution received from Mr. John H. Lemon of New Albany, Floyd Co., Maryland, a box of material collected by him at the Falls of the Ohio. The material consists of a piece of very porous and highly fossiliferous chert about five inches square, and is accompanied by a small phial containing what the sender describes as "small shells which were picked from the dust of crushed Devonian chert." The so-called shells may be seen in small numbers scattered through the matrix, thus leaving no doubt as to the correctness of the assertion that they actually come from the same horizon.

The formation from which the material comes is the Corniferous limestone of the Lower Devonian. It is, of course, a marine deposit, and the material examined contains, besides the problematic organisms, numerous examples of two species of coral (*Zaphrentis sp.* and *Cladopora sp.*) and two Brachiopods (*Streptorhynchus Chemungensis* var. *pandora* Hall, and *Spirifera gregaria* Clapp), which have been identified for me by Mr. Chas. D. Walcott of the U. S. Geological Survey. These problematic organisms were first sent to Mr. Walcott under the impression that they were foraminiferous shells, but as he failed to recognize any foraminiferal characters and regarding them as more probably of vegetable origin, he sent them to the Department of Fossil Plants.

The organisms under consideration are minute, spirally grooved bodies from 1·50 to 1·80 mm. long and about 1·70 mm.

* This Journal, III, xxxiii, 311.

† Published by permission of the Assistant Secretary of the Smithsonian Institution.

broad. They have been hollow spheres and the now solid interior has probably been infiltrated through the very small orifice at one extremity (See fig. 2). The outer wall has been

1. 2. 3.

moderately thick and when broken away, leaves impressed upon the nucleus, lines indicating the position of the spirals. (See fig. 3). The "shell" breaks away very easily and it is a matter of some difficulty to obtain absolutely perfect specimens from the matrix. I am unable to detect structure in the outer wall. Ten, or perhaps rarely nine, spirals (cells?) have entered into the composition of the "shell" (sporostegium ?). About eight turns of the spiral are visible in lateral view.

The figures and description, it will be observed, correspond very closely, at first sight, to the well known "fruits" of the genus Chara, and the probability of their being fruits of this kind is greatly strengthened when it is remembered that more than forty species have been described in a fossil state, and as I am informed by Prof. J. D. Dana, they have actually been referred with little hesitation to the genus Chara by the late Prof. F. B. Meek, who examined material from this same locality many years ago. Prof. Meek writes of them as follows :* "In the same matrix with the above described shell (*Trichonema tricarinata* Meek) I have been surprised to notice numerous minute bodies that I can scarcely doubt are really the fruits of the fresh-water genus Chara. At any rate, they seem to present all the external characters of the same. These little bodies are globose, about 0·05 of an inch in diameter, and each ornamented by nine strongly defined and very regularly disposed spiral ridges, which start on one side around a minute pit, and pass with perfect regularity spirally, so as to converge to an exactly opposite point on the other side, making each about one spiral turn in passing from side to side. If really the seeds of this fresh-water genus of plants, they must have been carried into the sea by streams, and deposited where we now find them, along with numerous marine shells." This description agrees so closely with my own that there can be no doubt that the specimens are the same.

* Fossils of the Corniferous Group: Geol. Surv. of Ohio, Palæontology, vol. i, 1873, p. 219, Note.

Prof. Dana also refers briefly to these organisms described by Meek, in his Manual of Geology (Ed. 1875, p. 259).

As the lowest point at which unquestioned Chara has been found fossil is the Muschelkalk of Moskau, the discovery of a species in the Devonian would naturally excite great interest, for it would then be shown that the genus was much older than is generally supposed. This led to a more detailed examination of the material, when it was found that they could not possibly be referred to Chara as ordinarily accepted, since in all the known species, both living and fossil, the sporostegium is composed of five cells twisted to the left, while in this the spirals (sporostegia?) are nine or ten in number and *twisted to the right.* There is, however, no vital objection to the supposition that this might have been an archaic or original type from which the more modern forms have been developed. This view is amply confirmed by what we already know of the lines of development that have been followed by some well known types of vegetation, as for example the conifers.

In order to be more certain in the matter, the specimens and drawings were submitted to Dr. T. F. Allen of New York, the well known authority upon the *Characeæ.* He was at once struck by their resemblance to the fruits of Chara and immediately wrote* that it was probably a new type, a new genus, "still descended direct from the Floridæ, perhaps, and grown in salt water. The whole plant must have twisted to the left, because our plants now twist *opposite* to the twist of the sporostegium; or perhaps the twist changed when only five cells enveloped the spore." Dr. Allen also suggested their resemblance to the so-called Rhizopod *Saccammina?* (*Calcisphæra*) *Eriana* described by Dawson from the Corniferous limestone of Kelley's Island near Sandusky, Ohio; a paper that had been before overlooked. On referring to the article in question,† it is at once apparent that the specimens under consideration certainly have a very marked resemblance to those described by Dawson. They are described by him as follows: ". . . they are minute globular bodies, one millimeter in diameter, and occur in great numbers in light gray limestone containing *Strômatopora*, crinoidal joints and corals, as well as multitudes of minute organic fragments. The exterior surface of the specimens is dull or granular in aspect, and either smooth or marked with slight spiral ridges, giving an appearance which at first sight suggests a resemblance to the spore-cases of *Chara.* On microscopic examination, they are found to be hollow spheres filled with calcite introduced by infiltration, having one small aperature; and the test or wall of the sphere presents a granular appearance as if composed

* In Litt., April 9, 1888.

† Canadian Nat., New Ser., vol. x, p. 5.

of fine calcareous grains. . . . It can scarcely be anything else than a Rhizopod, probably allied to the modern *Saccammina globosa*, or to the Carboniferous *S. Carteri*, though much smaller than either, and differing in its tendency to external ornamentation. It is, of course, possible that a test of this kind might belong to an animal of very different character from *Saccammina*, but in the present state of knowledge of such forms, I think it quite justifiable to refer it to this genus."

In a note appended to the above article (l. c., p. 8), Dawson says, "In a letter just received from Mr. H. B. Brady, he says that he knows of no rhizopod test, recent or fossil, precisely corresponding to the little Erian fossil above described. He says—'the more I examine your little fossil the more confident I am that it bears no relation to any rhizopod type that I know.' It will then be seen that he does not admit its affinity to *Saccammina* and that he even doubts as to its rhizopodal character."

I am not aware that any further examinations have ever been made of these Kelley's Island specimens by Dawson.

After submitting the specimens and drawings from the Falls of the Ohio to Dr. A. Nordstedt, the distinguished Swedish authority on *Characeæ*, Dr. Allen writes: * "After repeated investigations, comparisons, and correspondence, we must come to the conclusion that the little seeds you sent me are Foraminifera and not Chara. I enclose Dr. Newberry's decision in the matter. There are two distinct features about this matter, which cannot be overlooked. The first is that these bodies are very uniformly diffused through the rock; this certainly would not be the case were they seeds of any Chara. The second point is that these rocks were formed under a considerable depth of salt water. Now while some species of Chara are known to inhabit salt water, they are as a rule, found near the mouth of large streams and are not found in any great depth of salt water; indeed, Chara will not grow out of the reach of sunlight, and ten to fifteen feet in depth is the limit of growth in Chara."

Dr. J. S. Newberry, as referred to above, is of the opinion that these organisms are unquestionably identical with the *Saccammina* of Dawson. He suggested that they be submitted to Mr. H. B. Brady, of London, the well-known authority on the Foraminifera. This was accordingly done, and from him the following reply has been received :† "I am duly in receipt of your letter, enclosing specimens and drawings. The minute spiral organism sent is not altogether unknown to me. I do not in the least believe it to be Foraminiferal. In

* In Litt., June 20, 1888. † In Litt., July 2, 1888.

point of minute structure it shows no approximation to any type of Foraminifera with which we are acquainted. Like yourself, I should have set it down as the nucleus of a Chara, or some closely allied organism, and if it be not that, I should seek for affinities amongst the calcareous Algæ. The so-called *Saccammina* (*Calcisphæra*) *Eriana*, I have not much doubt, belongs to the same or a closely allied group, but I have never been able to accept it as a Foraminifer.

It is a very rare, almost unknown thing, to find Foraminifera of any one species in any deposit, recent or fossil. There are often two or three species, or a very limited number, but where one exists in abundance my experience is, one always meets with a few specimens among allied forms."

In the hope that it might find a resting place among the calcareous Algæ, the specimens and drawings were next sent to Prof. W. G. Farlow, of Cambridge, who reports upon them as follows:* "At first sight, the specimens you send certainly appear to be more like the spores of Chara than any other plant. In saying that the bodies were not Chara spores I presume Nordstedt was influenced by the fact that there appear to be more than five spirals.

Query. Would it be impossible that there are Charas with a different number of spirals than in living species?

With regard to the question of the possibility of the bodies being Algæ, I presume that the suggestion arose in consideration of Meunier-Chalmas's discovery that some supposed Foraminifera were really portions of Algæ. The Algæ in question are all *Siphonocladiæ* of which *Bornatella* appears to be both recent and fossil. I do not think it possible that your fossil could belong to this group. When whole they are columnar or with stalks and they can only be mistaken for Foraminifera when the radiating disks are broken off and separate.

Your fossil is globular. The fragments of *Siphonocladiæ* are disk-shaped and composed of numerous cells, and all are much larger than what you send. Nor is it at all probable that they are spores of this or any other group of Fungi. I know none grooved in this way. Besides, the spores of *Siphonocladiæ* are not calcareous, as a rule, but are soft. The sporangium is calcareous but does not at all resemble your fossils. The spores would hardly be likely to survive as fossils.

In *Siphonocladiæ* the external cells may be decidedly calcareous, but if broken off from the rest, which is not apt to be the case, the incrustation would not be grooved, but uniform except at the ruptured spot.

In short the fossil is very much less like any Algæ than like Chara spores, and they have already been excluded by competent experts."

*In Litt., Oct. 23, 1888.

These problematic organisms which have been excluded from the Characeæ, Foraminifera, and the calcareous Algæ, were described and exhibited informally to several members of the Washington Biological Society, in the hope that some one might be able to suggest a possible relationship. Dr. Th. Gill suggested their resemblance to certain ova-capsules of Mollusks and Hydroida. Dr. W. H. Dall, to whom they were shown, was also at first struck by the resemblance between these organisms and the ova-capsules of Mollusks, but after a careful examination concluded that they could not possibly belong to them as the shell of the organism is very thick and calcareous while the ova capsules of the Mollusks are uniformly thinner and not calcareous, but chitinous, which would not be likely to be changed in fossilization. Mr. Richard Rathbun, of the U. S. Fish Commission, also denied the possibility of their being eggs or ova-capsules of star-fish.

As to their resemblance to the gonangia of the Hydroida, an examination of the Monographs by Allman in the Challenger Reports shows it to be impossible. One of the species most resembling it is *Calamphora parvula* All.* ; but the gonangia stand upon well marked stalks and they are described as "distinctly annulated" while these organisms are no less distinctly spiral, and without positive evidence of a stalk or pedicel.

The only other point which it now remains to consider in this connection is the result of the observations made by Professor W. C. Williamson and recorded in number X of his invaluable memoirs "On the Organization of the Fossil Plants of the Coal Measures." Having formerly shown that one of the supposed Carboniferous Foraminifera was really a plant he has been lead to examine several other Carboniferous forms, thinking it probable that some of them might also be proven to be vegetable and not animal. The organisms investigated by Professor Williamson were mentioned by Professor Judd before the Geological Society of London†. He regarded them as undoubted *Radiolarians.* They come from the limestone rock near Rhydymwyn which is near Mold, in Flintshire. It was impossible to separate the organisms from the matrix and the only means of studying them was by thin sections. They are shown to be hollow spheres, "most of which are furnished with varying forms of peripheral appendages." Several forms are named by Williamson, in some of which the wall of the sphere is structureless, while in others it is described as "double, but the inner and outer layers enclose between them numerous small cubical compartments separated by radiating partitions. The compartments are filled, like the central sphere

* Challenger Reports, vol. xxiii., Pl. x, fig. 3a.

† Quart. Journ. Geol. Soc., vol. xxxiii, Lond. 1877, p. 835.

cavity, with infiltrated translucent calcic carbonate." The peripheral marking, as stated above, varies greatly, some being perfectly smooth, others provided with long irregular projections or spines. None seem to be distinctly spiral.

Professor Williamson examined at the same time examples from Kelley's Island of the *Saccammina* of Dawson. Of these he says: "Like the Welsh specimens, they have been more opaque than the surrounding matrix, when viewed by transmitted light. * * * Each organism has been a hollow sphere. The sphere wall has been much thicker in proportion to its entire diameter than is the case among the Welsh specimens. Externally the transverse section of each sphere presents an undulating outline, due to the intersection of prominences and ridges that characterize its surface. Sometimes these projections surround the entire section, but more frequently they are absent from limited portions of the periphery. Occasionally these ridges may be seen pursuing an oblique direction like the bands across the nucleus of a *Chara*. The central cavity is always occupied by crystalline infiltrated carbonate of lime. Though the sphere wall often exhibits a granular texture, I discovered a radiating structure in a sufficient number of the specimens to convince me that in this respect they have closely resembled some of the Welsh specimens." In conclusion he says: "Whilst I am thoroughly satisfied that these objects are *not Radiolarians*, it is not easy to say what they are."

In order that these organisms may be distinguished they have been referred by Professor Williamson to a provisional genus *Calcisphæra*, created for the purpose. The Kelley's Island form is called *Calcisphæra robusta*.

The Calcisphæra of Williamson has still later been found by Wethered in the Carboniferous Limestone of Gloucestershire.* After discussing the views held by Professor Judd and Professor Williamson he concludes that "the tests were originally calcareous and not siliceous." "This was urged as a strong argument against regarding the organisms as Radiolaria, and the author, while considering it unwise to come to a decided opinion, believed it safe to say that they are Protozoa."

The evidence in regard to the nature of this most puzzling organism has been passed in review. It will be observed that the first impression of almost all who have examined it has been that it is a "fruit" of Chara. The principal objection to this view is that the sporostegium has nine or ten cells, while all the heretofore discovered species, both living and fossil, possess only five cells. There is also the difference in the direction of the spiral. The further objection that the organisms are too uniformly distributed throughout the matrix to be

* Quart. Journ. Geol. Soc., vol. xliv, p. 91, Lond. 1888.

Chara does not seem to be well taken since we have abundant examples of the shells of small mollusks very evenly distributed through the matrix. The objection that Chara could not grow in the depth of salt water indicated by the numerous corals and Brachiopods, is much more serious and may be fatal to the view that it can be Chara. Be that as it may, the evidence both *pro* and *con* is presented, and it is to be hoped that some one may be able to relegate it ultimately to its proper systematic position.

In order that these organisms from the Falls of the Ohio may be referred to independently I propose to call them *Calcisphæra Lemoni* after the collector, particularly as I can not regard them as Foraminiferal and identical with Dawson's *Saccammina*, and moreover the name *Calcisphæra* is not misleading whatever their nature may eventually be proved to be.

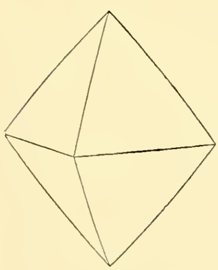
ART. XXIV.—*On some curiously developed pyrite crystals from French Creek, Delaware Co., Pa.;* by S. L. PENFIELD.

ORDINARILY simple octahedrons and cubes of pyrite occur at French Creek, Pa., while occasionally rarer combinations are met with, as the cube with $\pi(420)$, $\frac{1}{2}(4\text{-}2)$. The crystals are bright and have a good luster, but are usually covered with vicinal faces and are sometimes quite distorted by them. The crystals, which are to be especially described in the present article, are five which are in the collection of Mr. C. S. Bement of Philadelphia, and two in the collection of Professor Geo. J. Brush of New Haven, and I take pleasure in expressing my thanks to these gentlemen for their generosity in placing the crystals at my disposal for study. They are in all cases isolated crystals, built out in all directions and showing no attachment. I have been unable to obtain any exact information as to their mode of occurrence, and can only state that they are very rare and are from the iron mines of French Creek.

The special peculiarity of these crystals is that they are abnormally developed, i. e., lengthened out, in the direction of one of the crystallographic axes. If we take this direction as the vertical, the crystals will appear either as steep tetragonal or orthorhombic pyramids. In all cases the pyramidal faces are curved toward the apex and as a result of this the pole edges, running from the lateral to the vertical axes, are curved while the middle edges, running between the lateral axes, are perfectly straight. Owing to this curving the angles between the faces can not be measured with the reflecting goniometer and admit of only approximate measurement with the contact goniometer. The crystals have a remarkably perfect geometrical development, that is, similar faces are developed to almost exactly the same size and extent.

The first three crystals to be described, which are in the Bement collection, appear as tetragonal pyramids. By measurement of the interfacial angles over and near to the middle edges the faces were found to be steep enough to cut the vertical axes at 1·25, 1·50 and 1·80 respectively, but owing to the curving the distances at which the faces actually intercept the vertical axes are less. Figures 1, 2 and 3 represent the three crystals, drawn with the same length of the lateral axes and with the pole edges straight for a short distance from the lateral axes and steep enough to cut the vertical axes at 1·25, 1·50 and 1·80 respectively, but curved toward the top so that the vertical axes are really cut at 1·16, 1·25 and 1·50 respectively, according to actual measurement of the diameters of the crystals. The crystals are of good size and measure in the direction of the vertical axes respectively, 22, 22 and 33^{mm}.

1



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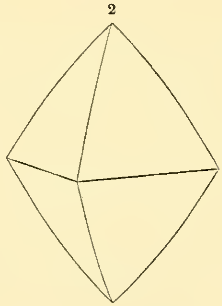

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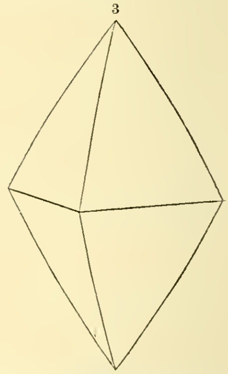
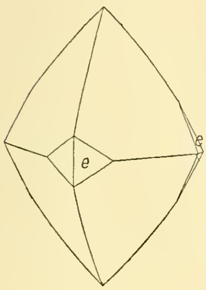


The remaining crystals are perhaps more interesting owing to the occurrence of pyritohedral or pentagonal dodecahedral faces, which in all of the crystals occur only at the extremities of the lateral axes. The faces are rough, but approximate measurements with the contact goniometer determine the crystals to be the ordinary pyrite form $e, \pi(210), \frac{1}{2}(i\text{-}2)$. The pyramid is in all cases the curved $\frac{3}{2}$ form, r, like fig. 2. The pyramid faces are always striated near to and about the front pyritohedral faces, the striæ being a little steeper than the combination edge between e and r and having about the direction of the combination edge $\pi(421), \frac{1}{2}(4\text{-}2)$ and r. The pyritohedral faces have very different shapes at the extremities of the two lateral axes and the crystals, having only three symmetry planes, resemble orthorhombic forms. The two crystals in the Brush collection, which are so nearly alike that they can not be told apart, are represented in fig. 4. Fig. 5 represents a crystal in the Bement collection where the edges between the *e* faces at the sides and *r* are replaced by a form *x* in the zone *e*, *r*. The *x* faces are all rough and admit of only approximate measure-

4



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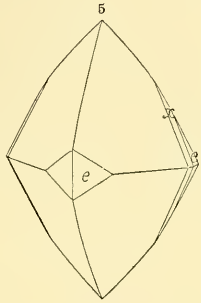

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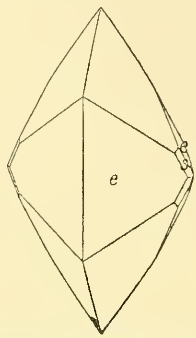
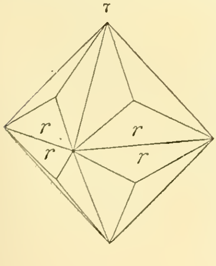


ment with the contact goniometer. The symbol was determined to be (6, 12, 7), $2\text{-}\frac{12}{7}$. There are only eight of these faces instead of the twenty-four which we should expect in an ordinary pyrite crystal. Fig. 6 represents a crystal in the Bement collection in which the *e* faces are larger. This is the most unsymmetrical of all the crystals; on the side, which is turned away from the observer, the *e* faces are so large that the front and side ones just meet forming a solid angle and leaving none of the middle edges between the lateral axes; on the other side, which is shown in the figure, the *e* faces are still larger and the edges between them are replaced by the small *s* faces 231, $3\text{-}\frac{3}{2}$. The *s* faces were bright and admitted of approximate measurements on the reflecting goniometer giving $s \wedge s$, $231 \wedge 23\bar{1} = 30° 40'$, calculated $31° 0'$. These *s* faces differ from the ordinary pyrite combination, for with 210 and 021 usually 321, 132 and 213 occur in one octant, while here only one of the alternating faces 231 occurs.

All who have seen these crystals pronounced them the most curious and interesting pyrite crystals that they have ever seen. Why they have been distorted in this peculiar way I cannot venture to say. Some law must have governed them for they all have such perfect, though lower than isometric, symmetry. It is perhaps the result of the vicinal development of the faces which is so common at the locality. If in fig. 7, which is the ordinary isometric trigonal-trisoctahedron 332, $\frac{3}{2}$, the four *r* faces in front and the corresponding ones behind were ex-

7



tended they would give a tetragonal pyramid like fig. 2, except that fig. 2 has been somewhat shortened by the curved nature of the faces. The curious forms which we have been considering I prefer to regard as abnormally developed trigonal-trisoctahedrons. That they are really isometric is proved by the occurrence of the ordinary pyrite form $\pi(210)$, $\frac{1}{2}(i\text{-}2)$. The behavior of one of the curved crystals on the reflection goniometer is also quite striking. Measuring from pyramid to pyramid over the vertical axis the very points gave sharp reflections of the signal and then on turning the crystal there followed an unbroken band of light, with no sharp reflection of the signal, as long as different parts of the curved surfaces were in a position to reflect the light. The angle between the sharp reflections of the signal, obtained from the very minute flat surfaces at the points, was found to be 109° 36′, calculated for $o \wedge o$ $(111 \wedge \bar{1}\bar{1}1)$ 109° 28′. We see from this that our steep $\frac{3}{2}$ pyramid at the base, becomes by the curving gradually flatter till it corresponds to a unit pyramid or octahedron at the vertex.

The specific gravity of two of the crystals represented in figs. 2 and 4 was found to be 5,016 and 5,022 respectively.

I would also mention here a specimen from French Creek which has been in Professor Brush's collection since 1850. The pyrite crystals which are implanted on magnetite are very flat trigonal-trisoctahedrons, appearing at first sight like octahedrons. These are the only crystals which I have seen from this locality where the vicinal faces form a distinct and clean cut pyramid on the octahedron faces. The faces, however, are not perfect enough to give a distinct and single reflection with the goniometer. The angle between two of the faces is not over 3° 50′ and consequently the value of m in the symbol ma, a, a cannot exceed $\frac{1}{1}\frac{3}{2}$ although it is useless to assign a definite symbol to faces where the angle cannot be measured more exactly, and where a slight variation in the angle causes a very decided change in the symbol.

Mineralogical Laboratory, Sheffield Scientific School, Dec. 18th, 1888.

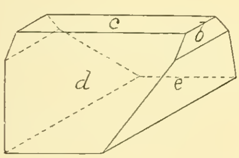
Additional note.—Very recently Mr. Geo. L. English of Philadelphia sent me a suite of French Creek pyrites from his private collection containing six of the elongated pyramids, mostly of the fig. 4 type, also a number of cube octahedron and pyritohedron combinations which are modified and rounded by the occurrence of vicinal faces and one crystal, forming a sort of connecting link between an octahedron and the fig. 2 type, where the octahedron and some trigonal trisoctahedral faces round off and blunt the apex of the pyramid. He also informs me that the isolated crystals occur imbedded in calcite. S. L. P.

ART. XXV.—*Crystallized Bertrandite from Stoneham, Me., and Mt. Antero, Colorado;* by S. L. PENFIELD.

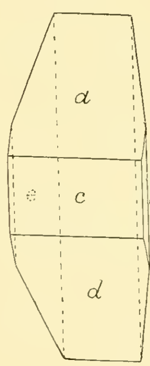
1. *Stoneham, Maine.*

FOR the bertrandite from Stoneham, Me., the second locality in the United States,* I am indebted to Mr. George F. Kunz of New York. He states that, at the time herderite was found and described by Mr. Hidden,† he noted the small crystals occurring in pockets with the herderite and laid them aside as an unknown mineral; the quantity was too small to warrant any further investigation at the time. Becoming convinced, after the identification of bertrandite at Mt. Antero,‡ that his crystals were the same mineral he generously turned them over to me for identification and description. Only a few specimens were observed and the crystals were all small, the largest of the three which were detached for measurement being about $2{\cdot}5^{mm}$ long by $1{\cdot}5^{mm}$ broad. The luster of the faces is not very perfect and the measurements with the reflecting goniometer not as good as could be desired. The habit of the crystals is unlike anything that has been previously described and as it throws considerable light on the crystallization of the mineral is worthy of a detailed description. The forms which were observed were as follows:

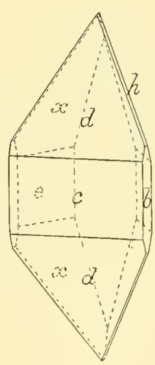
1



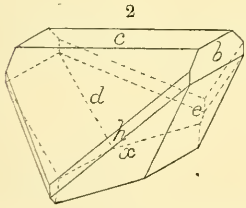
1a



2a



2



c, 001, *O*; *b*, 010, *i*-ĭ; *h*, 130, *i*-3̆: *d*, 102, ½-ī; *e*, $03\bar{1}$, 3-ĭ and *x*, $16\bar{2}$, 3-6̆.

The simplest combination is shown in fig. 1, where the faces *c* and *d* are prominent at one end of the vertical axis and *c*

*In a letter, dated Sept. 26, 1888, Mr. W. E. Hidden announced to us that he had identified bertrandite (or a new mineral) on specimens of herderite from Stoneham.—EDS.

† This Journal, III, xxvii, 135, Feb., 1884. ‡ Ibid., III, xxxvi, p. 52, 1888.

and *e* at the other. This can be explained most readily by considering the crystal as hemimorphic in the direction of the vertical axis. As in our ordinary crystallographic projection the figures of our crystals are very much fore-shortened in the direction of the brachy axis $\breve{a}$, and as the bertrandite crystals are elongated in this direction, I have re-drawn fig. 1 making $\breve{a}$ the vertical axis, $\overset{|}{c}$ the front and leaving $\bar{b}$ unchanged as in fig. 1*a*, which gives a very good idea of the crystals. Figures 2 and 2*a* drawn the same as above represent a more highly developed crystal. The most conspicuous faces on these crystals are *c* and *d* above, both of which are highly polished and give good reflections. The faces at the other end of the *c* axis are by no means as good, the luster is poor and the faces oscillate and combine with one another in such a way that the edges are not sharp and continuous; this is especially the case when *x* is present. The *x* faces are not sharp and well defined but round off the ends of the crystal in such a way that they do not form straight edges with *c* and *e*; they gave also no sharp reflection of the signal with the goniometer. Approximate measurements, however, and the occurrence of the faces in the zone *d*, and *h* determine its indices to be $16\bar{2}$ (3-$\breve{6}$). The brachy-pinacoid *b* gave fairly good reflections, *h* was in all cases small and gave faint reflections. One twin crystal was observed, the basal plane *c* being the twinning plane and the *d* faces making a very prominent reëntrant angle. The crystals are usually attached at one end of the brachy axis and as only one of the bright *d* faces is conspicuous they have a very decided monoclinic appearance. In one of the detached crystals part of a second *d* face was present developed as in the figures and showing that the crystals are truly hemimorphic and not monoclinic. In detaching one of the crystals a very perfect cleavage parallel to *b* was developed which has not been observed before; the highly perfect prismatic and basal cleavages were also observed, the same as in the Mt. Antero crystals. If we take the best measurements which were obtained,

$$c \wedge d,\ 001 \wedge 102 = 27°\ 42' \quad \text{and}$$
$$m \wedge m,\ 110 \wedge 1\bar{1}0 = 59°\ 16',$$

the latter being cleavage faces, we obtain the axial ratio given below, while for comparison the ratio obtained from the Mt. Antero mineral is also given:

Stoneham, Me. $c : b : a = 0{\cdot}5973 : 1 : 0{\cdot}5688$
Mt. Antero, Col. $c : b : a = 0{\cdot}5953 : 1 : 0{\cdot}5723$

I am inclined to give the preference to the measurements on the Stoneham crystals; if so, the angles which have been measured and the calculated values are as follows:

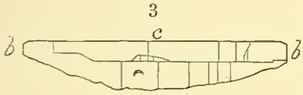
	No. 1.	No. 2.	Calculated.
$c \wedge d$ $001 \wedge 102=$	27° 40′	27° 42′	27° 42′
$c \wedge e$ $00\bar{1} \wedge 03\bar{1}=$	60° 22′	60° 53′	60° 50′
$c \wedge e$ $001 \wedge 0\bar{3}\bar{1}=$	60° 58′	60° 50′	60° 50′
$c \wedge b$ $001 \wedge 010=$	90° 1′		90°
$m \wedge m$		59° 16′	59° 16′
$b \wedge h$ $010 \wedge 130=$		29° 30′	30° 22′

The crystals are not very transparent and favorable for the determination of the optical properties; in converging polarized light with the microscope, an obtuse bisectrix was seen normal to *c*, the plane of the optic axes being the brachypinacoid. The specific gravity was carefully taken, by just floating the mineral in the Thoulet solution, and found to be 2·598, exactly the same as that found for the Mt. Antero bertrandite. The material being very limited no chemical tests were made.

2. *Bertrandite from Mt. Antero, Colorado.*

In a previous communication* I described crystals from Mt. Antero which had a curious hemimorphic development. The crystals were composed of the three pinacoids; but while one of the basal planes was flat the other was rounded and striated parallel to the *ă* axis by oscillatory combinations of the basal plane with a brachy-dome, probably 011. Figure 3 represents a section across one of the Mt. Antero crystals parallel to the macropinacoid which was drawn with a camera lucida and magnified 17 diameters. During the past summer a number of bertrandite specimens were found and all of them showed this peculiarity. Some of the crystals which are now in the collection of Mr. C. S. Bement of Philadelphia, are 25mm long, 8mm wide and 3mm thick. That the rounding of one of the basal planes is not accidental, but is owing to a hemimorphic development of the crystals, cannot be doubted. As proof of this, one of the largest crystals was tested for pyro-electricity by the admirable method proposed by Prof. A. Kundt.† The crystal was heated in the air-bath to 100° C. and on cooling was dusted with a mixture of red oxide of lead and sulphur. The experiment was most satisfactory, the flat basal plane showed strong positive electricity and became coated with the yellow sulphur, while the rounded basal plane showed negative electricity and was coated with red oxide of lead.

3



Tests for pyro-electricity were also made on the Stoneham crystals but they were so small that it could scarcely be deter-

* This Journal, III, xxxvi, p. 52, 1888.

† Annalen der Physik u. Chemie, xx, p. 592, 1883.

mined with certainty. It seemed, however, as if the basal plane in combination with the *d* face showed positive electricity, the same as the flat basal plane of the Mt. Antero crystals, while the other basal plane showed negative electricity.

In closing, I wish to express my thanks to Messrs. George F. Kunz and C. S. Bement, who provided me with material for study and to Mr. George L. English of Philadelphia, who sent me a large number of Mt. Antero crystals for examination.

Mineralogical Laboratory, Sheffield Scientific School, Dec. 12, 1888.

Art. XXVI.—*Mineralogical Notes*; by J. S. Diller.

1. *Dumortierite from Harlem, N. Y., and Clip, Arizona*; by J. S. Diller and J. E. Whitfield.

In this Journal for Nov., 1887, p. 406, Dr. R. B. Riggs published a description, including a chemical analysis, of "The so-called Harlem Indicolite," which was regarded as probably a new boro-silicate. The notice led to correspondence with Prof. E. S. Dana, who identified the mineral as dumortierite and kindly sent us some of the original dumortierite from near Lyons, France, for comparison.

The physical properties of the Harlem dumortierite agree very closely with those mentioned by Bertrand,* Gonnard† and Damour.‡ Crystals are very rare. An imperfect one§ has been observed with $a(\infty\bar{P}\infty)$ and $m(\infty\breve{P})$ equally developed. Both planes are striated parallel to the vertical axis. Indistinct reflections allowed only approximate measurement $am=152°$, and therefore $mm=124°$. Obtuse terminal planes rarely observed on embedded crystals.

Cleavage parallel to *a* is distinctly developed so that when the mineral is crushed and examined under a microscope cleavage plates may be found which show an obtuse bisectrix lying parallel to $b(\infty\breve{P}\infty)$. Cross fractures occasionally yield basal sections which may be made to exhibit an acute bisectrix. Extinction always takes place parallel to the vertical axis and the

* Bull. Soc. Min. d. France, vol. iii, p. 171, 1880, and vol. iv, p. 9, 1881.

† Bull. Soc. Min. d. France, vol. iii, p. 2, 1881.

‡ Bull. Soc. Min. d. France, vol. iv, p. 6, 1881.

§ It was kindly loaned to us by Mr. R. T. Chamberlin of New York. Our thanks are also due to Mr. Geo. F. Kunz for the material he so generously furnished for this investigation. It was collected along Fourth Avenue at 120th and 122nd Streets as well as near Ft. George, a new locality of the same district.

mineral is evidently rhombic.* In cross sections imperfect cleavage is rarely seen parallel to some prismatic plane. Polysynthetic twinning is very common parallel to *b* as well as other planes in the prism zone. Liquid inclusions and long tubular cavities parallel to the vertical axis are abundant. Hardness =7 and sp. gr. slightly above 3·265.

The rock in which the dumortierite occurs at Harlem is the pegmatoid portion of a biotite gneiss. These coarse vein-like parts are composed of quartz with both red and colorless orthoclase, some plagioclase and tourmaline. The other portions of the rock contain much biotite and garnet. The fibers of dumortierite are sparingly scattered through the quartz in the coarse granular rock. A few were observed penetrating plagioclase. The thin thread-like fibers are occasionally so small as not to be distinctly dichroic, but they are intermingled and connected with larger dichroic fibers by every intermediate gradation in size, so that an observer at once regards them all as the same mineral. They sometimes closely resemble the trichitic forms in granitic quartz which Dr. G. W. Hawes† and many others following his suggestion, regarded as rutile.

The presence of tourmaline in the rock at Harlem was not at first recognized. It is so intimately associated with the dumortierite that they cannot be easily separated. Their pleochroic phenomena, however, are so unlike that they can be readily distinguished under a polarizing microscope. The presence of tourmaline renders the results of Mr. Riggs' analysis less trustworthy. By means of the Klein solution and an electro-magnet the tourmaline was separated from the dumortierite. The ·217 gram of the latter thus obtained was analyzed with the following result.‡ Only the smallest trace of B_2O_3 was observed.

SiO_2 31·44 Al_2O 68·91

Fortunately, at the time it became particularly desirable to obtain a larger quantity of dumortierite for analysis a collection of minerals was sent by Mrs. C. A. Bidwell from Clip, Yuma Co., Arizona, to the National Museum for identification. Among them Prof. F. W. Clarke noticed a blue mineral which proved to be dumortierite. It is finely fibrous and so abundant as to give color to the rock which is composed chiefly of granular quartz. A few grains of magnetite and limonite are the only other minerals intermingled with the quartz and dumortierite, so that it seems an easy matter by means of a heavy solu-

* My observations, noted in Mr. Riggs's paper, already referred to, were very hastily made with imperfect apparatus, and published before I had an opportunity for their revision.—J. S. DILLER.

† Mineralogy and Lithology of N. H., p. 45, 1878.

‡ The chemical work for this paper was done by Mr. Whitfield.

tion and an electro-magnet to obtain the latter mineral for chemical analysis. The results are given under I, below.

These figures appear to show the material analyzed to be impure and it was thought advisable to obtain more of the rock and endeavor to separate the dumortierite as far as practicable from all impurities. Mrs. C. A. Bidwell kindly furnished a sufficient amount of much better material in which the only mineral associated with the dumortierite was quartz. As dumortierite is not acted upon by hydrofluoric acid the rock after being crushed to small particles, was digested in this acid for a length of time sufficient to decompose most of the quartz. The mass was then washed with water, dried and any quartz that might still remain, separated by Thoulet's solution. After thorough washing the material was examined with the aid of a microscope and found to be free from gangue. Having been ground exceedingly fine and dried at 104° C. for about three hours the mineral was analyzed with the following results (II):

	I.		II.	
Si_2O_2	31·52		27·99	
Al_2O_3	63·66		64·49	
CaO	trace		----	
MgO	·52		trace	
Na_2O	·37		----	
K_2O	·11		----	
B_2O_3	2·62		4·95	4·93
P_2O_5	----		0·20	
Ignition	1·34	H_2O	1·72	
	100·14		99·35	

Analysis II shows less impurity than the first specimen analyzed. These results indicate either that dumortierite is not a simple silicate of alumina as stated by Damour,* or else that the material analyzed was a mixture of dumortierite with some other compound.

If we assume the formula of Damour to be correct and estimate all the SiO_2 in the analysis as belonging to the formula $Al_8Si_3O_{18}$, then there will be left unaccounted for a small amount of Al_2O_3, H_2O and B_2O_3 and these are present in the proportions represented by the formula $AlB_3O_6 . 2H_2O$. If this mode of interpretation be correct then the mineral from Arizona corresponds approximately to the formula $3Al_8Si_3O_{18}AlB_2O_6 . 2H_2O$ which requires $Al_2O_3 = 65·2\%$; $SiO_2 = 27·6\%$. $B_2O_3 = 5·4\%$; $H_2O = 1·8\%$ agreeing quite closely with the actual analysis. A borate of alumina corresponding to the above formula is, we believe, not actually known, and concerning its properties noth-

* Bull. Soc. Min. d. France, vol. iv, p. 6.

ing can be predicted. If it exists it is certainly remarkable that it should withstand the treatment with hydrofluoric acid which the dumortierite received during the process of purification.

We are greatly indebted to Mrs. C. A. Bidwell for the supply of material for investigation, which at the cost of much personal labor she so liberally furnished.

U. S. Geol Survey, Washington, D. C., Jan. 19, 1889.

2. *Supplementary note on the Peridotite of Elliott Co., Ky.*;* by J. S. Diller.

Dr. Geo. H. Williams recently identified perofskite in the serpentine of Syracuse, N. Y. (this Journal, vol. xxxiv, p. 140), and suggested that the yellowish grains which were supposed to be anatase in the peridotite of Elliott Co., Ky. (U. S. Geol. Surv. Bull. No. 38), may be the same mineral. To definitely identify, if possible, the mineral in question the powdered peridotitic rock was digested for a long time in HCl until there was nothing left with the yellowish mineral but a few grains of garnet, enstatite and chromite. After careful washing, the residue was subjected to the action of H_2SO_4 raised slightly above the temperature of the water bath. The yellowish grains readily dissolved and an analysis by Mr. L. G. Eakins yielded the following results:

Insoluble residue	50·79
TiO_2	22·75
FeO	5·35
CaO	10·28
Al_2O_3	1·48
MgO	2·49
SiO_2	6·13
Total,	99·27

The presence of Al_2O_3, MgO, SiO_2 and part of the FeO is due to the fact that part of the garnet and enstatite were dissolved, for after the removal of the yellowish mineral they were found to be slightly soluble under the conditions of the experiment. The analysis clearly demonstrates that the yellowish mineral is composed essentially of TiO_2 and CaO, and there is good reason to believe the mineral is perofskite as Dr. Williams suggested.

In the rock the ilmenite is frequently surrounded by a granular border of perofskite which may be so broad that the perofskite appears to completely replace the ilmenite as if derived from it by alteration. Like the perofskite in the melilite

* This Journal, vol. xxxii, p. 121.

basalt from Hochbohl by Owen, it is frequently grouped with the magnetite. In the Kentucky rock, however, the perofskite is so intermingled with dolomite and other secondary products as to suggest that it belongs in the same category. It is not found included in the central portions of ilmenite grains nor in fact in any of the primary minerals as if present at the time of their crystallization, but occurs only under such circumstances as to lead to the conjecture that it may have originated subsequently from the alteration of the ilmenite.

This opinion is rendered less probable when we remember the pyrogenous methods employed in the artificial production of perofskite, and recall the fact of the chemical stability of the ilmenite which occurs abundantly with pyrope in the sand resulting from the disintegration of the peridotitic rock.

In the same sand with the pyrope and ilmenite a lameller monoclinic pyroxene is sparingly found. The crystals are not simple as those of enstatite previously noted, but made up of a multitude of twinning lamellæ lying parallel to the orthopinacoid along which it may be readily split. Some of these pyroxenes are dull but others are clear greenish yellow like olivine.

A part of this olivine rock is holocrystalline granular like the dunites, but a much larger portion than was at first supposed is decidedly porphyritic. Numerous crystals of olivine, many of them idiomorphic, are embraced in a ground mass which has been greatly altered since its consolidation. This rock plainly belongs to the type which the late Prof. H. Carvill Lewis (Rept. of British Assoc. for Adv. of Sci., 1887, p. 721) designated kimberlite, and which Prof. Rosenbusch classes among the Pikrite-Porphyrites (Der Massigen Gesteine, 2 Ed., 1887, vol. ii, p. 519).

3. *Gehlenite in a Furnace Slag.*

Numerous square prisms of gehlenite occur in furnace slag found near McVille, Armstrong, Penn.; accordingly in the thin section it appears square or oblong rectangular. The isotropic square sections are readily found to be uniaxial and negative. Spherical liquid and rod-like inclusions are numerous. Cleavage lines are not conspicuous. The easy gelatinization of the mineral in hydrochloric acid and its difficult fusibility before the blowpipe readily distinguish it from similar minerals. Although not previously reported as occurring in this country, gehlenite is probably one of the most easily obtained specimens to illustrate the optical properties of quadratic minerals in thin sections and on this account alone is worthy of notice.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Determination of molecular mass by means of vapor pressure.*—As early as 1878, Raoult had observed a relation between the diminution of the vapor pressure of a saline solution, the lowering of its freezing point and the molecular mass of the substance dissolved. The relation between the molecular mass and the depression of the solidifying point was developed in 1886 (*Ann. Chim. Phys.*, VI, viii, 317, July, 1886). He has now investigated the relation between the molecular mass of a substance and the lessening of the vapor pressure of a liquid in which it is dissolved, taking ether as the particular solvent employed. He finds that for substances whose vapor pressures are very low compared with that of the ether, there is a relation expressible by the formula $100\frac{f'}{f}=100-\mathrm{KN}$; in which f and f' are the vapor pressures of the ether alone and of the etherial solution respectively, at the temperature of the experiment, N the number of molecules of the substance in 100 molecules of the solution and K a constant depending on the character of the dissolved substance, whose value is not far from unity. Thus for turpentine, aniline and ethyl benzoate it was found to be 0·90, for methyl salicylate 0·82 and for nitrobenzene 0·70. Since these values do not greatly vary, K may be taken as equal to unity for all substances, provided that the solutions be dilute, the value of N not being greater than 15. Where N is less than 3, the relation is more complex, arising probably from the fact that the condition of the substance in solution changes with the degree of concentration. If in the above formula N be replaced by $100-\mathrm{N}'$, in which N' represents the number of ether molecules contained in 100 molecules of the solution, the above expression (taking K as unity) becomes $100\frac{f'}{f}=\mathrm{N}'$; or, in etherial solutions of moderate concentration, the partial pressure of the ether vapor is proportional to N', the number of ether molecules existing in 100 molecules of the mixture, and is independent of the nature of the dissolved substance. Direct experiment showed the ratio of $f':f$ to be independent of temperature between 0° and 21°. The first expression above given $100\frac{f'}{f}=100-\mathrm{KN}$ may be put into the form $\frac{f-f'}{f}=\frac{\mathrm{KN}}{100}$. The first member of this equation is called the relative diminution of vapor pressure, for the given solution; and hence the law that for all etherial solutions of the same character, the relative diminution of vapor pressure is proportional to the number of molecules of substance which are dissolved in 100 molecules of the solution. Moreover, since K is

unity for moderately dilute solutions, $\frac{f-f'}{fN}=0{\cdot}01$. Therefore if the relative diminution of the vapor pressure be divided by the number of molecules of substance existing in 100 molecules of the solution, a quotient of 0·01 is obtained, whatever be the character of the dissolved substance. If R molecules be dissolved in 100 molecules of ether, $N=\frac{100\times R}{100+R}$; and replacing N in the last equation by its value thus obtained, we have $\frac{f-f'}{fR}=\frac{1}{100+R}$. In proportion as R decreases, or the solution becomes more dilute, the ratio $\frac{f-f'}{fR}$ tends toward 0·01; reaching it when R=1 apparently. Hence if one molecule of a substance be dissolved in 100 molecules of ether, the vapor pressure of the ether is diminished by a fraction of its original value which is nearly constant and which is sensibly equal to 0·01. If m be the mass of the substance dissolved in 100 grams of ether and M be its molecular mass 74 being the molecular mass of ether, $\frac{N}{100}=\frac{74\times m}{100\times M+74\times m}$; and since as above stated $\frac{N}{100}=\frac{f-f'}{f}$, where K=1, we have for the value of the molecular mass $M=0{\cdot}74\,\frac{fm}{f-f'}$. Of course this value is approximate only; but if the boiling point of the dissolved substance is above 140° and not more than 20 grams of it be dissolved in 100 of ether, it is sufficient to enable the molecular mass to be fixed as between multiple values. Thus the molecular mass of turpentine thus determined, is 132; of aniline 87; of ethyl benzoate 159·2: and of benzoic acid 124·6; in place of 136, 93, 150 and 122 the true molecular masses. In general the author regards his cryoscopic or fusing point method as preferable; though in special cases the present method is evidently useful.—*Ann. Chim. Phys.*, VI, xv, 375, November, 1888.

G. F. B.

2. *On a Method of Avoiding "Bumping" in Distillation.*—MARKOWNIKOFF has suggested the use, in place of platinum wire, charcoal, etc., introduced into solutions to prevent bumping during ebullition, a few thin capillary glass tubes 3 to 10 mm in length sealed at one end. Under these circumstances the boiling goes on quietly, both at the ordinary and at reduced pressures, even when a finely divided precipitate like barium sulphate exists in a saline aqueous solution. Even caustic soda solution may be made to boil quietly in this way. Branner recommends that the tubes be made of different sizes so as to float in different layers of the liquid. For the distillation of concentrated acids he has found this method invaluable.—*J. Ch. Soc. Russe,* 1887, 520: *J. Chem. Soc.*, liv., 1155, Nov. 1888. G. F. B.

3. *On Thiophosphoryl fluoride.*—THORPE and RODGER have published a preliminary notice of a new gas, thiophosphoryl fluoride, PSF_3. It is obtained by heating phosphorus pentasul-

phide with lead fluoride, preferably in a tube of lead. Bismuth fluoride may also be used but a higher temperature is required for the reaction. The gas has also been prepared by heating a mixture of sulphur, phosphorus and lead fluoride, the last substance being added in excess to moderate the reaction. It may also be produced by heating a mixture of arsenic trifluoride with thiophosphoryl chloride in a sealed tube at 150°. The first method, however, is the best since it is the most convenient and gives a pure product. Thiophosphoryl fluoride is a colorless gas, liquefiable in the Cailletet apparatus. It spontaneously ignites in contact with the air, burning, as it issues from a jet, with a pale yellow-green flame tipped with blue. If a considerable quantity of the gas be exposed to the air, it produces a beautiful blue flash, followed by the yellow-green flame. It is sparingly soluble in water, has no action on mercury, is easily decomposed by heat or by the electric spark, and, heated for some time in a glass tube over mercury, the volume alters, phosphorus and sulphur are deposited on the tube and the resulting gas is silicon tetrafluoride. It is slightly soluble in ether, is insoluble in alcohol and benzene, is completely absorbed by lead peroxide and forms a white solid with ammonia. Heated sodium takes fire in it, burning with a red flame, yielding a residual mass evolving spontaneously inflammable hydrogen phosphide on treatment with water.—*J. Chem. Soc.*, liii, 766, Aug. 1888. G. F. B.

4. *On the Relation between the Absorption-spectra of Organic Compounds and their Chemical Composition.*—Krüss has examined the spectra of various organic compounds with a view of obtaining a relation between the absorption-spectra of these compounds and their chemical composition. Solutions of indigo and anthracene derivatives in chloroform or concentrated sulphuric acid were used, and also solutions of fluorescein derivatives in alcohol or water. The paper gives the wave-length of the spectrum lines of maximum absorption for each of the sixty-four compounds examined. In general, the author finds that the substitution of a methyl, ethyl, methoxyl or carboxyl group, or even of bromine, for hydrogen, moves the absorption lines farther toward the red; the similar substitution of a nitro or amido group producing a displacement toward the violet. In four cases only were exceptions found to this law: dibromamido-indigo and bromalizarin being the exceptions to the former, and tetranitro- and dibromodinitro-fluorescein, both in alcoholic solution, to the latter; the displacements produced by these substances being exactly opposite to that normally produced. In the case of the last two compounds, indeed, the aqueous solutions are normal in their displacements. To some extent also the amount of change which the introduction of any of the above groups into a compound produces in its spectrum, appears to depend upon the nature of the compound itself. If absorption lines be considered as produced by the absorption, by the molecules of a compound, of those ether waves whose period is the same as their own, then the vibration-

frequency of these molecules would be represented by the expression $n = \frac{v}{\lambda}$, in which v is the velocity of light and λ the wave-length of the absorption line. Consequently, whenever λ is increased by the displacement of the line toward the red, n will decrease and *vice versa.* Hence when a methyl, ethyl, methoxyl or carboxyl group, or bromine, is introduced into a molecule in place of hydrogen, its period of vibration increases, while when an amido or nitro group is so introduced, the period diminishes.—*Zeitschr. Physikal. Chem.*, ii, 312–337; J. Chem. Soc. liv, 1141, November, 1888. G. F. B.

5. *On the Absorption-Spectrum of Oxygen.*—LIVEING and DEWAR have examined the absorption spectrum of oxygen at high pressures. The apparatus consisted of a steel tube, 165 cm. long, fitted with gun-metal ends carrying quartz plates and capable of sustaining a pressure of 260 or more atmospheres. At or near its middle point this tube contained a quartz lens of 46 cm. focal length; so that, when a source of light was placed 10 cm. from one end of the tube, an image of it was formed on the slit of a spectroscope at about the same distance from the other end. On admitting oxygen into the tube until the pressure reached 85 atmospheres, and using an arc-light as the source, the authors observed: (1) a very dark band in the position of A of the sun spectrum, sharply defined on its more refrangible side and divided by a streak of light; (2) a precisely similar but much weaker band in the position of the solar band B; (3) a dark band diffuse on both edges, extending from λ 6360 to λ 6225, its maximum intensity being at λ 6305; (4) a still darker band a little above D, beginning with a diffuse edge at about λ 5810, rapidly coming to maximum intensity at about λ 5785, gradually fading out and disappearing at λ 5675; (5) a faint narrow band in the green at λ 5350; and (6) a strong band in the blue, extending from λ 4795 to λ 4750, and diffuse on both sides. By means of photographs it was shown that the oxygen was quite transparent for violet and ultra-violet rays up to λ 2745, then gradually diminishing until at λ 2664 it was wholly absorbed. Upon increasing the pressure to 140 atmospheres, all the bands were strengthened, but only one new one appeared, a faint one at λ 4470 in the indigo. By using a higher dispersion, none of these bands (which appear to be identical with the terrestrial bands observed by Ångström in the sun spectrum) were resolvable into lines. Subsequently a steel tube 18 meters long was employed, which at 90 atmospheres contained a mass of oxygen about equal to that of a vertical column of the atmosphere of the same section; but the intensity of the bands produced by the compressed gas was far greater than that of the corresponding bands in the solar spectrum with a low sun.—*Phil. Mag.*, V, xxvi, 286, September, 1888. G. F. B.

6. *On the Spectrum of Oxygen at high altitudes.*—JANSSEN has observed the solar spectrum at the Grands Mulets station on Mt. Blanc at an altitude of 3000 meters and has proved that the

lines and bands of terrestrial origin which it contains, especially those due to oxygen, are absent from sunlight before its entrance into our atmosphere. Experiments showed that at this height the bands of oxygen in the red, yellow and blue disappeared completely, the lines B and *a* became very much weakened and the line A was scarcely visible.—*C. R.*, cvii, 672, October, 1888.

G. F. B.

7. *On the Compressibility of Oxygen, Nitrogen and Hydrogen.*—AMAGAT has subjected oxygen, nitrogen and hydrogen gases to pressures up to 3000 atmospheres. He finds that at 1000 atmospheres the compressibility of gases is no greater than that of liquids and increases similarly with the temperature. Calling the density of water unity, the density of oxygen under a pressure of 3000 atmospheres is 1.1054, that of air is 0·8817 that of nitrogen is 0·8293 and that of hydrogen is 0·0887.—*C. R.*, cvii, 522, September, 1888. G. F. B.

8. *On the Heat of Vaporization of Volatile Liquids.*—Since very little is known of the heat of vaporization of liquids which boil at temperatures below 0°, CHAPPUIS has undertaken the determination of this constant in the case of methyl chloride boiling at −23·75°, of sulphurous oxide boiling at −10·08°, of carbon dioxide boiling at −78·5°, and of cyanogen boiling at −28·4°. The apparatus consisted of a glass cylindrical reservoir having at top a glass spiral or worm, united above to a larger tube cemented into a steel cylinder the opening in which could be closed by a screw cone. A lateral tube permitted this cylinder to be put in communication with a steel reservoir. The whole weighed about 100 grams. This apparatus is exhausted, the reservoir is attached, and the cylinder is two-thirds filled with the liquid to be examined. It is then placed in an ice-calorimeter of Bunsen and the cylinder and worm surrounded with mercury. On opening the compression tap, the liquid evaporates slowly, the heat of vaporization being taken from the calorimeter. After the experiment is ended the apparatus is again weighed. Knowing the mass of the liquid evaporated, the volume of mercury issuing from the calorimeter and the constants of this instrument, the heat of vaporization may be calculated. The results obtained were as follows: For methyl chloride at 0°, the heat of vaporization is 96·9 calories; for sulphurous oxide 91·7 calories; for carbon dioxide 56·25 calories; and for cyanogen 103·0 calories. If these values are referred to the gaseous volume corresponding to the molecular mass in grams, i. e., 22·32 liters, we obtain 4·86, 5·90, 2·48 and 5·36.—*Ann. Chim. Phys.*, VI, xv, 498, December, 1888. G. F. B.

9. *On the Combination of Oxygen and Nitrogen in Gaseous Explosions.*—It is well known that when hydrogen, in presence of nitrogen, is exploded with excess of oxygen, the nitrogen is itself to a certain extent oxidized. If the eudiometer contains a seven per cent solution of sodium hydrate, the nitrogen oxide produced is absorbed and the liquid contains nitrite and nitrate. VEITH

has undertaken to determine the quantitative relation of this oxidation by exploding repeatedly a mixture of hydrogen and oxygen in the same portion of air, until the volume had perceptibly diminished. Knowing this volume and the composition of the residual gas, he was able to ascertain that one volume of nitrogen had united with two volumes of oxygen. Nitrogen dioxide, or perhaps first nitrogen monoxide which is more permanent at a high temperature, is therefore formed under these circumstances. The quantity of the former produced is at constant pressure, directly proportional to the quantity of mixed gases burned. The quantity of nitrogen oxidized increases with the pressure up to about 300 millimeters; and above this appears to be constant. —*Ber. Berl. Chem. Ges.*, xxi, 695, November, 1888. G. F. B.

10. *Dissipation of Fog by Electricity.*—Soret places a platinum cup full of water in connection with one pole of an electrical machine. A point above the water is connected with the other pole of the machine. The water is caused to boil by means of a Bunsen burner. When the machine is not excited steam ascends in a regular manner, but when the water is electrified the clouds whirl about until the vapor disappears. The cup is illuminated by an electric light and the experiment is made in a dark room.—*Arch. des Sciences*, April, 1888. J. T.

11. *Magnetization of iron and other magnetic metals in a very strong field.*—The results of recent experiments by Professor J. A. Ewing and William Low show that no considerable change takes place in the value of the intensity of magnetism in wrought iron when the magnetic force is varied from 2000 to 20,000 C. G. S. units. Throughout this range of force the intensity of magnetism has a sensibly constant value of about 1700 C. G. S. units which is to be accepted as the saturation value for wrought iron. The following are the probable values of the intensity of magnetism when saturation is reached in the particular metals examined:

Wrought iron	1700
Cast iron	1280
Nickel (with 0·75 per cent of iron)	515
Nickel (with 0·56 per cent of iron)	400
Cobalt (with 1·66 per cent of iron)	1300

Hadfield manganese steel, which is noted for its extraordinary inpermeability to magnetic induction, was found to have a constant permeability of about 1·4 throughout the range of force applied to it, namely from 2000 to nearly 10,000 C. G. S.—*Nature*, Dec. 13, 1888, p. 165. J. T.

12. *Figures produced by electric action on photographic dry plates.*—Mr. J. Brown illustrates his articles by interesting photographs obtained by passing an electrical discharge immediately over or upon the surface of a sensitive dry plate. He believes that the figures are not due to the brush discharge, that actual disrupture discharge over or in the film is not needed to produce an effect visible on development, but that figures are produced

partly at least by direct electric action on the sensitive film which would be usually understood as a purely photo-chemical cause.—*Phil. Mag.*, Dec., 1888, p. 502. J. T.

13. *Spectrum of Cyanogen and Carbon.*—H. W. VOGEL has examined the spectra of the Bunsen flame, the cyanogen flame, the electric light and the various oxides of carbon with the electric spark, and has photographed with Azalin plates the spectra from the orange to the ultra violet. The spectra were photographed over each other in order to measure coincidences. After a discussion of the various bands and lines observed in the different sources of light, the author concludes that the cyanogen spectrum is identical with that of carbon. It seems to him that carbon can emit two spectra—one which gives the bands to the Bunsen flame and another the group of lines which appear clearly in the spectrum of cyanogen when seen by the aid of the electric arc. The channelled bands of the cyanogen spectrum in the red and yellow can be attributed to a compound. A full and remarkable coincidence of an especially bright indigo colored band with the dark back-ground of the G band of the solar spectrum appears in all the spectra. Vogel therefore attributes the dark back-ground of the G line to carbon in the sun.—*Sitzungsber. d. Berliner Ak.*, 21, 1888. J. T.

14. *Determination of the focal length of a lens for different colors.*—HASSELBERG places the objective upon a suitable bar somewhat more than four times the focal length of the lens and obtains, in two positions, clear images of the spectral lines formed by aid of a collimator and suitable prisms. If E is the length of the bar, ε the difference of both positions of the objective, one has $4f = E - \varepsilon^2/E$ in which the thickness of the lens is neglected.—*Bull. de l'Ac. des Sc. de St. Pet.*, xxxii, p. 412, 1888. J. T.

15. *Electrodynamic Waves.*—At a late meeting of the Physical Society of Berlin, Helmholtz gave an account of the recent researches of HERTZ on the propagation of electrical waves. Weak induction discharges between small metallic cylinders with rounded ends were employed, and a similar apparatus for the detection of the electrodynamic waves. The action was not propagated more than 2 or 3 meters through space; when it fell on a metallic surface it was reflected, interference phenomena were observed and from these the length of half a wave was found to be 30 centimeters. When a metallic parabolic mirror, 1 meter across its opening, was placed behind the apparatus used to produce the discharge, the action was propagated to a distance of 8 meters; and the action was greatly increased when a second concave mirror was placed behind the receiving apparatus. When a conductor was interposed the action ceased, while non-conductors allowed the waves to pass. By interposing perforated metallic screens, it was found that the waves are propagated in straight lines; the waves passed through a dry wooden partition. Polarization of the waves could be determined in several ways. When the receiver was placed at right angles to the apparatus

producing the waves, no action between them could be detected, the vertically produced waves not being picked up by the horizontally placed receiver. When the two pieces of apparatus were placed parallel to each other, and a wooden cable, with a number of insulated metallic wire rings wrapped round it was placed in the path of the electrodynamic waves, it produced the same effect as does a tourmaline plate on polarized light. When the wires were vertical—that is to say, parallel to the exciting apparatus—the action was not propagated through the cube; but it was, on the other hand, when the wires were horizontal. When the receiver with its mirror was placed horizontally, so that it did not record any action on reaching it, and the wire arrangement described above, was placed in the path of the waves, no change took place in the receiver when the wires on the cube were either vertical or horizontal, but the receiver was affected when the wires were placed at an angle of 45°. The laws of reflection of electrodynamic waves at metallic surfaces were found to be the same as those for the reflection of light at plane mirrors. The refraction of pitch for electric waves was found to be 1·68.—*Nature*, Jan. 17, 1889. J. T.

16. *Resistance of electrolytes.*—Professor J. J. Thomson (Royal Society, Jan. 17, 1889) has examined the screening influence of conducting plates upon alternating currents of great frequency, and has deduced thereby the resistance of electrolytes and of graphite. He shows that the screening effect depends on the conductivity and thickness of the plate and upon the frequency of the alternations. The secondary induced currents are confined to the skin of the plate next to the primary, the thickness of this skin varying with the conductivity of the plate and the frequency of the currents. Thus a thin plate of badly conducting material will be efficient with currents of great frequency such as those of the rate 10·8 per second while a thick plate of the best conducting material will not be sufficient to screen off currents of low frequency such as those with a rate below 10·2 per second. Thus to measure the resistance of electrolytes it is necessary to have vibrating electrical systems such as those examined by Hertz, whose frequency is of the former class; and if two different plates produce the same screening effect, their thickness must be proportional to their specific resistances. He supports Maxwell's theory that the rate of propagation of electrostatic potential is practically infinite, a point called in question by Hertz, and he agrees with Hertz that the rate of propagation of electrodynamic action is finite and measurable. He shows that the rate of propagation of an electromagnetic disturbance through a metallic conductor and through the surrounding dielectric is the same, and this differs from one of Hertz's conclusions. But he also shows that this is not so when the conductor is a dilute electrolyte or a rarefied gas. In such cases there would be interferences and standing vibrations. Hence the striæ in so-called vacuum tubes. He also concludes that the relative resistance of electrolytes is the same when the

current is reversed a hundred million times a second as for steady currents."—*Nature*, Jan. 24, 1889. J. T.

17. *Orthochromatic Photography.*—H. W. Vogel criticises Abney's method of sensitizing a plate, which consists in flowing the dry plate with a colored collodion, and claims that it does not produce the same effect as the direct mixture of the coloring matter with the gelatine layer of the dry plate. The collodion film prevents the molecular action of the sensitizing substance upon the bromide of silver molecules.—*Photog. Mittheil.*, xxv, p. 117–119, 1888. J. T.

18. *Voltaic Balance.*—Mr. G. Gore finds the following apparatus extremely sensitive. An unamalgamated zinc plate and a platinum plate are immersed in a small vessel of distilled water and are connected, through a galvanometer, with a platinum and a zinc plate in another vessel filled with distilled water. The smallest addition of a foreign substance to one or the other vessel causes swing of the galvanometer, and the apparatus can be used to detect extremely small traces of various substances.—*Chem. News*, lviii, p. 64, 1888. J. T.

II. Geology and Mineralogy.

1. *Fossil Plants of the Coal-measures of Rhode Island;* by Leo Lesquereux. (Communicated by the author).—The following is a list of the coal plants of Rhode Island, sent for determination by the Museum of Brown University, Providence, R. I., May, 1888.

1. Pecopteris dentata *Brgt.*, 1 a fruiting pinna, Pawtucket.
2. Sphenpoteris (Hymenophyllites) furcata *Brgt.*, Valley Falls.
3. Sphenophyllum oblongifolium *Germ.*, Pawtucket.
4. Dictyopteris Scheuchzeri *Hoffm.?* obscure; nervation obsolete, Pawtucket.
5. Odontopteris Stiehlerian *Goepp.*, fragment, Pawtucket.
6. Odontopteris Reichiana *Goepp.*, separate pinnule, Pawtucket.
7. Odontopteris Reichiana, var. latifolia *Lx.*, Pawtucket.
8. Odontopteris Neuropteroides *Roem*, Pawtucket.
9. Neuropteris decipiens *Lx.*, Valley Falls.
10. Goniopteris (Pecopteris) unita *Brgt.*, Valley Falls.
11. Pecopteris lepidorachis *Brgt.*, Valley Falls.
12. Asterophyllites equisetiformis *Brgt.*, Pawtucket.
13. Pecopteris Miltoni *Brgt.*, Pawtucket.
14. Schizopteris (Rhacophyllum) trichomanoides *Goepp.*, Pawtucket.
15. Oligocarpia Gutbieri *Goepp.*, Pawtucket.
16. Sphenopteris lanceolata *Gutb.*, Pawtucket.
17. Odontopteris Bairdii *Brgt.*, Pawtucket.
18. Pecopteris hemiteloides *Brgt.?* fruiting pinna, obscure, Pawtucket.
19. Pecopteris Miltoni *Brgt.*, Pawtucket.
20. Pecopteris abbreviata *Brgt.*, fruiting fragment, Pawtucket.
21. Pecopteris arborescens *Brgt.*, fruiting fragments, Pawtucket.
22. Pseudopecopteris dimorpha *Lx.*, fragment of a pinna, Bristol.
22*a* Pseudopecopteris dimorpha *Lx.*, obsolete form, Bristol.
23. Odontopteris cornuta *Lx.*, Pawtucket.
24. Parallel narrow rachises of pinnæ of No. 7, mostly deprived of leaves, Pawtucket.
25. Neuropteris dentata *Lx.* See remarks below, Pawtucket.
26. Odontopteris obtusiloba? *Baum.*

Remarks.—The remains of plants determined above are generally in small fragments more or less deformed, like most of the fossil plants of the Coal-measures of Rhode Island, and therefore their characters are not always satisfactorily recognized. In this lot, they represent mostly species of the Upper Coal-measures, some of which have been recognized in the Lower Permian formations of Europe. Of this kind are Nos. 6 and 7, *Odontopteris Stiehleriana* Goepp., *A. Reichiana* Goepp., *Odontopteris obtusiloba* Baum, etc. This last species has not been recognized before in the Coal-measures of North America, but has been described by Gutbier only from specimens of the Lower Permian, and Geinitz from the Dyas.

No. 25. *Neuropteris dentata* Lesqx., is a very rare species, first described in Rogers's Geol. of Pennsylvania, 1858, p. 859, pl. v, figs. 9 and 10, from four separate pinnules obtained in the Anthracite Coal-measures (the Salem vein of Port Carbon), Pennsylvania the highest coal of the measures. The specimen from Pawtucket, R. I., is more complete, representing the upper part of a pinna with two pairs of large opposite lanceolate pinnules, irregularly sharply dentate on the border, very oblique, decurring to a narrow rachis, with close flabbellate veins derived from a narrow indistinct midrib and very thin though deeply marked. The nervation like the border teeth of the pinnules, is of the same character as represented upon the figures in the Geology of Pennsylvania, the leaflets merely differing by the narrowed, cordate (not decurrent) base.

June 25, 1888.

2. *History of Volcanic Action during the Tertiary Period in the British Isles;* by Archibald Geikie, LL.D., F.R.S., Director General of the Geological Survey of the United Kingdom. 184 pp. 4to, with maps and cuts. Trans. R. Soc., Edinburgh, vol. xxxv, Part 2.—The contrast between the eastern and western borders of the Atlantic in amount of volcanic action has great geological significance, and hence full and detailed descriptions of the facts from the eastern side, like those here presented by Dr. Geikie, have an importance far beyond that of their local or volcanic interest. The facts with regard to the great basaltic areas, those of Antrim of northern Ireland and those of the islands of Mull and Skye and intermediate islands off the coast of Scotland, are described in detail and mapped; and besides these, the many dikes, or subordinate lines of eruption, over Scotland, Ireland and northern England, far away from the main centres, which make the area of fractures and ejections in the Tertiary, according to the author, over 40,000 square miles in extent. The region of outside dikes, referred to, includes the southern half of Scotland, which is intersected by many east and west as well as northwest dikes ; and the northern part of Ireland and England where the courses are mostly northwestward. The eruptions may have begun, Dr. Geikie states, in the Eocene ; they continued through the Miocene period probably to its close, and perhaps into the Pliocene.

After full descriptions of the great fields of basalt and the surface and intruded outflows, and an account of the rocks—which, although mainly basic, include trachytic, and related kinds and even granite,—Dr. Geikie discusses the origin and history of the disturbances. In the closing summary he observes that, while denudation may have made extensive removals of the lavas, there is still, in the basalt-plateau of Antrim and the region of the Inner Hebrides to the northward, an accumulation of lava streams in some places to a thickness of 3000 feet; and that the outflows continued until they had filled the hollows of the great valley stretching northward from southern Antrim. The region was then mostly above water-level, as is shown by the leaves, stems, fruits and remains of insects found between the streams. The ejections were mainly of lava, fragmental materials being of small amount. The streams appear to have flowed off almost horizontally, not in Dr. Geikie's opinion from any one center, but rather from many. Reviewing the history he remarks that basic outflows, raising the surface some thousands of feet, were followed by other lavas which solidified as coarsely crystalline doleryte, gabbro, troctolyte and picryte. Later, probably after volcanic action had mainly ceased, a renewal of activity brought up trachytic and felsitic rocks, recalling in some respects the trachytic *puys* of Auvergne, and granophyres and granitic vein-like dikes were made in the felsitic masses or spread out in sheets between the beds below. Still later, basic lavas anew outflowed over the surface. Further, the dikes of pitchstone at Antrim and the region north are probably of yet later origin; for "these vitreous protrusions traverse every other of the volcanic series and do not appear to be cut by any"; and at one locality the Scuir of Eigg, the streams of pitchstone flowed out over the basaltic plateau, after it had been cut through by valleys, making "an impressive memorial" of the Tertiary topography of the place.

The greatness of the volcanic results in Tertiary Britain, and not less in many parts of Europe, give emphasis to the fact, alluded to above, that the *western* border of the Atlantic in the same era from the far north to the West India seas, afford no evidence of volcanic fires. J. D. D.

3. *Geological and Natural History Survey of Minnesota.*—Volume II of the final Report on the Survey of Minnesota, by N. H. Winchell, assisted by Warren Upham, has recently appeared—a large quarto volume of 695 pages, with forty-two plates. The volume contains reports on the geology of thirty-nine counties by one or the other of the authors above mentioned. Both have made a careful study of the regions. Mr. Upham's attention, as notices of the annual reports in former volumes of this Journal have shown, has been especially directed to the drift—a very prominent feature over the great State, having special interest from the relations of the State in position and

geological history to the Winnipeg region, and the various fortunes of the Mississippi, Minnesota and Red rivers; and through his descriptions Mr. Upham shows that he has well mastered his subject. His reports also cover the stratigraphical geology of many of the counties.

The reports by Prof. Winchell bear especially on the Lower Paleozoic and Upper Mesozoic formations; but also on the drift, the drainage, the topography and the economical resources of the State. A highly interesting part relates to the history of the Falls of St. Anthony, in Hennepin Co., which is illustrated by a nnmber of beautiful views and copies of former pictures. The geology of each county is also presented on a finely colored geological map, adding much to the value of the volume. The State is to be congratulated on the successful results of the survey, and the high character of the Reports.

4. *Geological Survey of Kentucky*, JOHN R. PROCTER, Director.—In the survey of Kentucky under Mr. Procter, several County Reports have been recently issued: on Mason, Bath, Fleming, Henry, Shelby and Oldham Cos., in 1885 to 1887 by W. M. Linney; on Elliott Co., by Prof. A. R. Crandall, in 1887, with notes on the Trap dikes by A. R. Crandall and J. S. Diller (see Mr. Diller's paper in this Journ., xxxii, 121, 1886); on the Jackson Purchase Region, or the seven counties lying between the Tennessee River and the Mississippi, by R. H. Loughridge, 357 pp. 8vo, 1888; and a Chemical Report, by Dr. Robert Peter, containing very many analyses of the coals, soils, clays, petroleum, mineral waters, etc., 171 pp. 8vo, 1888. Besides colored geological maps of some of the counties in the Reports, a small but handsome State geological map was issued in 1887, by J. B. Hoeing, who is at the head of the Topographical Survey. The Reports treat of the Paleozoic rocks, and chiefly of the coal formation of Kentucky; but also of the soils and other points of economical importance. Mr. Procter's Report of Progress of 1887, states that in addition to the coal beneath the Conglomerate, at the base of the Coal-measures, there are above it, north of Pine Mt., 1650 feet of Coal-measures, containing nine beds of workable thickness, and between the Pine and Cumberland Mts. a still greater thickness with twelve or more beds. Mr. Loughridge's Report presents evidence from the results of boring a well at Paducah in western Kentucky, on the Ohio, of a fault of 1350 feet. On the Illinois side, the St. Louis limestone of the Subcarboniferous is at the surface, overlying the Keokuk, while on the Kentucky side the Keokuk, as the boring shows, is about 1350 feet below the surface, and the overlying rock is the Chester limestone, or upper division of the Subcarboniferous. The fault probably extends for some distance southeastward along the east side of the Tennessee River near the junction of the Cretaceous beds of Mississippi valley and the Subcarboniferous.

5. *Geology of New Jersey. Final Report of the State Geologist*, Prof. GEORGE H. COOK. Vol. I, 440 pp. 8vo, with a

colored topographical map of the State. Trenton, N. J. 1888.—New Jersey is the first State in the Union that can boast of a completed topographical survey. The admirable atlas of seventeen maps published the past year—the result of the Geodetic Survey by Prof. E. A. Bowser of the U. S. Coast and Geodetic Survey and of the topographical work of Mr. C. C. Vermeule and his assistants—has prepared the way for the final report of the State Geologist, and the volume now issued is the first of the series. This volume is occupied with a physical, geographical and topographical report of the State, and also a report on the magnetic survey, both of them by Mr. Vermeule, and also by an account of the climate by Prof. Smock. The magnetic report is accompanied by a map of isogonic lines; and the volume by a large colored topographical map of the State of New Jersey, printed in nine colors to indicate altitudes, and by a detailed geographical map.

6. *Woodham Artesian Well, on Long Island, two miles east of East New York*, on the line of the Long Island Railroad; communicated by E. Lewis, Jr., of Brooklyn, N. Y.—The facts afforded by this well have great interest because they give the thickness of the surface gravels, 213 feet, and of the earlier sand and clays and the depth of the gneiss beneath the surface. The locality is 35·6 feet above high tide. The distance to the outcrops of gneiss on the north shore of the island is 3½ miles, showing a steep incline southward of the floor of gneiss. The only fossils found were the pieces of lignite at 387 feet. No trace of greensand was passed through. The section here given is condensed from memoranda presented to the Long Island Historical Society, on the 5th of February last, by Francis H. Luce.

		Feet.
1.	Surface deposits, sand and gravels, yellowish brown or rusty, in thick beds, to a depth of	213
2.	Sandy clays, clays, varying in color and fineness, in beds, 145 ft., to depth of	358
3.	Quicksand, fine, gray, Lignite in middle of beds	417
4.	Layers of sandy clay, 16 ft., blue clay, 3 ft.	436
5.	Quicksand, very fine, 7 ft., coarse, clayey sand, 13 ft.	456
6.	Coarse, angular, nearly white quartz, sand and pebbles, 4 ft.	460
7.	Sandy clay, 10 ft.	470
8.	Coarse, silicious sand and pebbles, very light color, *very little water-worn*, 50 ft.	520
9.	Clayey sand, 3 ft.	523
10.	Very fine, tough, light colored clay, 22 ft.	545
11.	Coarse, clayey sand, on the bed rock, 11 ft.	556
12.	Bed rock of gneiss, penetrated 21 ft.	577

7. *Bowlder-Glaciation.*—In a paper read before the Tyneside Field Club in 1884, Mr. Hugh Miller draws attention to the glaciation of stones and bowlders *within* the mass of the bowlder clay, producing what he calls pavement bowlders. He observes that in 1852, Hugh Miller, his father, brought into notice certain causeway-like pavements of bowlders near Portobello. The agent appealed to by the father was icebergs. This recent paper states similar facts from near Edinburgh and elsewhere. The views

given of the "bowlder-pavements" at Fillyside, which, have become exposed to view through seashore action, represent the bowlders as lying close together in the bowlder-clay, and having their *upper* surfaces planed off flat and striated in a common direction. "The smaller stones that are fitted in among the others have escaped striation altogether; others rising a little higher have been brushed atop; while others, again, have been planed off as flat and square-edged as a laundry-maid's iron." The author mentions the common occurrence of small stones with striæ that were evidently derived from fluxion movement in the body of the moving bowlder-clay, and of fluxion structure indicated by the arrangement of the stones. The author is led to conclude that in many cases at least the bowlder-clay is built up slowly and under pressure, and that this pressure was that of a slow-moving, heavily-dragging, wide-spreading mass. "To the theory, if it must still be termed a mere theory, of confluent glaciers one turns as to a really competent agent. For the fluxion-structure it accounts at once. It needs only to be assumed that the dragging ice communicated something of its own motion and structure to the clay over which it passed." "The fluxion-structure is the result of movement; the pavement-bowlders are those elements in the materials that, making of themselves inclined slides, could best resist the movement and were striated atop in resisting."

8. *Archæocyathus of Billings.*—This Cambrian genus hitherto regarded as including only fossil sponges, has been shown by Dr. G. J. Hinde to comprise mainly fossil corals. He makes *Archæocyathus Minganensis* a true lithistid sponge, and names the genus *Archæoscyphia. Archæocyathus profundus*, Billings's type of the old genus, is retained still as such, but of the family of *corals*, Archæocyathinæ. *A. Atlanticus* is made the type of a new genus, *Spirocyathus.* The family includes the genera *Archæocyathus* of Billings, *Ethmopyyllum* of Meek, *Coscinocyathus*, *Anthromorpha* and *Protopharetea* of Bornholm, together with *Spirocyathus.* Mr. Hinde states also that *Calathium* and *Trichospongia* of Billings are, like *Archæoscyphia*, undoubted siliceous sponges.—*Proc. Geol. Soc. London*, Dec. 19, 1888.

9. *Analyses of waters of the Yellowstone National Park*, by F. A. Gooch and J. E. Whitfield. (Bull. U. S. Geol. Surv., No. 47.)—These careful analyses of the geyser waters,—43 samples in all—have great interest because of the evidence they appear to afford that the silica present in the silicious waters is mostly if not wholly in the state of dissolved silica and not that of an alkaline silicate. In the waters of the Old Faithful Geyser, the silica constituted 26·54 parts of the total material in solution; in the Giantess, 27·62 p. c.; the Beehive, 25·12 p. c.; the Grotto, 18·15 p. c. Of the other ingredients the analyses give 1·43 p. c., 1·75 and less of boric acid in 100 parts of the total solid material; 16·89, 26·67, 27·06, 35·39, 37·00, 39·22, etc. of chlorine; and mostly 15 to 28 p. c. of sodium. The memoir deserves careful study by the geologist.

10. *Elemente der Paläontologie* bearbeitet von Dr. GUSTAV STEINMANN, Ord. Prof. Geol. Min. Univ. Freiburg, i. Br., unter mitwirkung von Dr. L. DÖDERLEIN, Dir. nat-hist. Mus. Strassburg. 1 Hälfte (Bogen 1–21). *Evertebrata, Protozoa, Gastropoda.* 336 pp. 8vo, with 386 woodcuts. Leipzig, 1888. (Wilhelm Engelmann).—This general treatise on Zoological and Botanical Paleontology describes the groups and genera and illustrates them with many figures representing species and details of structure. It also gives tables showing the geological distribution of groups. The figures are well chosen, and beautifully engraved. The work will be found of great value by students in Geology and Paleontology. The second half, treating of the Invertebrates, the Vertebrates and Plants, is promised in the course of the current year.

11. *Die Stämme der Thierreichs* von DR. NEUMAYR, Wirbellose Thiere. Erster Band., 603 pp. with 192 text-figures. Vienna and Prague, 1889. (F. Tempsky).—Dr. Neumayr treats, in his valuable work, of the successional relations of species in the animal kingdom, in illustration of the subject of evolution. He describes the various groups in zoological order, illustrates their structure and forms by figures, and dwells at length on all the zoological and geological facts that have a bearing on the question of derivation. This first volume of 600 pages carries the work to the close of the Molluscoids (Brachiopods).

12. *Fossil Cockroaches.*—S. H. SCUDDER has described seven new species of *Etoblattina*, from the Barren Coal-measures of Richmond, Ohio.—*Proc. B. S. N. H.*, vol. xxiv, 45, Nov., 1888.

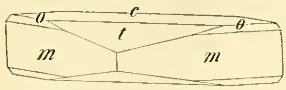
13. *Visual area in the Trilobite, Phacops rana;* by J. M. CLARKE.—This excellent paper is the result of a thorough study, as far as material allowed, of the composition and structure of the different parts of the eyes in this trilobite, and the relation as regards the eye between the Phacopidæ and other trilobites.—*Journ. Morphol.*, ii, Nov., 1888, Boston.

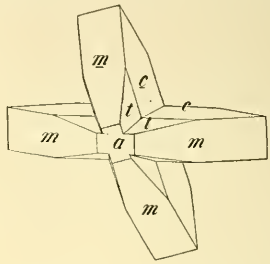
14. *Mineralogical Notes;* by E. F. AYRES (communicated). *Thenardite.*—Some specimens of thenardite recently obtained from Borax Lake, San Bernardino Co., California, exhibit a method of twinning that has apparently not been described. The crystals average about an inch in length and are tabular or short prismatic in habit. They show the unit prism, $m(110)$, basal plane $c(001)$, the unit pyramid $o(111)$, and a low macrodome, probably $t(106)$ and probably the pinacoid $a(100)$; the oscillations of the form t give rise to a flat striated surface often replacing c. The crystals are rough and allow only of approximate measurements with a contact goniometer; these are given here with the angles calculated from the axial ratio of Bärwald.* The position taken is that which makes the prism of nearly 60° vertical.

* Groth's Zeitschr., vi, 36.

The crystals are for the most part clustered in open loosely coherent groups. They are many of them cruciform twins, crossing at angles of 102° and 78°, which gives as the twinning plane

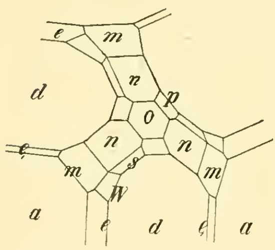
	Measured.	Calculated.
$110 \wedge \bar{1}10$ =	120°—121°	118° 17′
$110 \wedge 111$ =	21° 40′	22° 17′
$106 \wedge \bar{1}06$ =	40° 32′	38° 31′





the unit brachydome (011, 1-ĭ) for which we have $001 \wedge 011 =$ 51° 24′. The twins previously described have (101, 1-ī) as the twinning plane. The habit of the crystals is shown in the accompanying figures.

Pyrite.—A group of crystals from Colorado has yielded an unusual combination of forms as represented in part in the accompanying figure. The planes here present are:



a(100, *i-i*), *d*(110, I), *e*(210, *i*-2), *l′*(120, −*i*-2), *o*(111, 1), *n*(211, 2-2), *m*(311, 3-3), *p*(221, 2), *s*(321, $\frac{3}{2}$), *w*(851, 8-$\frac{8}{5}$). The occurrence of both + and − pyritohedrons *e* and *l′*, is unusual; the measured angles on the cubic plane are 26° 36′ and 53° 35′. Other edges of the same crystal gave a series of reflections corresponding to the following pyritohedrons, viz: 210, 430, 540, 450, 340, 230, 120.

15. *Barite from Aspen, Colorado;* by J. F. Kemp (communicated).—While on a recent visit to Aspen, Colorado, the writer obtained from the Smuggler mines several specimens of beautifully crystallized wine-yellow barite, which closely resemble the variety described by Beckenkamp* from the phonolite of the Kaiserstuhl. The ordinary gangue mineral of the Aspen lead-silver mines is common white barite in foliated masses. The Smuggler mine alone seems to afford crystals. The ore body lies in blue Carboniferous limestone and in this particular mine shows considerable zinc. Cavities in the decomposed ore are found lined with the barite crystals. The largest in my possession are about one-quarter of an inch on a side, but others have been found larger. They are tabular in form showing most prominently 0P and ∞P. Together with these are seen P, $\frac{1}{2}P\bar{\infty}$, $P\bar{\infty}$, $\infty P\bar{\infty}$, $P\breve{\infty}$, $\infty P\breve{\infty}$ and a macro-pyramid whose faces, though distinct, are somewhat curved and give measurements which vary several degrees. $mPn \wedge 0P = 107° - 112°$; $mPn \wedge \frac{1}{2}P\bar{\infty} = 153° 50'$ to $156° 40'$.

* Groth's Zeitschrift, xiii, 24, 386.

This face is seen only on one side of $\frac{1}{2}P\bar{\infty}$. The angles of the dome and unit pyramid agree within one or two minutes with those tabulated in Dana's System.

Like the Kaiserstuhl variety the crystals are strongly pleochroic; almost colorless parallel with the *b*-axis, deep yellow parallel with the *a*-axis, less intense yellow parallel with the *c*-axis. The crystals are abundantly filled with inclusions of irregular form arranged zonally parallel with the prism faces, making an analysis impracticable. They are doubtless mere dirt or debris brought in by the original barium-bearing solution.

16. *On the serpentine of Montville, N. J.*; by George P. Merrill.—A paper recently published in the Proceedings of the U. S. National Museum (pp. 105–111, 1888) gives an interesting description of the New Jersey serpentine, tracing its alteration from the original diopside which is observed in many cases as a nodular nucleus. The following analyses give for one case, the composition of the pyroxene and the resulting serpentine.

	SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3	FeO	Ign.	
Pyroxene	51·45	18·43	24·02	2·94	1·06	0·96	1·08	= 99·94
Serpentine	40·23	39·46	....	2·18	4·02	*tr.*	14·24	= 100·13

17. *Slipping planes and lamellar twinning in Galena*; by W. Cross.—It is shown that the cleavage masses of galena from Bellevue, Idaho, are remarkable for the exhibition of lamellar twinning due to pressure. Two kinds of structure are described; in one, bands are seen on a cleavage surface that are parallel to a dodecahedral plane; in another, the laminæ are parallel to different planes but all conform to a common law, the twinning-plane being the octahedron 3.—*Proc. Colorado Sci. Soc.*, vol. ii, part 3.

18. *Some New York Minerals and their localities*; by Frank L. Nason.—An account is given of fine crystals of brown tourmaline from Newcomb, Essex Co.; pyroxene and associated minerals from Ticonderoga, and calcites from Rossie, the last collected by Professor Emmons.—*Bull. N. Y. State Museum*, No. 4.

III. Botany and Zoology.

1. *Certain relations of the cell-wall.*—Dr. Kohl (Bot. Centralbl. xxxvii, 1) demonstrates that the growth in thickness of the hairs of many plants is not strictly by intussception nor by apposition, but by periodic depositions of layers of cellulose; and he notes the fact that, between these successive layers, there is generally a trace of protoplasmic matter not easily detected by the use of Millon's reagent. Krabbe has already shown that the growth of bast-fibres is substantially of the same character. G. L. G.

2. *The chemical nature of assimilation.*—Th. Bokorny (Erlangen, 1888) has conducted some interesting experiments designed to test the truth of the hypothesis of Baeyer, namely, that when sunlight acts on chlorophyll which is surrounded by carbon-dioxide the gas undergoes dissociation as if it were exposed to

a high temperature, and oxygen is eliminated. Further, from this dissociation, carbon monoxide results, and is united to the chlorophyll, where it at once takes up a molecule of water, forming formic aldehyd. In the presence of the free alkalies of the assimilating cells, this primary product can pass at once into the form of sugar. Bokorny has contrived to exclude carbonic acid from the assimilating cells of *Spirogyra*, providing in place of this gas formic aldehyde, methylaldehyde, methyl-alcohol, and, as others had done before him, glycerin. He found that formic aldehyde killed the protoplasm, but he does not regard this as vitiating the hypothesis of Baeyer, since it is possible that this substance is in normal assimilation converted at once into a carbohydrate. With the other substances employed he was moderately successful, and states that from them, even with complete exclusion of carbonic acid, the green cells of a plant can produce starch.

G. L. G.

3. *Improvement in the "races" of the Sugar Beet.*—C. Viollette and F. Desprez (Comptes rendus, 7 Jan., 1889) have carried on a very interesting series of experiments in regard to the Sugar Beet which may be interpreted as indicating that still greater improvement in this useful plant may be reasonably looked for. They state that the manufacturers of sugar have endeavored to use the earlier varieties although the content of sugar is so much smaller, because in this way they have been able to cover a longer time in the manufacture, taking the poor early varieties first, employing some of wretched quality. But the legislation of 1884 compelled the manufacturers to use better varieties, and the only ones at their command were late, coming into maturity during the first fifteen days of October, whereas the earlier ones ripened off at the beginning of September.

The experiments were carried on at Cappelle (Nord) and consisted of careful selection of rich varieties which showed any tendency to hasten maturity. The results are surprising. Whereas the early varieties formerly used contained from 9 to 11·26 per cent. of sugar, the new early varieties or, rather, true *races*, yield from 14 to 16 per cent. Thus the manufacturers have now at their command early races (that is, varieties which come true to seed) which are very rich, and they have also the rich races which mature later, and which furnish from 13·8—16·5 per cent.

G. L. G.

4. *The primordial leaves of Abietineæ.*—Daguillon (Comptes Rendus, 14 Jan., 1889) points out the fact that the primordial leaves (that is the leaves intermediate between the cotyledons and the adult leaves) of Abietineæ are pretty constant in form. In some instances, as for example in the genus Pinus, no intermediate steps are to be seen, but in some others various transitional shapes are discernible. The passage from one to the other is characterized by a progressive development of the hypodermis and of the Sclerenchyma adjacent to the fibro-ligneous bundle. In certain cases there is a division of the central nerve into two bundles

under a common Endodermis. The differentiation begins in the internal morphology of the organ. G. L. G.

5. *Notes on Cestoid Entozoa of Marine Fishes;* by EDWIN LINTON.*—This second report on Fish Entozoa, has been handed in for publication.

The paper contains notes on forty-two species of Cestoids, eight of which were described in the first paper.† Only adult forms are described. The following changes in the nomenclature of the first paper have been made.

Phyllobothrium thysanocephalum is referred to a new genus and is recorded under the name *Thysanocephalum crispum*. *Rhynchobothrium tenuicolle* Rud. is referred to a new species *R. bulbifer*. *Rhynchobothrium bisulcatum* is put in Diesing's genus *Tetrarhynchobothrium*. The reasons for these changes are given under the observations on the species. Van Beneden's genus *Acanthobothrium*, which had been combined with the genus *Calliobothrium* by Diesing, is retained. The genus *Echeneibothrium* has been so emended as to exclude those species with echeneiform bothria which are destitute of a myzorhynchus. These are combined in the new genus *Rhinebothrium*.

There are peculiar difficulties in the way of classifying the unarmed *Tetrabothriidæ* and more investigation is needed before the truth is arrived at. Further investigation upon new material may make it possible to unite several genera of the *Phyllobothrinæ*. Several forms were discovered in which the bothria were united into a globe or disc. These have been referred, for convenience, to a common group, to which the family name *Gamobothriidæ* has been given. The genera which have been referred to this group differ greatly from each other but agree in having the bothria united.

One of the most remarkable of the new forms is the one I have named *Paratænia medusia*. This is a small tænia-like worm, which, instead of having a simple papilliform proboscis, or a retractile proboscis armed with hooks, has sixteen flexible tentacular proboscides, which it can either retract, leaving a circular terminal os, or extend, forming a rosette or crown of tentacles like those of an Actinian.

It is to be observed that the species which I have succeeded in identifying with European species belong to hosts which, for the most part, are found on both sides of the Atlantic. The species described in this paper were collected in the months of July and August in the summer of 1886 and 1887 at Wood's Holl, Mass. During the summer of 1887 I made most careful

* Abstract prepared by the author; published with the consent of Marshall McDonald, U. S. Commissioner of Fish and Fisheries. The first paper is incorporated in the Report of the U. S. F. C. for the year 1886. Pp. 453–510. Plates I to VI.

† Lack of space makes it necessary to omit the list of species and the families to which they belong.—EDS.

search for small forms and was eminently successful in my examination of *Trygon centrura* and *Carcharias obscurus.* In the course of these researches a great many encysted forms were obtained. These were most abundant in the Teleostei. The parts most affected were the peritoneum, liver, submucous and muscular coats of the stomach and intestine. Many species of Trematods, Nematods and Acanthocephala were also found. So far as my investigations teach, it appears that very few of the Cestoid entozoa of fish pass their adult stage in specifically different hosts. With regard to the encysted form, however, the range of hosts appears to be greater.

Probably the most interesting result obtained from these researches is the demonstration of a somewhat complicated nervous system in *Rhodobothrium pulvinatum.* This in brief consists of a squarish ganglion in the head at the base of the pedicels connected by paired commissures with smaller ganglia of which there is one in each of the four pedicels. From the latter ganglia smaller branches proceed to the cushion-like bothria. Two lateral branches originate with the principal ganglion, extend back through the neck and presumably continue into the body. Transverse sections made through the head and neck of a *Tetrarhynchobothrium* show that the walls of the contractile bulbs are very thick and are composed of several diagonally interlacing layers of muscles. In these sections the central retractor muscle of the proboscides was seen to be made up of a number of fine longitudinal fibers. What was interpreted as nerves were also seen lying one beside each proboscis sheath and communicating with the anterior ends of the contractile bulbs.

Acknowledgments should here be made to my wife, Margaret B. Linton, for the sketches (XV Plates), which accompany the report and which will doubtless be found to be of more value in establishing the identity of species than the written descriptions.

Washington, Pa., Nov. 9, 1888.

Miscellaneous Scientific Intelligence.

1. *Photographic Map of the Normal Solar Spectrum.*—Physicists will be interested in the announcement that a new and greatly improved edition of the map of the solar spectrum by Professor Rowland, extending from the extreme ultra violet down to and including B to wave-length 6950, is now ready. There are ten plates, lettered from *a* to *j*, each 3×2 feet and containing two strips of the spectrum. Of these ten, all are ready except the first, from wave-length 3350 to the extremity of the spectrum; the work on this may be accomplished this summer and it will be sold as an extra plate. The charge for single plates is $2.50 and for the set of nine (*b* to *j*) $18.00. Subscribers to the old edition will have the preference in the delivery of the new one and a reduction of 10 per cent in the price. The three plates *h*, *i*, *j*, to complete their set, will be furnished for $6.00, or the four, *g*, *h*, *i*, *j* for $8.00.

There are also two plates, each 3×2 feet, suitable for framing of the B and D lines, the latter 3 inches apart and the former having an extent of about 24 inches. Enlargements of some of the carbon bands from the arc electric light have also been made, these bands containing many hundred lines, each one of which is a close double or, in some cases, a triple. These plates will be sold for $2.25 unmounted or $2.50 mounted on cloth.

All subscriptions and orders should be sent and remittances (by draft, or money order) made to the *Publication Agency of the Johns Hopkins University, Baltimore, Md.*

2. *Temperature record at Hilo, Hawaii.*—The following table gives a digest of the thermometric observations made at the United States Consulate Agency at Hilo on Hawaii, by Mr. Charles Furneaux, between April 1 and November 8, 1888. The temperatures are given in the record for each day and from these the means for successive periods of ten days were deduced.

April.	7 a. m.	2 p. m.	7 p. m.	August.	7 a. m.	2 p. m.	7 p. m.
1—10	69	74½	72	1—10	73	80	74
11—20	70	78	71½	11—29	74	81	76
21—30	71	81	75	21—31	73½	81	76
May.				September.			
1—10	70	78	73½	1—10	73	83	76
11—20	72	79	75	11—20	72	82	77½
21—31	74	79	75	21—30	73	82	78
June.				October.			
1—10	73	81	76	1—10	72	82	78
11—20	74	82	76	11—20	72	79½	75
21—30	74	80	76	21—31	71	78	74
July.				November.			
1—10	73	80	76	1— 8	70	78	73
11—20	74	80	76	9—20	71	79½	75
21—31	74	80	76	21—30	71	77	73

December, 1–10, 11–20, 21–31; 69, 77, 72; 68, 76½, 71½; 68, 78, 71.

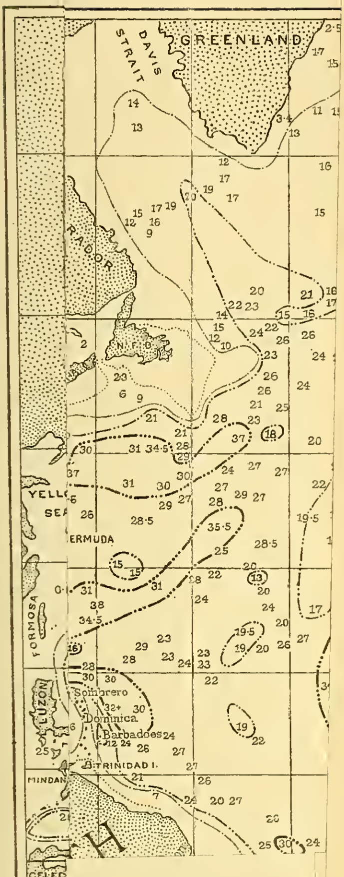
3. *A short Account of the History of Mathematics;* by WALTER W. ROUSE BALL. 8°, pp. xxxiii, 464, 1888, Macmillan & Co.—Mr. Ball has given us a very readable history and the work is well done. As a general outline history it is a decided advance upon anything we have in the English language. The earlier history especially is well given. There are inherent difficulties when he comes near to the present time, and it is not surprising that Mr. Ball has not entirely overcome them even to his own satisfaction. Something like a defect in perspective is evident in the final chapters. Thus three lines to Grassman and a page to Hamilton will not, we think, be the proportionate space given to the two men in the pages of a history written a century hence. To something like the same cause may be attributed the statements (pp. 413, 414) that Felix Klein is now Professor at Berlin, Otto Hesse Professor at Heidelberg, and that Camille Jordon died in 1878. The persistent misspelling of Bernoulli is so common to other writers as to be easily excused in Mr. Ball's pages. We find only one American name in the book. Among the many excellencies of the book is its admirable index.

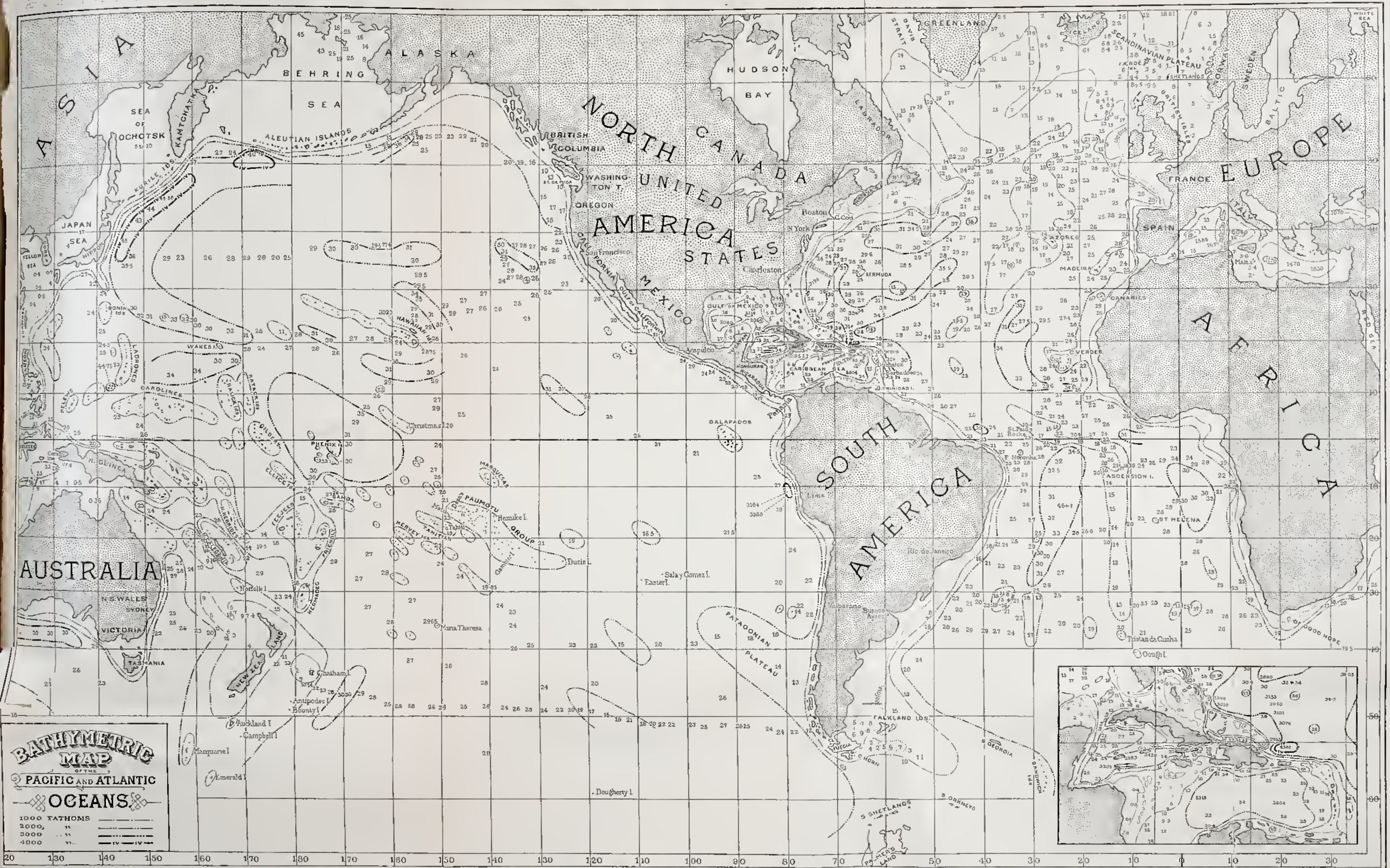
4. *The National Geographic Magazine.* Vol. I, No. 1, 98 pp. Washington, 1889.—The "National Geographic Society" was organized in January, 1888, "to increase and diffuse geographic knowledge," and this magazine now appears as the organ of the Society and to aid in the accomplishment of its aims. It is expected that, though issued at irregular intervals at first, the numbers will later appear periodically. The magazine opens most auspiciously in attractive form with a number of valuable papers liberally illustrated. These include the address of the president, Mr. Gardiner G. Hubbard, and also the following: Geographic methods in geologic investigation, by Wm. M. Davis; classification of geographic forms by genesis, by W. J. McGee; the great storm of March 11–14, 1888, by A. W. Greeley and Everett Hayden, with four folded plates; the survey of the coast, by H. G. Ogden; the survey and map of Massachusetts, by Henry Gannett. The proceedings of the Society, by-laws, list of members, etc., close the number. The subjects with which the new Society has to deal are such as will interest and appeal to a large number of persons, and it is to be hoped that it will meet with the hearty support and coöperation which it merits.

Many readers will regret the method too rigidly adhered to of cutting down the adjectives ending in *ical* to a common "*ic*," thus depriving the language in a number of cases of the distinction of meaning which the use of the two independent forms now allows. A *Geologic* society or association is well exemplified in the early Tertiary association of fishes in the Green River basin; a Microscopic society, in the Richmond Infusorial stratum. Magazines may be Microscopical, Geological, Geographical, but not Microscopic, Geologic or Geographic.

5. *Bathymetric Map, Plate VII.*—After the preceding paper was printed, I received a communication from Marshall McDonald, Commissioner of the U. S. Fish Commission, dated February 12, in which he mentioned the very interesting fact that the Albatross, of the Fish Commission, has proved the extension of the deep depression south of the eastern part of the Aleutian Islands to a distance westward of about 400 miles. In crossing it a depth was obtained, in Lat. 52° 20′ N. and Long. 165° 00′ W., of 3820 fathoms. The trough was found to be 30 miles wide. In 52° 18′ N. and 163° 54′ W., the depth found was 2848 fathoms, in 52° 20′ N., 166° 05′ W., 2654 in 52° 40′ N., 166° 35′ W., 2267 fathoms, in 52° 53′ N., 166° 44′ W., 1961 fathoms. The direction obtained for the deep trough was S. 65° W. The conclusion is stated that "The soundings revealed a depression only" and not a continuation of the trough "to the Tuscarora's soundings of 4037 fathoms off Attou." J. D. D.

6. *Soaps and Candles.* Edited by JAMES CAMERON, F.I.C. 306 pp. 12mo. Philadelphia, 1888.—This little volume presents in compact form a large amount of information upon a subject of much interest in applied chemistry. It forms one of a series of technological handbooks based upon articles in Cooley's Cyclopedia.


GREENLAND
DAVIS STRAIT
N.F.D.
Sombrero
Dominica
Barbadoes
TRINIDAD I.
FORMOSA
LUZON


BATHYMETRIC MAP
OF THE
PACIFIC AND ATLANTIC
OCEANS
1000 FATHOMS
2000 "
3000 "
4000 "
ASIA
EUROPE
AFRICA
NORTH AMERICA
SOUTH AMERICA
AUSTRALIA
ALASKA
BEHRING SEA
SEA OF OCHOTSK
KAMTCHATKA
ALEUTIAN ISLANDS
KURILE IDS.
JAPAN SEA
NIPPON
BRITISH COLUMBIA
WASHINGTON T.
OREGON
CALIFORNIA
MEXICO
GULF OF CALIFORNIA
GULF OF MEXICO
UNITED STATES
CANADA
HUDSON BAY
LABRADOR
DAVIS STRAIT
GREENLAND
ICELAND
SCANDINAVIAN PLATEAU
SHETLANDS
NORWAY
SWEDEN
BALTIC
BRITISH ISLES
FRANCE
SPAIN
ITALY
AZORES
MADEIRA
CANARIES
VERDE
ASCENSION I.
ST HELENA
Tristan da Cunha
GOOD HOPE
RED SEA
Boston
N.York
Charleston
San Francisco
Acapulco
BERMUDA
CARIBBEAN SEA
HONDURAS
NICARAGUA
Panama
TRINIDAD I.
Barbados
GALAPAGOS
Lima
Rio de Janeiro
Valparaiso
Buenos Ayres
PATAGONIAN PLATEAU
FALKLAND IDS.
C. HORN
GEORGIA
SANDWICH
S. ORKNEYS
S. SHETLANDS
PALMER'S LAND
Gough I.
HAWAIIAN IS.
CAROLINES
LADRONES
BONIN IDS.
WAKE I.
PHENIX IS.
MARQUESAS
PAUMOTU GROUP
Christmas I.
Tahiti
Henderson I.
Ducie I.
Easter I.
Sala y Gomez I.
Dougherty I.
Maria Theresa
Chatham I.
Antipodes I.
Bounty I.
Auckland I.
Campbell I.
Macquarie I.
Emerald I.
Norfolk I.
NEW ZEALAND
KERMADEC
N. GUINEA
N.S. WALES
SYDNEY
VICTORIA
TASMANIA
YELLOW SEA
SAMOA
FEEJEES
HERVEY IS.
TAHITIAN
NEW HEBRIDES
NEW CALEDONIA
ELLICE IS.
GILBERT IS.
PELEWS
130
140
150
160
170
180
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150
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120
110
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WALCOTT,

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THE

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[THIRD SERIES.]

Art. XXVII.—*Contributions to Meteorology;* by Elias Loomis, Professor of Natural Philosophy in Yale University. Twenty-third paper.

[Read before the National Academy of Sciences, Nov. 14, 1888.]

Relation of rain-areas to areas of high and low pressure.

1. In former papers (Nos. 6, 7, 12, 17 and 18) I have investigated the circumstances attending remarkable rain-falls both in the United States and Europe, and obtained some important results. Since the publication of those papers, the materials suited to this inquiry have greatly increased, and I have revised the investigation, availing myself of all the materials within my reach. The published volumes of Signal Service tri-daily observations embrace a period of 41 months, whereas when I prepared papers 6 and 7, only 15 months' observations had been published. The observations of 41 months show 106 cases in which there was a rain-fall of at least two inches in eight hours, at some station east of the Rocky Mountains, and North of the parallel of 36 degrees. These cases were distributed by seasons as follows: Winter, 7; Spring, 14; Summer, 53; and Autumn, 32; which shows that great rains occur most frequently during that period of the year in which the atmosphere contains the greatest amount of vapor.

Great rain-falls occur much more frequently near the Atlantic coast, than they do at interior stations. Of the 106 cases compared, 60 occurred on or near the Atlantic coast, and 46 at the interior stations. As there were numerous changes in the stations during the period of the observations, the ratio of the number of the interior stations to the coast stations was variable; but for the entire period, the former were nearly three times as numerous as the latter; showing that near the Atlantic coast north of Latitude 36°, great rain-falls occur *four* times as frequently as in the interior of the United States, east of the Rocky Mountains.

2. The rain-areas were generally associated with areas of low pressure, and the rain center was generally on the east side of the low center. The number of cases for each of the four quadrants was as follows:

Rain center in the N.E. quadrant,		30	per cent of the whole number.		
S.E.	"	28	"	"	"
N.W.	"	9	"	"	"
S.W.	"	9	"	"	"
The two centers coincident,		24	"	"	"

The greatest rains are generally associated with areas of low pressure of only moderate depression. For the cases which occurred during the winter months, the average height of the barometer at the low center was 29·50 inches; and for the cases which occurred during the summer months, the average height of the barometer at the low center was 29·70 inches. In only one case did the barometer sink as low as 29 inches, although in the United States and Canada the barometer sinks below 29 inches on an average 17 times annually, as indicated by tri-daily observations.

Generally a rain-fall amounting to two inches in eight hours does not last more than eight hours, either at the same station or at any neighboring station. Among the 106 cases compared, there were only five cases in which two inches of rain fell in two successive periods of eight hours at the same station, and there were four other cases in which two inches of rain fell in the succeeding eight hours at a second station so near the first station, that the rain may be presumed to have fallen at this rate uninterruptedly for sixteen hours or more.

3. During the period of 41 months' observations, there were 67 cases in which there was a rain-fall of at least $2\frac{1}{2}$ inches in eight hours at stations east of the Rocky Mountains, and south of the parallel of 36°. These cases were distributed by seasons as follows: Winter, 4; Spring, 9; Summer, 22; and Autumn, 32. The greatest number of cases occurred in the autumn, while north of Lat. 36° the greatest number occurred in summer. South of Lat. 36° the month of greatest frequency is September, while north of Lat. 36° the month of greatest frequency is July, but August shows an almost equal number of cases. The difference therefore in the date of maximum frequency for the northern and southern parts of the United

States, is not very great, and may disappear in a longer series of observations.

These great rain-falls occur somewhat more frequently near the coast of the Atlantic or the Gulf of Mexico than at interior stations. Of the 67 cases compared, 46 occurred on or near the coast, and 21 occurred at interior stations. During the period of these observations, the number of coast stations was somewhat greater than the interior stations, and the average number of great rain-falls at the coast stations was about one-half greater than at interior stations.

The rain center was generally on the east side of the low center, and the number of cases for each of the four quadrants was as follows:

Rain center in the	N.E. quadrant,	34	per cent of the whole number.
	S.E. "	21	" " "
	N.W. "	5	" " "
	S.W. "	18	" " "
The two centers coincident,		22	" " "

The most noticeable difference between these results and those for the northern portion of the United States is a less number of cases in the S.E. quadrant, and a greater number in the S.W. quadrant. This difference may perhaps be ascribed to the fact that in the southern portion of the United States, the Gulf of Mexico is an important source of the vapor which is precipitated, while in the northern portion, the Atlantic Ocean affords the principal supply.

Among the 67 cases under examination, there is only one case in which two and a half inches of rain fell in two successive periods of eight hours at the same station, and there are three other cases in which two and a half inches fell in a second period of eight hours at a station near the first. Thus we see that while heavy rains are of more frequent occurrence in the southern part of the United States than they are in the northern part, they have a less period of duration.

The depression of the barometer accompanying great rain-falls is not very great, the average pressure at the low center being 29·63 inches for that part of the United States north of Lat. 36°; and 29·77 inches for that part of the United States south of Lat. 36°.

4. In order to show what effect is produced upon the rain-fall by an extraordinary depression of the barometer, I have examined all the cases in which the barometer fell below 29 inches, at any station in the United States or Canada, during the period from September, 1872, to June, 1884. The number of such cases is 131, and the average rain-fall in 24 hours at all these stations was 1·58 inches, and the greatest rain-fall at any of the stations was 4·32 inches. At 38 of the stations the

rain-fall exceeded two inches, and at 34 stations the rain-fall was less than one inch. In all of the cases in which the rain-fall did not amount to one inch in 24 hours at any of the stations, the center of low pressure was over the Atlantic Ocean, or very near the coast. In these cases the eastern segment of the low area was over the Atlantic Ocean where the amount of the precipitation could not be measured; and we have found that the greatest rain-fall almost invariably occurs in this eastern segment. When the low center was over the interior of the continent, the average rain-fall at the principal rain centers was 2·48 inches; so that it seems reasonable to conclude that if we had observations from all parts of each of the 131 low areas, the average rain-fall for the principal rain centers would not be less than two and a half inches in 24 hours. Even this amount does not seem very large in comparison with the rain-fall accompanying an average depression of 29·63 inches; and we seem forced to conclude that a moderate depression of the barometer is as favorable to great rain-fall as an extremely great depression. This may appear to indicate that rain-fall has but little connection with barometric depressions. It should, however, be remembered that the depression at the center of a low area depends not merely upon the barometric gradient, but upon the geographical extent of the low area. If at the center of a low area having a diameter of 1000 miles, the depression of the barometer is one-half inch below the mean, at the center of a low area having a diameter of 2000 miles, with the same barometric gradient, the depression would be an entire inch below the mean. In the United States, when the barometer sinks below 29 inches, the average diameter of the areas of low pressure is 2140 miles; but when the lowest isobar is 29·5 inches, the average diameter of the low areas is 1185 miles; which shows that when the barometer is most depressed, the average barometric gradient is but little greater than it is with a moderate depression. Extreme depressions of the barometer are generally due to an unusual geographical extent of the low areas, and it appears that great rain-falls depend upon the barometric gradient more than they do upon the geographical extent of the low areas.

5. I next examined those cases in which the total rain-fall for all the stations was uncommonly great. From September, 1872, to November, 1873, I selected those cases in which the total rain-fall at all the stations east of the Rocky Mountains, amounted to at least nine inches in eight hours; from December, 1873, to January, 1875, I selected those cases in which the total rain-fall amounted to at least ten inches in eight hours; from January, 1877, to June, 1877, eleven inches; and from July, 1877, to December, 1877, twelve inches in eight hours.

This change in the amount of rain-fall adopted as the standard was rendered necessary by the gradually increased number of the stations of observation.

The number of cases of rain-fall which fulfilled the preceding conditions was 106. The geographical extent of some of these rain areas was remarkable. In ten cases the area of one inch rain fall was at least 500 English miles in length; and in three cases it exceeded 700 miles in length. Frequently the entire rain-area is an oval figure whose length exceeds 1000 miles, and whose breadth exceeds 500 miles.

These 106 cases were distributed by seasons as follows: Winter, 30 cases; Spring, 19; Summer, 15; and Autumn, 42. These great rain areas are thus seen to be most frequent in Autumn, and the month of greatest frequency is November. We have found that excessive rains at single stations are most common from July to September.

6. The directions of the station of greatest rain-fall from the point of minimum pressure were as follows:

Rain center in the S.E. quadrant,	40	per cent	of the	whole number.
N.E. "	37	"	"	"
S.W. "	10	"	"	"
N.W. "	3	"	"	"
Direction nearly South,	4	"	"	"
East,	5	"	"	"
North,	1	"	"	"

We see that the greatest rain-fall generally occurred on that side of the center of low pressure towards which the low area was advancing; that is, the low center moved towards the rain area. In about 60 per cent of the whole number of cases, these two directions were inclined to each other less than 60°. This coincidence would have been more frequent, if the direction of progress of the low centre had been compared with the direction of the greatest rain area, instead of the station of greatest rain-fall; for frequently the station of greatest rain-fall was not included in the greatest rain area. In several of the cases in which the principal rain center was on the west side of the low center, the geographical extent of the rain areas on the east side was greater than that on the west side. This fact seems to indicate that the general movement of the winds depends more upon the geographical extent of the rain areas, than upon the quantity of rain which falls at a single station. In two cases when the rain center was in the northwest quadrant, the center of least pressure moved towards the northwest, which appears to indicate very distinctly the tendency of a low center to incline towards a rain area. When the station of greatest rain-fall was southwest of the center of minimum pressure, the rain-fall on the southwest side accompanied the advance of an area of high pressure, with winds from the northwest quarter supplanting the southerly winds which had preceded. The barometric gradients within the rain areas were small, and the rain-fall in the southwest quadrant had but little influence in determining the general movement of the winds about the low center, because the southerly winds were soon supplanted by the advancing west and northwest winds.

7. There is generally a marked uniformity in the changes of pressure and temperature accompanying the eastward progress of an area of low pressure. In front of the low area the pressure diminishes, and in the rear the pressure increases. For the 106 cases under examination, the average diminution of pressure in eight hours on the front side of the storm was 0·24 inch, and the average increase of pressure on the rear side was 0·12 inch. For different storms, however, those numbers were very unequal. In some of the cases the barometer fell more than half an inch in eight hours in front of the storm, and in one case the barometer fell 0·86 in eight hours. On the other hand there were several cases in which the barometer remained nearly stationary during the eight hours preceding the approach of the low center.

There were four cases in which the rise of the barometer in the rear of the storm exceeded 0·40 inch in eight hours. There were several cases in which for eight hours the barometer was almost entirely stationary in the rear of the storm; and there were two cases in which there was an average diminution of pressure amounting to four or five hundredths of an inch during the eight hours succeeding the passage of the storm's center. These cases, in which the pressure remained nearly stationary for eight hours preceding or following the low center, generally resulted from the interference of a second area of low pressure. When an area of low pressure is preceded by a second area of low pressure, within a distance of a few hundred miles, the fall of the barometer in front of the first low center is generally very small; and when an area of low pressure is followed immediately by a second area of low pressure, the rise of the barometer in the rear of the first low center is generally very small.

8. For the 106 cases under examination, there was an average rise of the thermometer amounting to seven degrees during the twenty-four hours preceding the approach of the low center; and there was an average fall of eight degrees during the succeeding twenty-four hours. These numbers, however, fluctuated from twenty-eight degrees to zero, over a large geographical area, and in individual cases the fluctuations were considerably greater. In a few cases there was a noticeable correspondence between the magnitude of the barometric and thermometric fluctuations attending the progress of a low

center, but generally such a correspondence was not very distinctly marked; the changes of temperature being often due to causes which had but little influence upon the barometer.

9. A single rain-area seldom occurs alone. In 90 per cent of the 106 cases of great rain-fall under examination, there was more than one rain-area east of the Rocky Mountains with at least a half inch rain-fall, and if we include smaller rain areas, the percentage is still greater. In 36 per cent of the whole number of cases, there were at least four rain-areas with not less than a half inch rain-fall; in 9 per cent of the cases there were at least six rain-areas with not less than a half inch rain-fall; and in one case (Sept. 11.3, 1872), there were eight rain-areas all of which exceeded a half inch. These facts suggest the idea that those conditions which are favorable to rain-fall at one locality, are generally favorable to rain-fall over a much larger district. Extensive rains frequently result from an unstable condition of the atmosphere, in consequence of which the stratum of air near the earth's surface tends to ascend. This unstable condition may result from a temperature above the mean for the given time and place, and it may also result from the presence of an unusual amount of aqueous vapor. These conditions of unusual heat and unusual humidity often prevail simultaneously over an area several hundred miles in diameter. Over such a region the entire stratum of air near the earth's surface tends to ascend. A general ascent of the air over a large area is impossible, but some local cause may determine an upward movement at some point in this area, and the surrounding air will be drawn in to supply the place of the air which ascends. The vapor of the ascending air will be cooled by elevation, and be precipitated, and thus may commence a shower which under favorable conditions will increase and continue for several hours. When this unstable condition of the air prevails over a large area, there may be more than one point where such an ascending current is formed, and thus we may have several rain-areas prevailing simultaneously within a few hundred miles of each other.

Rain-areas, with a total rain-fall of 6 or 7 inches in eight hours for all the stations east of the Rocky Mountains, seldom continue for more than 24 hours; only five such cases having been found in a period of 41 months, and there were only six cases in which the rain-center continued at the same station for a period of 16 hours. These facts seem to indicate that the causes which produce rain do not derive increased force from the rain-fall for an indefinite period of time, but after a few hours they expend themselves and become exhausted.

10. The preceding examination of great rain-storms seems to warrant some generalizations respecting the conditions favorable for rain-fall.

A. One of the most common causes of rain is an unstable condition of the atmosphere resulting from an unusually high temperature combined with unusual humidity. This condition of the atmosphere is most frequently found where the barometric pressure is somewhat below the mean, although it sometimes extends beyond the isobar of 30 inches. It is most frequently found in the eastern segment of the low area, and is generally accompanied by easterly or southerly winds.

B. Another very common cause of rain, and one which is frequently associated with the former, is a cold northerly or westerly wind in the western segment of the low area. This cold wind pushes under the warm and humid wind which prevails in the eastern segment of the low area, and lifts it up from the earth's surface to such a height, that a considerable portion of its vapor is condensed. Frequently there is direct evidence that the westerly winds in the rear of a storm are merely surface winds, and that the southeast winds which prevailed in front of the storm extended to the rear occupying a stratum of considerable elevation. It is generally difficult to obtain evidence of the direction of the upper stratum of air, while a rain-storm is prevailing at the surface of the earth; but occasionally there are breaks in the lower stratum of clouds which enable us to observe the movement of the upper clouds. The observations on Mt. Washington afford us at all times the means of comparing the winds at low stations with the winds at the height of 6000 feet. We frequently find that the latter winds are from the south or southeast, while the surface winds are from the north or west.

C. Proximity to the ocean or to a large inland sea is favorable to rain-fall. We have seen that heavy rains are more frequent near the coast of the Atlantic ocean and the Gulf of Mexico, than they are at interior stations.

The following facts seem well established:

D. No great barometric depression with steep gradients ever occurs without considerable rain. This is true not only for the United States, but also for the cyclones of the West Indies, for those of the China sea, of India and the Bay of Bengal.

E. In great rain-storms the barometric pressure generally diminishes, while the rain-fall increases.

F. The greatest depression of the barometer generally occurs about twelve hours after the greatest rain-fall.

G. A great fall of rain is favorable to a rapid progress of the center of least pressure, while a small rain-fall is generally attended by a less rapid progress. It is, however, plain that the rate of progress of a low center depends partly upon other causes than the amount of rain-fall.

11. In my 7th paper I have shown that considerable depres-

sions of the barometer sometimes occur without rain, or at most with very little rain. This result is confirmed by 41 months of Signal Service tri-daily observations, which furnish 130 cases in which the total rain-fall, at all the stations east of the Rocky Mountains, was less than one-tenth of an inch in 8 hours. For a period of 40 hours from October 19.3 to 21.1, 1872, the total rain-fall, at all the stations east of the Rocky Mountains, was only 0·11 inch. An area of low pressure prevailed throughout the northwest, and the barometer at St. Paul fell to 29·57. The temperature at LaCrosse rose 27° above the normal. Throughout this low area not a drop of rain was reported during these 40 hours. For a period of 32 hours from May 6.3 to May 7.3, 1874, the total rain-fall at all the stations east of the Rocky Mountains was only 0·07 inch. The barometer at Fort Sully fell to 29·44, and the temperature rose 22° above the normal. From May 6.1 to May 8.3, a period of 72 hours, the rain-fall within the area of low pressure was only 0·09 inch. It may be said that these cases of low pressure generally occurred in that region where the stations of observation are widely separated, and that rain may have fallen at intermediate points where there was no observer. The long continuance of the rainless condition, in the cases just mentioned, is pretty conclusive evidence that the fall of rain must have been very slight over the entire area of low pressure. The month of October, 1872, was one of unusual drought throughout the whole of the northwestern part of the United States. During the first 27 days of the month, no rain fell at St. Paul, there was only 0·02 inch at Fort Sully, and only 0·09 inch at Omaha. From Feb. 8.2 to 10.3, 1877, a period of 64 hours, the total rain-fall at all the stations east of the Rocky Mountains was only 0·62 inch. An area of low pressure prevailed throughout the northwestern part of the United States (Bar. 29·51 at Bismark), and within this low area not a drop of rain was reported during these 64 hours. The thermometer at St. Paul rose 23° above the normal.

12. These examples are sufficient to show that in the northwestern part of the United States (east of the Rocky Mountains) there are sometimes formed areas of low pressure having great geographical extent, and accompanied by an amount of rain which is extremely small. Throughout nearly the whole extent of these low areas the average temperature was above the normal, and in the neighborhood of the low center it was 20° above the normal. We cannot ascribe this unusual temperature to the heat developed in the condensation of aqueous vapor. We must ascribe it to the direct effect of the sun's rays acting upon the sandy soil of the northwestern plains. These low areas in the northwest were all attended by an area

of high pressure on the east or southeast side, where the average height of the barometer was 30·36 inches. This high temperature over the northwestern plains, combined with an area of high pressure on the east or southeast side, is sufficient to cause a general movement of the surrounding air towards the heated region. The Signal Service maps are too limited in extent to show what were the atmospheric conditions on the north and west sides of the low area; but we must conclude that the colder air from the north would press down to displace the warmer air of the low area. Thus we find all the forces requisite to generate a cyclonic movement of the winds about the center of the heated region. The heat of the central area is continually recruited by the direct action of the sun's rays, and thus the cyclonic movement of the low area may be maintained for a long time, while the steady pressure of the air on the western side (arising from the same causes which determine the average system of circulation of the winds) fills up the low area on its western side, and thus crowds the low area slowly eastward.

13. If areas of low pressure of great geographical extent may be formed and maintained for several days with very little rain, is there no difference between the low areas which are attended by a heavy rain-fall, and those which are attended by very little rain? Differences do exist and generally they are strongly marked. The following are some of them:

Characteristics of areas of low pressure.

With excessive rain-fall.	With little or no rain.
a. Steep barometric gradients.	*a.* Feeble barometric gradients.
b. Violent winds.	*b.* Moderate winds.
c. Rapid changes of barometric pressure.	*c.* Slow changes of barometric pressure.
d. Rapid progressive movement.	*d.* Slow progressive movement.

These are the characteristics of an area of low pressure which stands alone, uninfluenced by the proximity of a second area of low pressure. When two areas of low pressure are formed near each other, their movements are often very complicated.

14. In my eighteenth paper, I investigated the relation of rain-fall to barometric pressure in Europe, as shown by the observations contained in the International Bulletin. A more extensive comparison of observations has led to conclusions differing but little from those stated in my former paper.

If we could have similar observations of the rain-fall over all parts of the Atlantic Ocean, they would be of great value in determining the influence of rain-fall upon barometric pressure. As such observations have never been made, I have sought for the best available information bearing upon this question.

This I have derived from the Atlantic Weather Charts from Aug. 1, 1882, to Sept. 3, 1883, published under the authority of the British Meteorological Council. These maps show for each day the region where showers prevailed and where rain prevailed. I have selected all the cases in which there is marked upon these maps a rain area more than 600 English statute miles in length, omitting the tropical regions. The number of these cases is 375. In order to exhibit more clearly the character of the results, I have divided the cases into seven groups. Group **A** contains 29 cases in which the center of the rain area coincided nearly with a center of low pressure; group **B** contains 161 cases in which the rain was associated with an area of low pressure, chiefly on its eastern side; group **C** contains 46 cases in which the rain center was almost exactly north or south of a center of low pressure; group **D** contains 54 cases in which the rain was associated with an area of low pressure chiefly on its western side; group **E** contains 25 cases in which the rain was partly over an area of low pressure, and partly over an area of high pressure, being about equally divided between them; group **F** contains 22 cases in which the rain-fall was accompanied by a barometric pressure above 30 inches, and the rain area was situated between two areas of high pressure; and group **G** contains 38 cases in which the rain fell chiefly over an area of high pressure, and was not distinguished by the peculiarity of group **F**.

15. These great rain areas are found in all months of the year. The distribution by seasons is as follows: Winter, 74; Spring, 128; Summer, 78; and Autumn, 78; showing that over the North Atlantic Ocean, great rains occur most frequently in the spring of the year, especially in the month of March.

These rain areas sometimes have very great extent, there being 120 cases in which the rain area was at least 1000 English statute miles in length; 29 cases in which it was at least 1500 miles in length; 8 cases in which it was at least 2000 miles in length; and 5 cases in which the rain area was over 2500 miles in length.

The number of rain areas associated with areas of low pressure, chiefly on the eastern side (group **B**) is 161; and the number chiefly on the western side (group **D**) is 54. The former number is three times the latter. If, however, in this comparison we include group **A**, and consider half of these cases as situated on the east side of the low center, and the other half on the west side, we shall have on the east side 176 cases and on the west side 68 cases; which numbers are in the ratio of 2·6 to 1.

16. Rain, with barometric pressure somewhat above 30 inches,

is unexpectedly prevalent over the Atlantic Ocean; there being 38 cases in which the rain center was associated with a pressure above 30 inches; 17 cases in which the rain center was associated with a pressure above 30·1 inches; and 5 cases in which the rain center was associated with a pressure above 30·2 inches, the highest being 30·4 inches. There were also 25 cases (group **E**) in which the rain was about equally divided between areas of high and low pressure. Similar cases sometimes occur in the United States, where great rain areas frequently extend somewhat beyond the isobar 30 inches.

Two-thirds of the cases included in group **G** were so near to the Gulf Stream that this stream may be presumed to have had an important influence on the rain-fall. The five cases in which the rain center was associated with a pressure exceeding 30·2 inches were all near the Gulf Stream, and appear to have been similar to cases in the United States.

We see that over the Atlantic Ocean the air does not always descend from the upper regions over every part of an area of high pressure. Over some portion of an area of high pressure, the air frequently ascends; and this appears to take place when the air contains an unusual amount of aqueous vapor.

17. A comparison of the results now obtained suggests some important conclusions respecting the influence of local causes in modifying the relation of rain-fall to barometric pressure. We have found that in the United States, east of the Rocky Mountains,—

1. South of Lat. 36°, a rain-fall of 2½ inches in 8 hours at any station occurs on the east side of a low area more frequently than on the west side, in the ratio of 2·6 to 1.

2. North of Lat. 36°, a rain-fall of 2 inches in 8 hours at any station occurs on the east side of a low area more frequently than on the west side, in the ratio of 2·8 to 1.

3. A total rain-fall of 9 inches in 8 hours at all the stations east of the Rocky Mountains occurs on the east side of a low area more frequently than on the west side, in the ratio of 6·2 to 1.

4. Over the North Atlantic Ocean great rain areas occur on the east side of an area of low pressure more frequently than on the west side, in the ratio of 2·6 to 1.

5. In Europe a rain-fall of 2½ inches in 24 hours at any station occurs on the east side of a low area more frequently than on the west side, in the ratio of 2·0 to 1.

These results indicate that in the United States and Europe, as well as over the North Atlantic Ocean, great rain-falls are generally associated with a barometric pressure somewhat below the mean, and the precipitation occurs chiefly on the eastern side of a low area. We notice, however, considerable discordances which may be partly due to the different modes of comparison which have been adopted. In *No. 1* a center of low pressure was compared with the station of greatest rain-fall when the rain-fall amounted to at least 2½ inches in 8 hours. In *No. 2* a center of low pressure was compared with the station of greatest rain-fall, when the rain-fall amounted to at least 2 inches in 8 hours. In *No. 5* a center of low pressure was compared with the station of greatest rain-fall, when the rain-fall amounted to at least 2½ inches in 24 hours. In *No. 3* a center of low pressure was compared with the station of greatest rain-fall, when the total rain-fall at all the stations east of the Rocky Mountains was unusually great. In *No. 4* the amount of rain-fall is entirely unknown, but the center of a great rain area was compared with the center of a neighboring area of low pressure.

The principal discordances in the preceding results cannot be ascribed to the different modes of comparison adopted, but must be due to some other cause. The great excess of rain centers on the east side of the low center in *No. 3* may reasonably be ascribed to the influence of the Atlantic Ocean with its Gulf Stream, furnishing an inexhaustible supply of vapor; and the comparatively small number of rain centers on the east side of the low center in Europe may be ascribed to the influence of the dry air in the interior of the continent.

18. The preceding results have been derived from a comparison of rain-falls of unusual magnitude. It is not safe to conclude that the same results would be derived from a comparison of the aggregate rain-fall for an entire year at each station, since small rain-falls may be subject to a law somewhat different from those of extraordinary magnitude. There is another mode of comparison which takes account of the total rain-fall at any station. Generally on the preceding side (which is usually on the eastern side) of a low center, the barometer is falling, and on the following side (which is usually the western side) the barometer is rising. The mode of comparison consists in determining the total amount of rain which comes during a year with a falling barometer, and also that which comes with a rising barometer, and finding the ratio of these two amounts.

19. In my 12th paper I gave the results of this mode of comparison derived from the best materials which I was able to obtain. More recently I have extended the comparison to Pawlowsk near St. Petersburg; to Brussels for an entire year; to Aberdeen for two years; and I have included the observations of two years at Indianapolis, Indiana. These last observations were derived from the Signal Service, the rain being measured three times a day. The time of least pressure was

determined from the tri-daily weather maps, and the rain was accordingly distributed under the two heads of falling and rising barometer. This method cannot give accurate results, but may furnish useful information in the absence of hourly observations. By grouping together those stations which seem most intimately related, we obtain the following results, showing the ratio of the amount of precipitation which comes with a falling barometer, compared with that which comes with a rising barometer.

Indianapolis, Ind.,	ratio,	1·32 to 1
Philadelphia, Penn.,	"	2·88 to 1
Seven British stations,	"	2·08 to 1
Paris and Brussels,	"	1·19 to 1
Pawlowsk, Russia,	"	1·06 to 1
Prague and Vienna,	"	0·80 to 1

20. These results exhibit a remarkable accordance, and indicate the operation of a general cause. They are similar to those previously stated, but are much more definite. At Philadelphia the amount of rain which falls while the barometer is descending is nearly three times as great as that which falls while the barometer is rising; and during the six colder months of the year, the rain-fall in the former case is nearly five times as great as in the latter case. In summer, thunder showers frequently occur with an abundant fall of rain accompanied by a slight rise of the barometer, and at such times there is more rain with a rising than with a falling barometer. The entire Atlantic coast of the United States, North of Lat. 36°, exhibits results similar to those found for Philadelphia.

As we proceed westward from the Atlantic coast, the ratio of the precipitation when the barometer is falling, compared with that when the barometer is rising, changes somewhat rapidly, and before we reach the Mississippi River the ratio is reduced to 1·32. These results indicate that the great excess of rain on the eastern side of areas of low pressure near the Atlantic coast is due to the fact that on the eastern side they have the Gulf Stream, which furnishes an inexhaustible supply of vapor.

In Great Britain the amount of rain with a falling barometer is twice that with a rising barometer; but as we proceed eastward this ratio diminishes rapidly, and in Central Europe the precipitation is greater when the barometer is rising, than when the barometer is falling. This result is due to the fact that in Central Europe, areas of low pressure have a comparatively dry air on their eastern side, and there is a more liberal supply of vapor on the western than on the eastern side. Hence we conclude that the amount of rain-fall on the eastern side of an area of low pressure depends largely upon the direction and distance of the principal supply of aqueous vapor.

ART. XXVIII.—*The Sensitive Flame as a means of Research*; by W. LECONTE STEVENS.

A LITTLE over thirty years ago the discovery was published in this Journal* that under certain conditions a naked flame of illuminating gas may become sensitive to sonorous vibrations. Nine years elapsed before any development grew out of this acquisition to science. In 1867, Mr. W. F. Barrett, who was at that time an assistant in the laboratory of the Royal Institution, published his independent discovery of the sensitiveness of flame; and the use of the manometric flame, in the hands of Rudolph Koenig, was subsequently developed with great skill for the analysis of compound tones. The use of Professor Barrett's flame has become widely known, especially through the familiar volume of lectures on Sound by Professor Tyndall. Govi in Italy, Barry in England, and Geyer in America independently discovered the method of securing a sensitive flame, with no pressure higher than that of the ordinary street mains, by causing air to mingle with the gas after it issues from the nozzle, and allowing the mixture to burn after passing through wire gauze While this flame may be made exquisitely sensitive, it is not so convenient in practice as the high pressure flame of Professor Barrett. It is well known that these flames are usually sensitive only to sounds of high pitch, and through a limited range of pitch, this range becoming generally narrower with increase of sensitiveness. During the last few years Lord Rayleigh has used the sensitive flame with signal success in studying certain analogies between sound and light. His interesting lecture on "Diffraction of Sound," delivered a little over a year ago before the Royal Institution,† served as my starting point; and I am further indebted to him for special instructions without which I should perhaps not have succeeded in performing satisfactorily all the experiments mentioned in his lecture. As this lecture has not thus far been re-published in America, a brief resumé of it may possibly be acceptable.

Waves of light are so short that special precautions are needed to exhibit the phenomena of diffraction. Light emanating from a point and interrupted by an obstacle produces a shadow that may be regarded for all practical purposes as geometric. Waves of audible sound, on the contrary, are so long that when an obstacle is interposed the effect of diffraction masks that of radial propagation, and hence it is not usually

* On the influence of Musical Sounds upon the Flame of a jet of Coal-gas. By John LeConte. This Journal, January, 1858.

† Proceedings of the Royal Institution of Great Britain, Jan. 20, 1888.

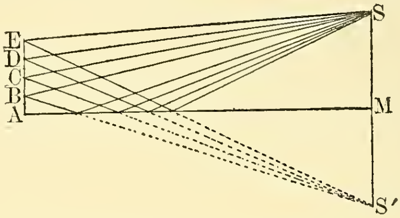
easy to make a sound shadow manifest. The difficulty in sound is not to produce diffraction but rather to limit it by using the shortest wave-lengths possible. The pitch employed by Lord Rayleigh was more than 20,000 vibrations per second, corresponding to a wave-length of less than two-thirds of an inch. To measure this the waves are reflected from a surface arranged vertically across the direction of propagation, thus producing interference with the direct waves. The position of the nodes and ventral segments is determined by moving the reflector toward or from a sensitive flame interposed between it and the source of sound. The flame flares in a ventral segment and burns quietly at a node. The distance between two points of quiescence is a half wave-length, from which the pitch is readily computed. Knowing the wave-length, if this be small in comparison with the diameter of an obstacle such as a disk, it is possible to calculate the deflection necessary for the meeting of secondary waves behind it, from its opposite edges, in order to produce a maximum or minimum of intensity. In this way, as much as eight or nine years ago, Lord Rayleigh repeated acoustically the celebrated experiment suggested by Poisson to Fresnel, and first performed by Arago, by which a bright point was found at the middle of the shadow of a small disk. Applying the formula for Huygens's zones, an acoustic diffraction grating was made by which sound was converged to a focus, as if by a lens, the flaring of the flame at this focus being very violent. Around it, according to theory, there should be several successive rings of motion and quiescence, or, in other words, of noise and silence. The first ring of noise, and the rings of silence that precede and follow it, are detected without difficulty by means of the sensitive flame.

All of these experiments by Lord Rayleigh have been repeated by me. The source of sound used is Galton's adjustable whistle, through which a blast is sent from a cylinder of compressed air or oxygen. The sensitive flame is fed from a similar cylinder of compressed coal gas, the pressure of the supply being carefully regulated in each case by means of a water manometer gauge. The whistle is capable of giving a pitch as high as 18,000 or 20,000, but as this limit is approached the intensity becomes too much diminished, and practically the best pitch it yields is about 13,000 vibrations per second. Lord Rayleigh's whistle is slightly different in construction, and probably better than the Galton whistle. But there is no difficulty in attaining good results with this pitch. The greatest practical difficulty is that of keeping the sensitiveness of the flame exactly right, the slightest variation of pressure making it inconstant, and causing it to give misleading indications when the attempt is made to apply it to purposes of measurement.

I have attempted by means of the whistle and flame to verify acoustically the experiment in light first performed by Grimaldi and analyzed by Dr. Thomas Young, that of producing diffraction bands by transmitting waves in the same phase through two small openings, and exploring the air with the sensitive flame for the hyperbolic lines of maximum and minimum motion. The whistle, giving forth waves 1·05 inch in length, was placed 34 inches from the screen of cardboard, whose width was two feet. Near the middle of this were cut two vertical slits, 3 inches apart, and each $\frac{1}{4}$ inch wide. The position required by theory for the hyperbolic bands was determined, the screen being at right angles to the direction of the whistle from its middle point. The middle line of maximum motion behind the screen was detected without difficulty. It was discontinuous, as might be expected when the wave length is so considerable in comparison with the distance between the apertures. The nearest hyperbolas on the two sides of this were found in their right position, and traced back rather more than a foot from the screen, but they were not so well defined as the middle line. The next pair of hyperbolas was also found, but with poor definition. By using slits a half-inch in width results were perhaps a little better, though in neither case could any measurements approximate to exactness.

Fresnel's celebrated experiment of producing interference bands by reflection of light from two mirrors inclined at an angle of nearly 180° was tried by Professor A. M. Mayer and myself conjointly, using sound waves. A large plate of glass was rested on the table, and another plate inclined to it at an angle of 152°, the whistle being 67 inches from the flame, 4 inches from the inclined mirror, and 13 inches above the table. Six interference bands were detected by means of the flame, their mean distance apart being 4 inches. By subsequent calculation this result was found correct to within a tenth of an inch. An important source of uncertainty, however, in this experiment arises from the waves proceeding directly from whistle to flame. Even if a screen is interposed, enough space has to be left below it to allow for the passage of sound rays reflected from the two mirrors. From the lower edge of the screen, therefore, waves are diffracted and may interfere with either or both sets of waves reflected from the mirrors. The trouble from this source caused the abandonment of this plan of experiment.

A modification of the Fresnel experiment is that of using but a single mirror, which may be rested horizontally on the table, and allowing the waves reflected from it to interfere with those radiated directly from the whistle. The effect is obviously the same as if they proceeded from two sources, but interference bands can be produced on only one side of the median line. In the accompanying diagram AM is the plane of the mirror, S the source of sound, and S′ the virtual source from which the reflected waves may be regarded as coming. Let the nozzle from which the flame issues be placed first at A and then lifted vertically. The flame will flare at the points B, C, D, etc., whose distances respectively from S and S′ differ by an even number of half wave-lengths. Midway between A



and B, B and C, etc., are points of complete interference where the flame should burn quietly. The distance AB is approximately equal to $\frac{AM}{SS'}\lambda$. The accompanying table gives a comparison between the results of theory and experiment, in which the height of the whistle above the table, MS, is 10 inches; the distance AM is 36 inches, and the wave length, λ, is 1·05 inch. The successive measurements are of distances above the table at which the flame became quiescent. The first column is calculated from the formula; the others are the records from five sets of experiments.

Theory.	I	II	III	IV	V
·945	·9	1·0	·9	1·0	1·0
2·835	2·8	2.7	2·7	2·8	2·9
4·725	4·7	4·6	4·7	4·9	4·7
6·615	6·7	6·7	6 7	6 9	6·7
8·505	8.9	9·0	8·8	9 0	9·1
10·395	11·0	11·3	11.0	11·2	11·3
12·285	....	13 6	....	13·6	13·6

The sensitive flame is not applicable for purposes of exact measurement, as these experiments show; but it is much more nearly so than has been generally supposed. Without its aid there would have been no possibility of establishing these important analogies between light and sound.

Art. XXIX.—*The Denver Tertiary Formation*;* by Whitman Cross.

Introduction.

It is the desire of the writer to present in the following article a succinct account of a newly recognized Tertiary Formation, which, while of very limited geographical extent, yet possesses characteristics of special importance in several directions. The points of interest to be brought out may be grouped as follows:

1. The Formation in question occupies a portion of the area about the city of Denver, Colorado, hitherto assigned to the Laramie Cretaceous.

2. The conglomerates and sandstones of the Formation are chiefly made up of materials derived from a great variety of andesitic lavas of whose outpouring and destruction alike there is no other record now known.

3. The celebrated fossil-plant beds of Table Mountain, at Golden, belong to the Denver Formation,—hence the taxonomic value which has been given to this rich flora must be considered subject to revision.

4. The vertebrate remains are of individual importance and also present some very remarkable associations, which are apparently in direct conflict with all past observations.

It must be assumed in this notice that the reader is already more or less familiar with the geological structure of the belt where the stratified rocks of the Great Plains abut against the Archæan foothills of the Rocky Mountains. Especially in Colorado has this band been repeatedly studied and described in well-known publications, by members of the Hayden and of other Government surveys.

The principal feature of the region in question is a sharp folding of the sedimentary rocks, in general parallel to the line of contact with the Archæan, so that the larger streams issuing from the mountains expose in their banks more or less extensive sections of vertical or of steeply dipping strata, which soon assume a horizontal position under the plains.

At Golden, twelve miles due west of Denver, the section is, from local causes, exceptionally thin, so that the horizontal beds of Table Mountain, protected by a basalt sheet, approach to within four thousand feet of the Archæan foothills. Midway in this interval stand the vertical coal beds at the base of

* Published with the permission of the Director of the U. S. Geological Survey.

what is now commonly called the Laramie Group. Numerous fossil leaves have been obtained in these vertical coal-measure rocks, but they have been found much more abundantly in the horizontal strata of Table Mountain, and although the intervening space is largely obscured by surface deposits, the plants of the two horizons have always been treated collectively, by both geologists and palæontologists, as coming from a single Formation, however that may have been designated. Among those who have described the vicinity of Golden, with more or less detail concerning the strata under consideration, may be mentioned: John L. LeConte, F. V. Hayden, Leo Lesquereux, A. R. Marvine, C. A. White, and Lester F. Ward.*

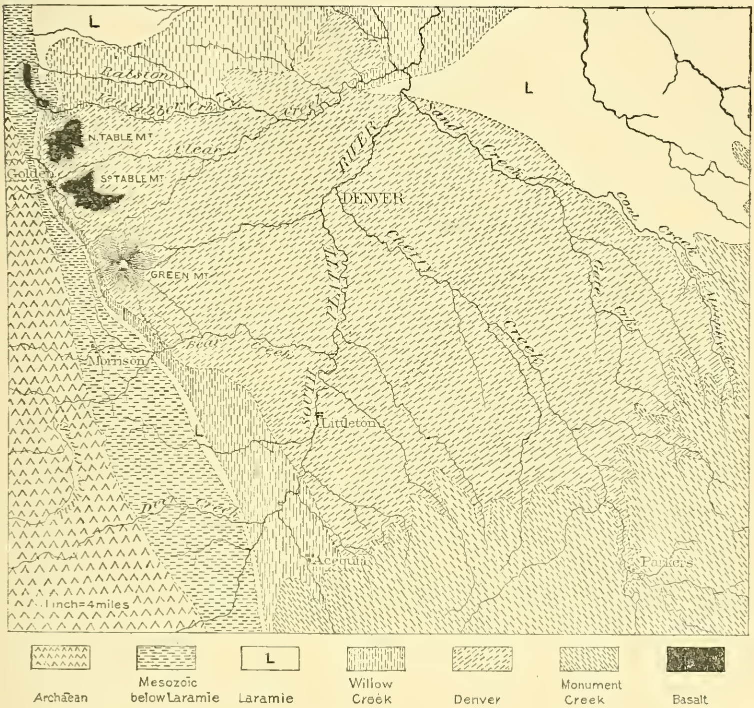
In the summer of 1881 the writer first observed that the Table Mountain strata possessed characteristics proving them to belong to a series distinct from the normal Laramie. In the course of the field-work preliminary to a report upon the geology of the Denver Coal Basin, under the direction of Mr. S. F. Emmons, of the U. S. Geological Survey, it was found that the beds of Table Mountain belonged to a series occupying a Tertiary basin extending eastward underneath and beyond the city of Denver,—whence the name here applied. It was further shown, by Mr. George H. Eldridge, my colleague in this work, that there existed another distinct Tertiary Formation between the Denver and the Laramie, provisionally called by him the "Willow Creek beds." Mr. Eldridge has moreover identified this lower Tertiary Formation even at Golden, in the gap between the coal beds and Table Mountain.

This article can only treat of the more important facts peculiar to, or best exhibited by, the beds in question, and broader or more local relationships must be left for the final report.

A preliminary statement of the most important results of this investigation was made in two papers read before the Colorado Scientific Society, July 2, 1888, by Mr. Eldridge and the writer. Aside from the identification of the two Tertiary Formations, many important observations were made by Mr.

* J. L. LeConte.—"Notes on the Geology of the Survey for the extension of the Union Pacific Railway, from Smoky Hill River, Kansas, to the Rio Grande." Phila., 1868, p. 51. F. V. Hayden.—Second Annual Report, U. S. G. & G. S., 1868, p. 135; Third Annual Report U. S. G. & G. S., 1869, p. 35; Bulletin 4, Second Series, U. S. G. & G. S., p. 215; Sixth Annual Report, U. S. G. & G. S., 1872, p. 328. Leo Lesquereux.—Monographs of the U. S. G. & G. S., vol. vii, "The Tertiary Flora," 1878; vol. viii, "The Cretaceous and Tertiary Floras," 1883. A. R. Marvine.—Seventh Annual Report, U. S. G. & G. S., 1873, pp. 109, 130. C. A. White.—Eleventh Annual Report, U. S. G. & G. S., 1877, p. 192. L. F. Ward.—"Synopsis of the Flora of the Laramie Group." Extract from the Sixth Annual Report of the Director, U. S. Geological Survey, Wash., 1886, p. 537. "Types of the Laramie Flora." Bulletin 37, U. S. Geological Survey. Wash., 1887.

Eldridge in studying the older groups. These two papers were published in full in the "Mining Industry" of Denver, July 13, 20, 27 and August 3 and 10, 1888. The monograph on the Denver Coal Basin, by Mr. S. F. Emmons, is now in preparation.



I. Description of the Formation.

The area occupied.—By reference to the accompanying map the surface distribution of the Denver beds may be readily seen. Upon that map the eastern limit of the Archæan rocks marks the line of the foot-hills. In the narrow zone between the Archæan and the Denver area are the upturned strata of the Trias, Jura, Cretaceous, and the Willow Creek Tertiary.

The area of Denver beds represented is somewhat less than 400 square miles. Its western boundary is determined by the upturning of the strata along the great fold and by the subsequent erosion. On the north and northeast the line apparently expresses the original limitations of the basin at this level. To the south and southeast the Denver beds disappear under the horizontal strata of the Monument Creek Tertiary, which are unconformable with all earlier deposits. What the extent of the Denver beds may be in this direction is now unknown, but it is probably not great, for the larger part of the Formation was destroyed prior to the deposition of the Monument Creek.

The important exposures.—The only strata belonging to the Denver beds which are particularly mentioned by earlier investigators are in Table Mountain, at Golden, and while these are truly typical of the Formation their stratigraphical relations are there certainly obscure. In the course of the present work hundreds of out-crops were studied, scattered over the entire area, in the banks of streams, of ditches, and in numerous railroad cuttings. The outcrops of the plains must, however, be interpreted in the light of the more extensive exposures of Table and Green Mountains. In South Table Mountain the lower third of the series is best shown, while one must go to the neighboring Green Mountain for all the higher strata and for a clear exhibition of the stratigraphical relations of the whole.

Green Mountain lies upon the western border of the plains, midway between Golden and Morrison (see map), and is so related to the great fold that the strata at its western base are in vertical position while those of the summit are horizontal, and upon the slope between these points the fold thus indicated is clearly shown. The "mountain" is a bald massive hill, of smooth and gentle slopes, rising 1000 feet above the eastern base, with long rounded ridges on all side but the west. Probably the absence of projecting outcrops explains why it has received so little attention from those who have repeatedly visited Table Mountain.

On the western face of Green Mountain, opposite the summit, upon a minor ridge and in a small ravine below it, is a practically continuous outcrop extending from near the summit down to the base of the steeper slope. Owing to the fold, mentioned above, 900 feet of strata are here exposed in a vertical distance of 500 feet. *These* 900 *feet of Denver beds are not elsewhere preserved.* At the bottom of this section is a very marked dark conglomerate dipping 45° eastward. The 500 feet of fine-grained Denver strata below this conglomerate are but poorly exposed near Green Mountain. They occupy a narrow band between a definite horizon of the Willow Creek beds and the dark conglomerate at the base of the described outcrop.

A second outcrop of great importance is at the southwestern base of Green Mountain, where a ravine cuts diagonally across vertical strata, giving a continuous section from the base of the Denver beds, which is clearly shown, down through the entire thickness of the Willow Creek and Laramie Formations, ending with the coal-bearing basal sandstone of the latter. From this ravine the coal horizon and the characteristic conglomerate of the Willow Creek beds may be traced far in either direction.

These two important outcrops do not seem to have been seen by any of those persons who have previously described this district, yet they contain the keys to the stratigraphy, without which the latter cannot be correctly interpreted.

The numerous outcrops of South Table Mountain, which do not need to be specified, supplement those of Green Mountain to a great degree. Here the peculiar constitution of the Denver beds may be conveniently studied in detail, though the well-preserved fossil leaves which they contain have hitherto received exclusive attention.

Clear Creek has not cut quite deep enough at Golden to reveal the actual base of the Denver beds. This horizon therefore continues westward from Table Mountain until brought to the surface by the great fold. It is only clearly shown at a point west of the State Reform School, in an old railroad cutting which also discloses the Willow Creek conglomerate.

Mechanical constitution.—The section of the Denver strata consists of two very distinct parts, both as regards texture and composition. By careful measurements projected upon a profile line surveyed across Green Mountain, the total thickness of Denver beds there represented is estimated to be 1440 feet. Of this series the upper 525 feet are mainly made up of very coarse conglomerates while the lower 915 feet are as a rule fine-grained strata. The coarse conglomerates and the upper half of the finer-grained beds are preserved only in Green Mountain.

A detailed section of the Denver beds is of little general value because variability in make-up is the preëminent characteristic of the finer-grained division. Yellowish brown friable sandstones prevail, with all manner of gradations into clays or into conglomerates. The transitions appear both laterally and vertically so that it becomes difficult or even impossible to closely correlate strata of isolated exposures occurring at the same general horizon. The conglomerates of the lower division are especially liable to variation, and few of them appear to have more than a local development, yet they are prominent features of almost any extensive outcrop. Few pebbles in these conglomerates exceed three inches in diameter. Cross-bedding and local unconformity between beds of sharply differing constitution are further features of common occurrence.

The heavy conglomerates of the upper division will be referred to later on.

Materials of the Denver strata.—The peculiar composition of the Denver beds was first observed in the dark conglomerates of Table Mountain, which contain only pebbles of andesitic rocks, some porous and some compact. The sandy matrix is merely finer material of the same character and the cementing substance is usually some zeolite (heulandite, stilbite, chabazite, etc.) or yellow calcite. Microscopical examination of the sands and of the sand grains in the clays reveals only particles which, so far as they can be identified, are like the constituents of the andesites seen in pebbles. Augite grains or rough crystals containing glass-inclusions and other characteristic interpositions; plagioclase, hornblende and biotite, with the peculiarities noticed in these minerals as components of the andesites; dull reddish brown grains with imbedded crystals, which clearly represent particles of the andesite rocks more or less decomposed,—all these are found, *the only recognizable mineral constituents of Table Mountain sandstones and clays.*

At the base of the main Green Mountain exposure which has been mentioned is a dark conglomerate, about 25 feet in thickness, dipping 45° eastward. This bed is probably at the horizon—also exhibiting a marked conglomerate—a few feet below the basalt cap of Table Mountain. While tracing out and studying this horizon in Green Mountain three Archæan pebbles were seen,—all others being eruptive and apparently all andesites. The average diameter of the pebbles in this bed is from two to three inches.

Above this conglomerate appear again fine grained sands and clays in an estimated thickness of 285 feet, in which there is no strongly developed pebble bed, though sand layers greatly predominate over clays. This series is like the lower one, almost exclusively made up of andesitic debris.

The fine-grained sediments are abruptly succeeded by a series of very coarse conglomerates or bowlder beds of an estimated thickness of 525 feet. In the first of these coarser beds the pebbles range in size from a diameter of two feet downward, and while eruptive rocks largely predominate there are many of granite or of gneiss and a few of red and white sandstone. The gravelly matrix is largely made up of angular quartz and feldspar grains. A return to fine-grained sediments is quickly followed by bowlder beds which continue to the top of Green Mountain, the average size of the bowlders gradually increasing upward in the series while the amount of eruptive material rapidly decreases and becomes at last quite subordinate. Bowlders of various sedimentary rocks are numerous in these beds, the characteristic Dakota conglomerate being perhaps most prominent among them.

The Denver strata of the plains belong to horizons represented in Table Mountain, i. e., to the lower third of the Formation. A study of numerous exposures shows that the remarkable freedom from non-eruptive materials characterizing the Table Mountain beds does not strictly hold for these equivalent strata. Along the Platte River and to the eastward one can generally detect a small amount of quartz or of red feldspar (microcline) in the more sandy Denver beds, though these substances are lacking in many places, even along Coal Creek, farthest from the foothills. Quartz and red microcline are taken as representing Archæan rocks, directly or indirectly They become prominent in the Denver beds of the plains area only locally and under circumstances which will be considered in another part of this article. As a result of their composition the finer-grained Denver rocks are easily recognizable when one is at all familiar with them. They possess a dull reddish brown color, and while friable and crumbling they resist degrading agencies in a manner peculiar to them. This is due to the admixture of clay with most sands, and to the development of a zeolitic cementing substance derived from the andesite. Tests show that as high as 50 per cent. of some sandy strata are soluble in hydrochloric acid with production of gelatinous silica.

Fossils.—The fossil flora of Table Mountain has been referred to. It is one of the richest yet discovered and has been very fully described. As one of the earliest discoveries in the west it has been an important element in discussing the floras found more recently in other formations. During the present work fossil plants were observed in many places and some collections were made, but so far few species have been found which were not already known in Table Mountain. Good localities might be developed in various places over the entire field.

A very few invertebrate fossils have been found in plant-bearing Denver beds, but they are not of much determinative value.

By far the most important, as well as the most interesting fossils of the Denver beds are the large bones found in several places, which are provisionally referred by Prof. O. C. Marsh to various Cretaceous types of the Dinosauria. A single fossil from the west bank of the Platte River, near Denver, has been described by Prof. Marsh as a new species of *Bison*, and a probable Pliocene age ascribed to the beds containing it.

A consideration of the evidence afforded by these various groups of fossils as bearing upon the age of the Denver Formation shows that these different elements are in conflict with each other and with the stratigraphy. This fact renders necessary an examination as to the relative values to be given to these conflicting evidences. Some results of this examination will be given in the succeeding sections of this article.

II. The Age of the Denver Formation.

Having given a description of the Denver beds and of their occurrence, there arises the problem as to their geological age, —a problem involving in its own solution that of several others of far greater importance. The evidences to be given touching the age of these beds are very conflicting and are plainly not to be brought into harmony until certain elements of that evidence have been subjected to renewed examination by competent hands. It is hoped that the necessity for this revision will be plain from the following discussion.

There are certain facts of primary importance which have been brought out during this investigation, and these facts must be regarded in all future discussions. From these facts certain apparently logical deductions may be drawn, which should be accepted unless the logic is proven faulty.

a. Stratigraphical evidence.

The Denver beds lie between two distinct Formations and the relations to each are definitely known. The upper Formation is of recognized Tertiary age,—the Monument Creek; the lower is the newly recognized Willow Creek Formation, which will be briefly described by some extracts from the article by Mr. Eldridge, which has already been cited.

Description of Willow Creek beds.—"The Formation next succeeding the Laramie in geological order and unconformably resting upon it is the lower of the three Tertiaries that occur in the Denver field, for which the name "Willow Creek" is here suggested, from the locality in the southern part of the field, from one to three miles southeast of the mouth of the Platte Cañon, where it has its greatest and most typical development. It is composed of a basal member of conglomerate or gritty sandstone, according to its distance from the foothills, with an overlying zone of gray, argillaceous or arenaceous shales containing lenticular masses of hard, quartzose sandstone, with an occasional ironstone. Where confined between under-and-over-lying groups, it has a thickness varying between 600 and 1200 feet.

"The conglomerate at its base has a thickness over the greater portion of the field of about 200 feet, though this may become the bulk of the formation, as in its type locality, or may decrease to the merest edge as at its northern limit, along the Platte River, near Brighton. It is extremely characteristic, containing as it does pebbles derived not only from every formation that lies below it in the Denver field, but also from others lying far beyond, especially the Carboniferous, of which the debris affords some excellent specimens of *Beaumontia*, a case parallel to that of the occurrence of Silurian pebbles in the Dakota. Like the pebbles of the Dakota, too, only in a far greater degree, those of this formation have undergone extreme silicification. Jaspers, agates, flints and silicified wood abound, and the debris of the older groups, including the fossiliferous limestone just noted, has often undergone the most complete alteration in this manner. This feature, however, is especially noticeable only in that portion of the formation which, from having been laid down within a comparatively short distance of what was probably the ancient shore line, contains a very large amount of pebbles of the older rocks, and is thus best calculated to show any changes of this kind that may have occurred."

Relation of the Denver to the Willow Creek.—The Denver beds occupy a basin eroded out of the Willow Creek, in the greater part of the area now under discussion. There is thus a general non-conformity between the two deposits, while the details of this relationship may be seen in certain places.

Though the actual contact line of the two Formations is seldom seen, owing to the friable nature of the strata and the prevalence of surface deposits, there is no difficulty in assigning isolated outcrops to the proper series, on lithological grounds which have been explained. The interval between the Denver and Willow Creek epochs will be spoken of in a succeeding section.

Relation of the Denver to the Monument Creek.—As has been stated in the descriptive part, about two thirds of the known thickness of the Denver beds were removed prior to the deposition of the Monument Creek Formation. There is, moreover, no reason to suppose that the upper strata of Green Mountain represent the actual top of the Denver beds, nor can we now determine the former lateral extent of the Formation.

Concerning the length of the time interval between Denver and Monument Creek deposits we have no data.

b. Lithological evidence.

The materials of the Denver beds.—It is a fact of general experience that quartz is usually the most abundant mineral in strata which are made up of the worn debris of older rocks. This position comes to the quartz largely by reason of its superior hardness and the absence of cleavage, properties enabling it to resist attrition better than the other common rock-making minerals. When detritus from areas of the crystalline schists has been the chief element in making up the sediments of adjacent oceans or seas, the relative amount of quartz in the strata formed will depend upon the violence of the destructive agencies and upon the rate and conditions of deposition. Abrasion and attrition or conditions favoring chemical decomposition will destroy the accompanying minerals more rapidly than the quartz and will hence tend to increase the proportion of the latter in resulting sandstones.

These generalizations are illustrated in all the groups of sedimentary formations known at the eastern base of the Mountains, from the Cambrian up to the Denver beds. The fine grained Dakota and Laramie sandstones are almost exclusively made up of quartz. In the Willow Creek grits and sandstones appears a variety of materials mentioned by Mr. Eldridge in the statement already given.

In view of the facts just considered the sudden and almost complete change in constitution which is met with in the Denver beds is certainly worth more than a passing notice. Instead of minerals and rocks derived either directly or indirectly from Archæan sources there is found material resulting from the degradation of a great series of eruptive rocks. It is a fact of much significance too, that for 900 feet of thickness the Denver beds are very fine grained, having been slowly deposited under conditions which have usually brought quartz into relative prominence.

The andesites represented by pebbles and bowlders in the Denver strata are of many different types and the name must be used in its widest sense to cover them. Hornblende or augite-andesites of rather basic composition are the most common types, but more acid varieties, carrying quartz or tridymite, with biotite, are numerous, while at the opposite extreme are hypersthene-bearing andesites of characteristic features. Only andesites have thus far been identified.

There is a variation in texture and structure shown by these andesites which is almost as marked as that in composition:—some are vesicular, many are porphyritic, and others are compact and fine-grained. In the development and in the mutual relations of the mineral constituents of these andesites one accustomed to studying the microscopical physiography of eruptive rocks will see abundant proof of their extrusive character. Some of the denser beds of Table Mountain seem composed of volcanic ashes or of small angular grains belonging to a single rock type. Such material may be called tufa, but the sandstones containing worn particles of various kinds are largely predominant.

It has already been stated that there is some quartz in the sandy strata of the plains and that great bowlders of Archæan and of sedimentary rocks are found in the upper division of the Denver beds.

The sources of materials.—The nature of the rock and mineral substances composing the Denver beds having been stated, it remains to consider their origin in order that the full value of this evidence may be appreciated. Attention is first called to the eruptive rocks, as the predominant material.

The first point in evidence is negative. *There is no known source which can be assigned with plausibility for any one of the many andesitic types represented in the Denver strata.* No andesite masses are known in the mountainous area to the westward as far as the continental divide, though it is admitted that they may exist in local development. The more distant andesitic masses in Middle or South Park cannot be considered, nor a hypothetical transient volcanic vent in the plains area, for neither of these explanations can meet the facts of observation. The problem is a double one, viz: to account for the exclusion of the common materials (quartz, etc.) simultaneously with the appearance of the unusual, and this in a basin adjacent to a mountainous Archæan district.

These considerations have determined the form of the solution to be offered. *The andesitic masses which furnished the materials for the lower part of the Denver sediments were so situated as to effectually prevent the access of all Archæan and sedimentary debris to the lake of that epoch.* That is to say, in the interval between the Willow Creek and Denver epochs there was an outpouring of andesitic lavas completely covering the Archæan and sedimentary rocks of the area afterwards contiguous to the Denver lake. When sedimentation began again only eruptive debris could appear in the deposits until erosion and general degradation had laid bare, here and there, small areas of granite, of gneiss or of sandstone.

The Denver strata contain the record of the destruction of a great series of allied lavas. The nine hundred feet of fine-grained sediments represent a vastly greater amount of rock destroyed, and in the series of coarse bowlder beds is evidence of the practical completion of this work. Then came a return to the surface conditions existing during the Willow Creek epoch.

The other materials of the Denver beds are easily accounted for. In the coarse bowlder beds of Green Mountain both Archæan and earlier sedimentary rocks are very prominent. They were undoubtedly derived from the adjacent western shore after the andesitic covering had been worn through.

A different origin is indicated for the quartz and red feldspar material in the fine-grained strata of the plains. Experience shows these substances to be very local in development and to be most abundant adjoining the northern and southern Willow Creek shore-lines, which were in great degree made up of friable or soft grits and sandstones. The absence of the quartz in strata nearest the mountains shows that it could not have come from that direction.

c. *The Fossil Flora.*

The Golden fossil flora has been fully described and repeatedly discussed in its bearing upon the age of the Laramie formation. Inasmuch, however, as some of the plants came from acknowledged Laramie and others from the Denver strata of Table Mountain, while all have been uniformly referred to the former group, through ignorance of the facts here presented, it seems plain that this fossil evidence cannot be used as a whole in discussing the age either of the Laramie or of the Denver beds. An examination as to the distribution of species in view of new evidence is naturally a matter for the palæobotanist to undertake, but it seems advisable to call attention in this place to certain facts concerning the past discussions of these fossil plants and to their present condition.

The Golden flora as described by Lesquereux.—By far the greater number of the plant remains from Golden have been described by Prof. Leo Lesquereux, originally in the annual reports of the Hayden Survey and afterwards in revised form in the previously cited monograph, "The Tertiary Flora." A few additional species were described in the later monograph, "The Cretaceous and Tertiary Floras." In the former work 95 species from Golden are described, and in the latter 8 others, making a total of 103 species and varieties from this locality.

In the following discussion two varieties of *Ficus planicostata* Lx., are omitted, as is likewise the Cycad species, *Zamiostrobus mirabilis* Lx., the single specimen of which is stated by Lesquereux to have been "found by Dr. F. V. Hayden on the surface soil without connection to any stratum of rock."* Deducting these three there remain just 100 species of fossil plants to be considered, hence many of the numbers to be given express *percentages* of the Golden fossil flora as described by Lesquereux.

An examination of the monographs cited shows that 81 species were originally described by Lesquereux; 59 species are known in the United States only at Golden,—52 of these being new species.

As to the exact geological horizons of the species; three per cent only are definitely stated, under the heading "Habitat," to come from the known coal-measure sandstones, while 13 per cent are said to come from Table Mountain. Through incidental statements as to the horizon it seems plain that 9 per cent came from the acknowledged Laramie and 16 per cent from Table Mountain

* "Tertiary Flora," p. 71.

strata. The writer cannot find any statements from which the horizons of the remaining 75 per cent of the Golden fossil plants can safely be assumed. Forty new species found only at Golden are not assigned to definite horizons.

The original specimens described by Lesquereux have been sent to the U. S. National Museum, where, through the courtesy of Prof. Lester F. Ward, Curator-in-charge of fossil plants, they have been examined by the writer within the past year. The following statements are made with Prof. Ward's permission:

Only 79 species of the Lesquereux collection from Golden could be found, the remainder being temporarily lost sight of in the confusion naturally attending the rapid growth of the Museum in such limited space. The specimens bear numbers, but there are very few labels giving localities, and the Museum catalogue contains no details, the locality "Golden, Colorado," standing for all alike.

Under the circumstances the lithological characteristics of the matrix containing the fossils is the only available means of determining the horizons from which they were obtained. The peculiar yellowish brown sandstones of Table Mountain are clearly distinguishable from the quartzose sandstone of the coal horizon, to anyone acquainted with the rocks, and the following result of an examination as to the matrix is satisfactory to the writer, though it may not be equally so to others.

Of 79 species found, 18 occur in what is judged to be Laramie sandstone or shale, and 59 in distinct Denver beds of Table Mountain, while 7 occur in both rocks, and 9 cases are in doubt. Lesquereux gives horizons for 6 species which were not found. By combining the two sources of information we get probable indications of horizon for 76 per cent of the Golden fossil plants; 22 per cent came from true Laramie strata and 63 per cent from Table Mountain beds; 9 per cent occurring in both formations.*

* After this article was completed the writer received a pamphlet by Prof. Lesquereux entitled:—"Fossil plants collected at Golden, Colorado." (Bulletin 3, vol. xvi, Museum of Comparative Zoölogy at Harvard College, Dec., 1888.) This paper (written in 1884) describes the Golden plants in the Museum at Cambridge, Mass. "They represent 118 species, or vegetable forms considered as species, 28 of which are admitted as new species, ... and 32 as new for the Flora of the Laramie Group, but known from other localities, making therefore for that Flora an addition of 60 species." There is in this paper no mention of a definite horizon or of an exact locality for a single species beyond the statement that they were collected at Golden and came from the Laramie. Prof. Arthur Lakes of Golden, who collected these specimens, has informed the present writer, upon inquiry, that he thinks the plants were all obtained from Table Mountain or Green Mountain, and that "none of them came from the proximity of the lower Coal Measures." If this is true all of these sixty species belong to the Flora of the Denver Formation, and not to the Laramie, as far as known. It is probable that more than sixty of the species from Golden, described by Lesquereux in the "Tertiary Flora" are likewise unknown, as yet, in true Laramie strata.

The work of Professor Ward.—The only recent descriptions of fossil plants from Golden are by Professor Lester F. Ward, who visited Golden in the summer of 1881, before any question as to the horizon of the Table Mountain strata had arisen. In the winter of 1882–83, however, Mr. S. F. Emmons submitted a number of fossil plants from the Denver field to Professor Ward, pointing out the lithological difference between the strata of Table Mountain and those of the Laramie proper, and stating that this marked characteristic was thought to indicate a probable Tertiary age for the former rocks. Professor Ward was requested to examine these specimens as well as his own collections at Golden, with reference to the possibility of distinguishing the two horizons by their plant remains. In an official letter to Mr. Emmons, of date of March 5, 1883, Professor Ward states his inability from the specimens at his disposal to make any important distinctions between the plants of the two horizons.

In his "Types of the Laramie Flora" (of date 1887) Professor Ward gives descriptions (with figures) of but five species from this district. The Denver strata containing plants are called "tufa;" the Laramie, "white sandstone;" but no further reference is made to this distinction. One species, *Ficus Crossii* Ward, came from the Laramie sandstone just below the coal horizon; *Ficus spectabilis* was found in Denver beds dipping 30° eastward, just south of the town of Golden; *Ficus irregularis* and *Berchemia multinervis* came from South Table Mountain; *Cornus Emmonsii* Ward, was found in the city of Denver, and is incorrectly accredited to Golden by Professor Ward. Four of the figured specimens are from Denver beds and but one from the Laramie proper.

Professor Ward's paper, "A Synopsis of the Flora of the Laramie Group" (1886), contains an elaborate table of distribution of Senonian, Laramie and Eocene plants; a discussion of this table; and descriptions of new collections of Laramie plants. In the table of distribution 323 Laramie species are enumerated. Of these, 103 occur at Golden, this flora as described by Lesquereux being inserted with a few omissions.

While describing his own collections, Professor Ward says that "the geology of Golden is very complicated,"* and he increases this complication by introducing a remarkable hypothetical fault,† between Table Mountain and the coal horizon, to explain the proximity of horizontal to vertical strata, in what he treats as a single Formation. Aside from the statement that the sandstone of South Table Mountain is "commonly called tufa"‡ Professor Ward does not, in either of the publications

* "Synopsis," etc., p. 537. † Ibid., p. 538. ‡ Ibid., p. 538.

cited, hint at any peculiarity of the Table Mountain strata, nor does he intimate in any way that they have been or might be regarded by any one as belonging to a series different from the coal-measure beds.

d. The Invertebrate Fossils.

A few invertebrate fossils have been found in the Denver beds, all of them coming from a ravine by St. Luke's Hospital, Highland (a suburb of Denver), where they were found by Mr. T. W. Stanton, in association with fossil leaves and a small tooth of a crocodile. The shells were submitted to Dr. C. A. White, of the U. S. Geological Survey, for determination, who reports as follows concerning them:

"The invertebrate fossils which have been collected from the Denver Formation comprise five species. One of them is a *Unio*, and another is a *Physa*, both too imperfect for specific determination. Another is apparently a *Corbicula*. The other two I have recognized as *Viviparus trochiformis* and *Goniobasis tenuicarinata*, respectively, of Meek and Hayden.

"If these fossils had been submitted to me without any statement of correlated facts, I should have hardly hesitated to assign them to the Laramie Group, because the two last named species are common and widely distributed in that Group and forms similar to the other three are common in that Formation also.

"That *Viviparus trochiformis* and *Goniobasis tenuicarinata* may have survived from the Laramie epoch into that of the Denver Formation is not at all improbable, especially in view of the fact that I found both those species in Utah to have passed up from the Laramie into the Eocene Wahsatch Group.

"The *Unio* and *Physa* are such forms as one might naturally expect to find in such a deposit as is the Denver Formation, which was presumably a purely fresh-water one. In such a deposit, however, one would hardly expect to find a *Corbicula*, but I am not aware of any reason why we may not assume that one of the many forms of that genus which are found in the Laramie Group survived to the Denver epoch in company with the two species mentioned.

"In short, I do not regard these invertebrate fossils as necessarily presenting any evidence against your conclusion that the Denver is a separate Formation from the Laramie."

e. The Vertebrate Fossils.

A number of isolated fossil bones have been found, both in the Willow Creek and in the Denver beds. These have been placed in the hands of Professor O. C. Marsh for identification and description. The fossils have proven very interesting and have raised a number of important problems, for the solution of which the material now available is in many ways inadequate. But there are certain phases of these problems which can be discussed now as well as at any other time.

Professor Marsh recognizes among the bones sent him various parts of the skeletons of turtles, crocodiles, dinosaurs, and of a bison. Specific determinations have not yet been made except in the case of the bison, but the numerous dinosaurian bones clearly indicate the presence of representatives of several types within this order of extinct reptiles. Until the recent discovery of "a new family of horned Dinosauria from the Cretaceous" in Montana,* Professor Marsh was inclined to assign some of the bones from the Denver area to types hitherto known in this country only in the Jura, while other remains seemed to belong to Cretaceous forms. He now considers it probable that some of the Dinosaur bones collected by Mr. Eldridge may be referable to the new family, the Ceratopsidæ.†

It is plain that the occurrence of these various animals in strata later than the Laramie introduces a very puzzling element into the discussion, and the first thing is to prove that they actually belong to the formation in question. The extinction of the Dinosauria in the Cretaceous period has been a doctrine seldom questioned by any authority. If the Dinosaur bones of the Denver beds do not belong there they must have been transported from some earlier formation, and, although unable to conceive of any method by which this transfer could have been accomplished, consistent with the other factors in the case, the writer has been slow in coming to the belief that the Dinosaurian life continued into the Denver epoch. In the paper read before the Colorado Scientific Society, in July last, I stated that it seemed most probable that these Dinosaur bones had been transported from Jurassic or Cretaceous strata to their present resting-place. This opinion has now been entirely changed, and it is firmly believed that the bones found in the Denver beds belong to animals that lived in the epoch in which those beds were deposited. A few facts in support of this belief will be given.

Science is indebted to Mr. George L. Cannon, Jr., of Denver, for several interesting discoveries, the results of a zealous detailed study of the vicinity of the city, continued for a number of years. The greater share of Dinosaurian bones thus far known from the Denver beds have been found by him. In an article read before the Colorado Scientific Society, in October,

* This Journal, Dec., 1888, p. 477.

† Loc. cit., p. 478.

1888,* Mr. Cannon gave a review of the circumstances attending the finding of all Dinosaur bones known to that time in the Denver beds, and drew the conclusion that they must belong to the horizon in which they were found.

The majority of the bones thus far secured were apparently isolated, no adjacent parts of a skeleton being found together, though different parts of the animal are represented. The finds thus indicate skeletons which have been dismembered and the various parts separated, though not very widely. Bones found imbeded in Denver sandstones are never worn, the articulations of ribs and leg bones are sometimes perfect, and delicate surface sculpturing uninjured. The bone matter is soft and could not have withstood transportation under ordinary circumstances. In the strata containing the bones are no pebbles of earlier sedimentary formations, and any agency which could have transported the bones uninjured would have left traces of the rocks from which the bones were derived. The present softness of the bones is not due to decomposition ; on the contrary, the original bone substance seems to be well preserved, for analysis shows eighty per cent of lime, phosphoric acid, and fluorine, in a typical specimen of bone material. It is also observed that fragments washed out of the Denver strata and now found lying in small gullies have been very much worn, even when carried but a few yards.

In the article cited Mr. Cannon also mentioned the finding of various fragments apparently belonging to one animal, in strata of South Table Mountain. He further stated that a number of bones belonging to an herbivorous Dinosaur had been obtained on the eastern slope of Green Mountain within a small area.

On January 7, 1889, Mr. Cannon gave a preliminary account before the Colorado Scientific Society of a quantity of large bones recently exposed by a cloud burst on Green Mountain at the spot where the before-mentioned bones were found. All these bones seem to belong to a large Dinosaur.

These later finds confirm the conclusions reached by study of the isolated bones. Until the new material has been studied by Prof. Marsh the full import of the discovery cannot be known, but it makes it clear that Dinosaurs lived in the Denver epoch.

Discussion of Evidence.

The strata here assigned to the Denver Formation have hitherto been considered as typical Laramie, but solely on account of their plant remains. No other evidence has been

* The Mining Industry, Denver, Nov. 9, 1888.

advanced for referring the horizontal strata of Table Mountain to the same formation with the vertical coal-measure rocks.

Both the Willow Creek and the Denver series lie between undisputed Laramie and a Tertiary Formation, which, though not yet closely studied, has been referred without question to the Miocene. The previous classification of the beds, and the fact that the fossils with a single exception are said to indicate or to require a reference to the Cretaceous, make the first problem to be considered, as follows: Do the Willow Creek and Denver Formations belong to the Laramie Group, or are they of later age?

The character of the evidence in the case has been submitted. The Denver beds are apparently separated from the acknowledged Laramie by a series of intermediate beds with important characteristics, which are visibly unconformable with the Laramie, as are the Denver beds, in turn, with the intermediate Willow Creek. But local unconformities, even greater than the angular ones here seen, may well exist with a great Group like the Laramie, and it is necessary to consider these unconformities in the light of the lithological evidence, before their real significance can be appreciated.

The Willow Creek conglomerate shows pebbles "derived from every Formation below it in the Denver field," and the unconformity here recorded was therefore not a local one within the Laramie, but extended down through almost the entire Mesozoic section. To explain this requires the assumption of a great folding of the strata adjacent to the foothills in the interval preceding the Willow Creek. In a similar manner the materials of the Denver beds testify positively to a period of great volcanic activity in the interval between the Denver and the Willow Creek epochs.

These are the facts of primary importance and the only question which can be raised is as to their interpretation. Whatever fossils have been, or may in future be, found in the Denver strata, the significance of these primary facts cannot be ignored. The claim that the Denver beds are Laramie involves the claim that the events indicated above took place within the Laramie time.

It seems to the writer that if stratigraphy and lithology can give grounds for drawing boundary lines the evidence submitted warrants the separation of the Denver and of the Willow Creek beds from the Laramie, and their reference to the Tertiary.

Above the Denver beds, and unconformable with them, as has been shown, comes the Monument Creek Formation. Hayden gave this name, in 1859, to "a series of variegated sands and arenaceous clays, nearly horizontal, resting on the upturned edges of the older rocks "* and situated on the divide between the waters of the South Platte and of the Arkansas rivers. The strata abut against the Archæan near Palmer Lake (on the Denver and Rio Grande R. R.) and extend out upon the plains an unknown distance. Hayden referred them provisionally to the Miocene, without definite data. Cope subsequently sought for fossils in these beds and as a result is inclined to confirm the assignment of Hayden. Remains of an *Oreodon* type are thought to prove an age later than the Eocene, while the occurrence of *Megaceratops Coloradoensis* indicates pre-Pliocene age.†

The strata here referred to the Monument Creek are plainly connected with the ones originally described by Hayden and no further evidence as to their age can be given.

It is clear that the Monument Creek beds are much later than the Denver beds. The latter have been folded into a vertical position along the line between Golden and Green Mountain, but the Monument Creek strata, as noticed by Hayden,‡ pass to a contact with the Archæan and are but slightly inclined (5°–15°), showing that the interval between the Denver and Monument Creek epochs witnessed important orographical changes. Two-thirds of the Denver beds in the area studied were removed during the interval.

Were it not for the presence of the fossil described by Prof. Marsh as *Bison alticornis*,§ the whole weight of evidence would be in favor of assigning the Willow Creek and Denver Formations—assuming that they are post-Laramie—to the earliest Tertiary possible. On account of this fossil, however, Prof. Marsh has stated that the strata containing it are "probably late Pliocene." But the bison specimen figured by Prof. Marsh was dug out of solid typical Denver sandstone at the same general horizon which has yielded all the other Denver vertebrates yet found. This conflict of evidence is not yet explained.

The preceding discussion has been confined to the evidence gathered in the district studied. A few more general considerations may now be brought out in conclusion.

It can scarcely be said that the reference of the Denver and Willow Creek Formations to the Eocene is opposed to the general doctrines concerning the succession of geologic events at the close of the Mesozoic. The reference is rather in full harmony with those doctrines, for they assume great disturbances at this time, causing nonconformities when sedimenta-

* Annual Report for 1869, pp. 39-42.
† Ann. Rep. U. S. G. & G. S., 1873, p. 430.
‡ Bull. 3, 2d Ser. U. S. G. S. of Ter., 1875, p. 210.
§ Am. Journ. Sci., Oct., 1887, p. 324.

tion began again and volcanic outbreaks are frequently mentioned as characterizing the beginning of the Tertiary Era.

As to the fossil flora, it is well known that Lesquereux and others have referred the entire Laramie Group to the Eocene, or Miocene, from the evidence of fossil plants. It remains a task for competent hands to ascertain whether the Table Mountain plants have influenced opinions as to what constitutes the "typical Laramie Flora," or not,—and to what extent.

The few invertebrate fossils of the Denver beds are declared by Dr. White to have no positive weight against the conclusion adopted.

As to the vertebrate fossils of the Denver strata the Dinosaurian remains certainly present an element of evidence, which, judged by current belief, is strongly opposed to the idea of a Tertiary age for the Formation. The doctrine that the Dinosauria became extinct in the Cretaceous period is generally accepted, yet it has been characterized as a "dogma" by Heer and Lesquereux.* How far is this doctrine supported by a knowledge of the actual conditions which led to the supposed extinction of this interesting group of peculiar animals? Are the facts of experience competent to establish the extinction at the time mentioned, independently of a knowledge of conditions?

The best record of accomplished extinction of the Dinosauria is found in the absence of their remains in the great Eocene Formations of the basin area west of the Rocky Mountains. The causes of this extinction are not as yet known. As Dr. C. A. White pointed out some years ago, "The climate and other physical conditions which were essential to the existence of the Dinosaurians of the Laramie period having evidently been continued into the Tertiary epochs that are represented by the Wasatch, Green River and Bridger Groups, they might, doubtless, have continued their existence through those epochs as well as through the Laramie period but for the irruption of the mammalian hordes to which they probably soon succumbed in the unequal struggle for existence."† That a group of animals with such highly specialized characteristics as are possessed by the Dinosauria could not adapt themselves to sudden changes of environment is no doubt true, but it is an assumption that the orographic movements causing or following the close of the Laramie produced sudden changes of more than local influence. In the Denver strata, whatever their age, is the proof that certain types of Dinosauria did survive the changes of conditions attending a period of folding and another period of great volcanic activity.

* Heer quoted by Lesquereux in "Cretaceous and Tertiary Floras," p. 112.
† Bull. U. S. G. and G. S., vol. iv, No. 4, p. 876.

The geological record of events in Eocene time is very imperfect, especially for the area on the eastern slope of the Rocky Mountains. Even in the Great Basin area the lowest recognized Eocene, the Wasatch, is found to contain a peculiar group of mammals (Coryphodon) and the record contains nothing concerning the development of this type. This argument may well close with the simple suggestion, offered as a possible basis for future discussion, that the Denver and Willow Creek Formations may represent earlier Eocene deposits than are elsewhere known at the present time in the western region.

Eocene deposits with which the Denver beds may be compared are at present unknown. The small interior basin about Florissant, Colorado, situated only sixty miles a little west of south from Denver, has been quite thoroughly described by Professor S. H. Scudder,* and its flora and fauna by Lesquereux, Cope and Scudder. From the very abundant plants, insects and fishes of the Florissant beds it has been supposed that they are equivalent with certain parts of the Green River Eocene, but this reference is not thought fully justified, by Cope.† In his "Cretaceous and Tertiary Floras" Professor Lesquereux describes 152 species of fossil plants from the Florissant beds, and but *one* of these is included in the Golden Flora as described by the same author. Such a difference seems quite remarkable in view of the fact that the Laramie flora has so much in common with various Tertiary horizons.

It is usually assumed by those who have written concerning the Tertiary deposits of the West, that in the Eocene period the plains area east of the Rocky Mountains was almost entirely a continental region, and that no seas or lakes existed there to receive sediments equivalent to those of the Great Basin. This assumption rests, however, on a very imperfect and general knowledge of the district in question. The known destruction of a large part of the Denver beds prior to the Monument Creek epoch suggests that other deposits may have existed which were either entirely destroyed or are now represented by as yet unidentified remnants, corresponding to the Denver and Willow Creek beds.

As an example of our lack of knowledge concerning even the best known regions of the west, may be cited the discovery by Mr. R. C. Hills of 8000 feet of Tertiary strata at the eastern base of the Sangre de Cristo range in the Huerfano river basin of southern Colorado.‡ These strata rest uncomfortably on Laramie and Colorado Cretaceous. They are provisionally

* Bulletin, U. S. G. and G. S., vol. vi, No. 2, p. 279, 1881.

† U. S. G. S. of Ter., vol. iii, Book 1, pp. 3, 10, 1884.

‡ Described in a paper entitled "The recently discovered Tertiary Beds of the Huerfano River Basin, Colorado," read before the Colorado Scientific Society, December 3, 1888. To be published in the Society's "Proceedings" for 1888.

assigned by Mr. Hills to the Eocene though no fossil remains have yet been determined. Above these beds are still others, assigned provisionally to the Pliocene.

The present article is intended to present some facts established in a special work. But the facts have a more or less direct value in considering many of the important problems of Rocky Mountain geology. Some of these questions have been hinted at in discussing the age of the Denver Formation, but a further development of the bearings of the facts stated is a task requiring a wide experience in various fields, and this presentation I gladly leave to my chief, Mr. S. F. Emmons, who will give a broader treatment of the subject in the monograph upon the Denver Basin. My sincere thanks are due to Mr. Emmons for his kindness and courtesy in approving the publication of this article.

Note.—Mr. Eldridge has recently ascertained that the name "Willow Creek" has already been applied to several local Formations in this country, and he has therefore decided to call the Formation between the Laramie and the Denver the *Arapahoe* instead of the *Willow Creek.* This decision was reached too late to allow of correction in the body of the above article. Arapahoe is the name of the county in which the city of Denver is situated, and the beds in question are there very prominently developed.—W. C.

ART. XXX.—*Events in North American Cretaceous History illustrated in the Arkansas-Texas Division of the Southwestern Region of the United States;** by ROBT. T. HILL.

DURING the last two years the writer has been permitted by the joint effort of Dr. John C. Branner, State Geologist of Arkansas, and the Director of the United States Geological Survey to investigate the stratigraphic and paleontologic conditions of the northern and eastern termination of the Texas Cretaceous, and to trace out its detailed relations to those of the Gulf and western states with their accompanying phenomena. The condition of knowledge previous to that time was fully set forth in this Journal for October, 1887. From later investigations I am able to present the following brief

* The southwestern region of the United States may be defined in stratigraphic terms as those portions of Arkansas, Texas, Indian Territory, southern Kansas, New Mexico and Arizona, south of the Uinta and Ozark uplifts and between the Sierras on the west and the great Atlantic timber belt on the east. Its principal divisions are the Arizona-Utah or Grand Cañon; the Rocky Mountain or New Mexican; the West Texan or Permo-Triassic; the Central Texas Paleozoic: and the eastern or Arkansas-Texas Cretaceous division lying between the last and the western borders of the Tertiary strata of the Mississippi embayment, as laid down upon Hitchcock's Geological Map of the United States.

sketch of the principal historical events recorded in their formations, and also a preliminary section which approximately outlines the Cretaceous history of the United States east of the Sierras.

Continental limitations at the beginning of the Cretaceous.

Early in these investigations it became apparent that the marine sedimentation of both divisions of the Cretaceous section had been limited on the north by an older continental shore line which must be defined before the subsequent history could be traced. The present remnant of this ancient shore line in the whole Neozoic history of the region was found to be a more or less connected orographic system, with a score of local names, which extends from the Ouachita river in the vicinity of Malvern and Hot Springs, Arkansas, almost due west through Indian Territory into the Panhandle of Texas. The remnant of this mountain system consists of some of the highest and most sharply defined ridges above the surrounding plain in America, as in western Arkansas, south of the Arkansas river, or again of strings of small knobs, as in the Potato hills of Indian Territory; but whatever their name or shape, it is every where evident that they are the now greatly degraded remnants of a series of nearly vertical folds which once constituted a continuous mountain system which was elevated at the close of the Paleozoic.

The former extent of this system can not be stated, for its present eastern termination was truncated abruptly and obscured by late Cretaceous and Tertiary deposits of the Mississippi embayment, while its western continuation is buried beneath Permian, Cretaceous and Quaternary sediments of the Texas Panhandle and obliterated by the later uplifts of the Rocky Mountain regions. The exact stratigraphic relations of this system to the Paleozoic area of Central Texas have not been determined, except that the latter's eastern margin presents a succession of sediments similar to those of the former, and its western border records an early Mesozoic history not seen along its eastern.* It is also evident that it was completely covered by sediments during the two great subsidences in Cretaceous time, while the eastern half at least of the Arkansas Indian Territory system remained above sea-level until present time.

* The western border of this Central Paleozoic region, which presents an entirely different system of strata from the eastern, will be treated in another paper.

The first Epoch of Subsidence.

Along the southern border of these mountains from the Little Missouri in Arkansas westward to the 98th meridian, thence southward to the Brazos along the eastern border of the Central Texas Paleozoic region, can be seen, resting with a slight dip upon the highly disturbed Carboniferous rocks and beneath the more calcareous chalky sediments of the Fredricksburg Division of the Comanche series, a littoral formation which marks the beginning of Cretaceous history in the region and whose beds, as far as the writer knows, are the oldest undoubted Cretaceous in the United States, except what are perhaps its eastward continuation, the Tuscaloosa and Potomac formations of Alabama and Maryland. This formation, as seen in its typical exposures along the Murfreesboro-Ultima Thule road in Arkansas, is composed of several hundred feet of variegated sands and clays, resembling in color the Potomac formations as seen in the railroad cuts at Baltimore, and, in addition, then fissile layers of shell-bearing limestone and great beds of gypsum and lignites, associated with a vertebrate and molluscan brackish-water fauna, which, notwithstanding our prejudices against trans-oceanic correlations, is unmistakably identical in general lithologic and stratigraphic features with the Purbeck and Wealden of England and Germany. This fauna, in addition to a profuse and unstudied flora, consists of Dinosauridæ and brackish water Mollusca including millions of individuals of a few species such as Corbiculidæ, Viviparus, *Ostrea Franklini* of Coquand and the undoubted *Pleurocera strombiformis* Schloth., so characteristic of the Wealden of Europe and not before found in America. These fossils with a single Ammonite are all indicative of its Wealden or transitional Jura-Cretacic age. West of the Paleozoic area of Central Texas, the writer has found only the sediments of this formation, but not its fossils. Its eastern termination is covered by the Upper Cretaceous and Quaternary. South of the Brazos, as at Austin, its position is occupied by a great deep marine chalk formation, now metamorphosed into hardest marble, which has strong Jurassic affinities. The Trinity formation, as it has been named, can be directly seen underlying the more calcareous and deeper marine beds of the Comanche series at many places, and clearly marks the interior shore line of the oldest American Cretaceous, as well as the beginning of a great subsidence which initiated that epoch and gradually covered the whole of the Texas Paleozoic area. How far the waters of the Atlantic extended southward and westward is yet unknown. Its northern limit was the unnamed mountain system above mentioned; for none of the lower (Fredricksburg) sediments of this division of the Cretaceous have until recently been found north of it. [Since this paper has been prepared for press, Prof. Crogin has noted the occurrence of rocks which belong, in my opinion, to the undoubted Comanche Series and probably the Trinity.] This subsidence, which has been overlooked in previous geological history, was profound and long continued. The evidence of its depth is recorded in the rocks and fossils of the Comanche series, which throughout consist of a deep infra-littoral deposit of chalk with and without flints, impure chalk and chalk marls often hardened into limestone, uniformly extending over wide areas and gradually succeeding the littoral Trinity beds. The thickness of these sediments increases southward, sometimes reaching 2000 feet. At Austin they are over 1500 feet. The evidence of a greater subsidence southward and absence of sediments northward indicate a continental condition in the latter region during Jurassic time and the possible continuation of deep sea conditions during that period in southern Texas and northern Mexico—a possibility which, as will be shown in another article, may be a fact, as indicated by an undescribed system of rocks in those regions.

The long continuation of this subsidence is well shown by its fauna. First, by the remarkable uniformity in the distribution of its successive horizons. The fauna of the Washita limestone horizon, in the section at the close of this paper, is almost identical at El Paso and at the Arkansas-Choctaw line, some 900 miles apart. The horizon of the remarkable and unique Exogyra arietina clays extends from Indian Territory to Presidio del Norte nearly 500 miles, with no perceptible variations in the outcrops. The long continuation of this subsidence is also shown by the gradual change which the species, a large number of which are identical with European Cretaceous forms, underwent without sedimental break. The species of Echinodermata, Ostreidæ, Gasteropoda, etc., of the Fredricksburg division are replaced in the Upper or Washita limestone by other forms of the same or allied genera, so similar in some predominant feature and at the same time so specifically different as to clearly show a line of progressive evolution in this epoch.* The time of this subsidence, as shown by paleontological evidence was Neocomian and Middle Cretaceous. It is also shown from its absence that this subsidence was not so extensive along the margins of the Appalachian regions. In fact, there is some circumstantial evidence that its northern shore limit, a portion of which is preserved to us in the Arkansas-Indian Territory orographic remnant, must have continued eastward without deflecting northward,

* The writer has in press a complete revision of the species of this division which will contain further mention of this fact.

as shown by the phenomenal outcrops in the salines of Louisiana and on the island of Jamaica.*

The Comanche epoch of subsidence was closed by the great elevation of an extensive land area of which little is as yet known, except that it must have endured a length of time sufficient for the complete modification of species, for not one of those of the Comanche series has thus far been found to pass upward into the later beds of America, although one or two are found in Europe. The records of this elevation are two-fold. First, an unmistakable and omnipresent unconformity between its beds and those of the succeeding Upper Cretaceous—the Meek and Hayden section of the northwest and its Atlantic coast equivalents. Second, the littoral conditions indicated by the land flora of the Dakota sandstone which must have been deposited along its shore line, marking the next great epoch to be described. This unconformity is seen not only in the absolute lack of parallelism in beds and the complete lithologic and faunal changes, but also in the fact that the same basal horizons of the Upper Cretaceous rest at different places, owing to unequal erosion, upon different horizons of the eroded surface of the lower Comanche series. The elevation at the close of the Comanche epoch is also illustrated by the disturbances recorded in the strata of southwestern Texas as shown in the following trans-section of the Austin-New Braunfels unconformity at Austin, the Upper Cretaceous series resting unconformably upon the greatly disturbed strata of the lower. The Comanche series are here greatly faulted along the fold of what could be appropriately termed the most eastward of the series of American monoclines and which marks the first plateau, the eastern margin of which continues westward to the Rio Grande. This elevation evidently took place before the beginning of the Upper Cretaceous.

* The peculiar occurrence of Cretaceous limestone in certain salines of Louisiana, some two hundred miles coastward from the main area of the Cretaceous exposures, was noted by Dr. Eugene W. Hilgard in various publications, but before the presence of any marine beds, except the Upper of the Cretaceous system, had been admitted in this country. Some two years ago, Judge Lawrence C. Johnson of the U. S. Geological Survey showed the writer some specimens of the material recently collected from these "Cretaceous Islands." They were found to be both lithologically and paleontologically identical with the marine Cretaceous of the Comanche series of the west Central Texas. The nearest outcrop of the main area of the formation is at Cerro Gordo, Arkansas, on the Choctaw line, and all the area intervening is covered by Quaternary deposits. Why these islands should occur along this Cretaceous "backbone" of Louisiana as Hilgard has termed it, can only be explained upon the hypothesis that there exists in that vicinity some ancient and as yet undescribed disturbance. Another datum which adds interest to this inquiry is the fact that upon the island of Jamaica, as personal observers and the reports of the Geological Survey of Great Britain have led me to believe, there are also Cretaceous rocks of the same horizon, directly in the strike of the Louisiana outcrops. In view of these facts, the investigation of Cuba is awaited with much interest, for it is probable that these outcrops were once continuous.

The second Epoch of Subsidence.

Following this mid-Cretaceous land epoch there was another profound subsidence. This epoch may be said to include geographically, stratigraphically, and paleontologically what was lately known as all of American Cretaceous history and which with slight modifications in correlation, is the section of Meek and Hayden and includes all the Upper Cretaceous of the Northwest, New Jersey and Alabama, except the basal, Tuscaloosa and Potomac beds, in the two latter regions. The paleontologic and sedimental sequence is continuous. In all these regions the grand development of the Lower Cretaceous strata of the Comanche series is missing, and the upper division rests either unconformably upon the basal littorals, equivalents of the Trinity beds, as in New Jersey and Alabama, or upon the pre-Cretaceous rocks of the mid-Cretaceous continent, as in the northwest. In Texas, however, this Upper Cretaceous system, which attains an even greater development

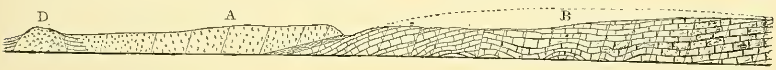


Fig. 1. Section across the Austin-New Braunfels unconformity, Travis county, Texas, showing disturbances at close of Upper (A) and lower Cretaceous (B), and unconformity between these systems. Basaltic extrusion (Pilot Knob) at D.

than in the typical "Nebraska" region, rests every where unconformably upon the Comanche series. The unbroken succession of the formations of this Upper Cretaceous, recorded both in Texas and the northwest by its sediments, is as follows:—(1) sands, (2) clays, shales changing upward into calcareous shales, (3) chalk, (4) chalk marls, (5) sandy marls, (6) sands with littoral fossils indicating a period of slow prolonged subsidence and gradual emergence.

This was the most profound submergence in all Mesozoic time, the Atlantic ocean having extended continuously, as shown by the remarkable identity of sediments similarly situated in relation to the shore line and by its fossils, from British America southward around the Appalachian continent. Its history is similar to that of the lower division—a long continued and gradual submergence, the sedimentation of which is marked by an immense chalk* deposit followed by a gradual transition upward without break into arenaceous littorals.

* The question of chalk in the North American Cretaceous is fully discussed in my report on the Geology of Southwestern Arkansas. It is sufficient to say that in sections of this basal Upper Cretaceous chalk, kindly prepared by Mr. J. S. Diller of the U. S. Geological Survey, were found almost a repetition of the foraminifera of the European Upper Cretaceous chalks.

Disturbances and Differentiation at the close of the American Cretaceous.

The uniformity of the littoral fauna at the close of the Upper Cretaceous is shown by a comparison of the species of the Ripley, Navarro and Pierre-Fox Hills beds. This similarity is in remarkable contrast with the great differentiation which followed it; for at the close of the Cretaceous, that emergence so well known to American geologists took place, which lifted the western interior region permanently above oceanic invasions. That the southern trans-Mississippi Gulf-Cretaceous was also slightly lifted above sea level is shown by a slight but unmistakable unconformity found in Arkansas, at Elmo, Texas, and elsewhere between the beds of these periods. The oldest littoral beds of the marine Tertiary (Lignitic), which are mostly composed of sediments derived from the soft strata of the underlying Cretaceous, are distinguishable from them only by a slight non-conformity sometimes accompanied by a thin sub-stratum of siliceous pebbles. This unconformity is made more certain, however, by the recent discovery of unmistakable paleontologic evidence. As in the case of the mid-Cretaceous non-conformity, the basal Tertiary rests upon different horizons of the Upper Cretaceous, owing to inequalities in its erosions. In Texas, southwest of Bastrop and Austin to the Sabinas river in Mexico, for a distance of 300 miles, there is a more conspicuous and unmistakable sign of the disturbances at the close of the Cretaceous than this unconformity, and this is an elevation accompanied by a line of many basaltic outbursts* in close proximity to, but not immediately connecting with the line of elevation along the Austin-New Braunfels unconformity above mentioned, which seems to have been a line of weakness since Jurassic times. The basaltic outcrops occur at no less than fifty places in a line from near Yegua Hills in Bastrop County southwest via Hays, Kendall, Bandera, Kerr, Nueces and Val Verde counties to the Santa Rosa mountains in Mexico. Pilot Knob, seven miles southwest of Austin, is a typical example. This is a small dome-shaped protuberance of columnar basalt rising through the Upper Cretaceous chalks which surround it on all sides and producing in them a quaquaversal dip of ten degrees, and metamorphosing them into saccharoidal marble at the contacts. In decomposing, the basalt becomes amygdaloidal and zeolitic. The whole exposure has the appearance of a truncated laccolite. Throughout the whole region, as seen in fig. 1, there are other evidences of the presence of these igneous rocks beneath, as seen in the dome-like disturbances and meta-

* Conjointly with Mr. E. T. Dumble, the writer will publish at an early day, a paper upon this remarkable igneous area.

morphism. It is evident that the extrusions took place at or after the close of the Cretaceous, and probably belong in the same category with similar phenomena reported at Rockwall in north Texas, in the Chickasaw Nation, and in Arkansas.

Post-Cretaceous events which have concealed Cretaceous history.

The inequalities between the two great formations of the Cretaceous have been greatly obliterated by subsequent history, as illustrated in the following section along the Arkansas-Choctaw line, across Little and Red rivers, wherein can be seen the leveling and concealment produced by an early Quaternary subsidence, which has also worn away much of the mountains.

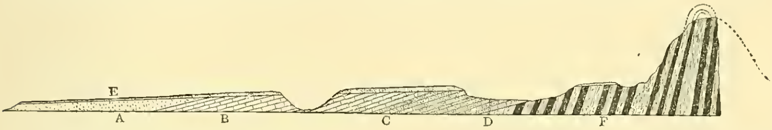


Fig. 2. Section forty miles in length north and south, along the Arkansas-Choctaw line showing the sequence of the Cretaceous formations, their relation to the Paleozoic Mountain axis F, and their post-Tertiary degradation by the Quaternary subsidence E. Upper Cretaceous, A; Comanche series, B; Trinity formation, C; Intrusive dike, D.

The whole Cretaceous history, as seen in the region of its most typical sediments, can be summed up as two profound subsidences, separated by a land epoch. These have left in their sediments two great chalk formations, as shown in the following table. The history of these subsidences has hitherto been confused owing to the fact that the littorals of one of them in regions favorable for study have been mistaken for the whole. Although each of the faunas and sediments of the two formations represents an unbroken series, I have mentioned for each horizon distinguishing species of Ammonites, Ostrea and Echinoderms.

University of Texas, March 7, 1889.

Events.		EPOCHS.		Distinguishing Fossils.	Prevailing Sediments.	Thickness W. Texas.
V. V. Tertiary Land EPOCH.						
IV. Second profound Marine Subsidence.	UPPER CRETACEOUS. Continuous sediments.	*Northwest U. S.*	*Texas.*		Sedimentation unbroken.	
		1 { Fox Hills-Pierre.	Navarro beds. Exogyra ponderosa Marls.	Am. placentaceras. O. vesicularis. O. costata. Cassidulus aequoreus.	Calcareous sands. Marly elays.	[1]1000
		2 Niobrara.	Austin-Dallas Chalk.	Inocerami. Nautilus.* Radiolites Austinensis. Hemieidaris Texanus Roem.	Chalk marls. Chalk gradating upward into next.	[2] 600
		3 Benton.	Eagleford Shales. (fish beds).	Scaphites, fish teeth. Inocerami.	Clay shales becoming more calcareous upward.	[3] 300
		4 Dakota.	Lower Cross-Timber beds.	Leaf imprints. Few easts.	Sands, Lignites, ete.	[4] 200
III. Mid-Cretaceous Land EPOCH.						2100
II. First Profound Marine Subsidence.	LOWER AND MIDDLE CRETACEOUS. Continuous sediments.	*Washita Division.*				
		Denison beds		O. crenulimargo Roem	Alternations of clay, lime and sand	100
		Vola, or red ehalk Limestone		Vola quinquecostata Sow. and undescribed fauna	Massive lime bed with oxidizing iron	50
		Exogyra Arietina elays		Exogyra arietina Roem	Calcareous, green clay shales	100
		Washita limestone		G. Pitcheri, var. Navia; Terebratula Wacoensis; Macraster elegans Sh.; O. carinata Lamk. and O. sinuata	Impure chalk	100
		Fredericksburg Division.				
		Hippurites limestone			Metamorphosed chalk	750
		Caprotina "		Caprotina (Requienia)	" "	
		Comanehe Peak limestone		Am. pedernalis V. B.; Toxaster Texanus Roem; O. flabellata (E. Texana) Gold	" with flints	300
		Trinity Beds.		Am. Walcotti, sp. nov. A. Franklini Coq.; Pleurocera strombiformis Schlot; Dinosaurs		300
I. Jurassie Land north of Texas. Deep seas to west and south.						1800 2100 3900

ART. XXXI.—*A General Method for determining the Secondary Chromatic Aberration for a double Telescope Objective, with a description of a Telescope sensibly free from this defect;* by CHARLES S. HASTINGS.

A FORMER paper by the writer* described a method of finding the practicable combinations of three kinds of glass to produce an objective without secondary chromatic aberration. The result of the investigation showed that there had been several optical glasses studied and described, notably one by Fraunhofer and one by Van der Willigen, which would meet the practical requirements of the problem in combination with types of optical glass now readily procurable. Since publishing that paper the writer has made very many experiments with a large variety of glasses, not only those made specifically for optical purposes but many others, without, however, finding any really useful combinations until recently. But within a few years the variety of material at the command of the working optician has been enormously increased by the invaluable labors of Dr. Schott and Professor Abbe; and within the last two years the results of their investigations have been put at the command of the working optician by the manufacturing firm of Schott and Company of Jena. What Professor Abbe and Dr. Zeiss have accomplished with these newly acquired means in the improvement of the microscope is a most interesting history familiar to all, but their utility in the way of improving the telescope has not been thoroughly investigated. With a view to this investigation the writer procured a number of these glasses of the most notable optical peculiarities just after the catalogue of Schott and Co. came into his possession, omitting, however, those which were known not to be permanent under ordinary atmospheric exposure; for, although small lenses of microscope objectives may be used with such care that the deterioration of the surfaces need not be serious for many months or even years, the larger and far more expensive lenses of the telescope must be permanent or their final cost would render them wholly impracticable. This purely practical limitation was imposed notwithstanding that the manufacturers recommended a number of combinations which would yield greatly diminished secondary dispersion if it were dispensed with.

The method employed in the paper cited above is rigidly accurate, but very laborious in its application. It required the making of a very accurate prism of each variety of glass and

* This Journal, III, vol. xviii, p. 429.

the determination of eight or ten indices of refraction for known wave-lengths as well as a protracted calculation. The manufacturers supply in their catalogue, however, the approximate refractive indices of their materials for several known wave-lengths, and the differential refractions with considerable accuracy. As the character of the color correction of an objective depends upon the latter quantity, it seemed that some method might be devised for a systematic study of all the materials founded upon these given constants, and thus avoid the large amount of labor required in the old method. This consideration led to the following solution.

The power of a binary lens having the sum of the reciprocals of the radii of the two lenses respectively A and B is

$$\varphi=(n-1)\mathrm{A}+(n'-1)\mathrm{B},$$

which, for a definite value of n, we will arbitrarily assume to be unity, thus:

$$\varphi_0=(n_0-1)\mathrm{A}+(n'_0-1)\mathrm{B}=1. \qquad (1)$$

For an achromatic combination we must have

$$\frac{d\varphi}{dn}=0=\mathrm{A}+\frac{dn'}{dn}\mathrm{B} \;\therefore\; \mathrm{B}=-\mathrm{A}\frac{dn}{dn'} \qquad (2).$$

The value of the differential coefficient in this equation is a variable, but the value which should be taken for the best color correction for visual purposes has been shown to be* that corresponding to a wave length of about 5164. By employing *these* values of n and n' in the above equations and designating them by n_0 and n'_0, equation (1) becomes the condition of definite power and (2) that of achromatism.

We now wish to find the expression for the secondary chromatic aberration. We may write

$$\varphi_o=(n_o-1)\mathrm{A}-(n'_o-1)\frac{dn_o}{dn'_o}\mathrm{A};$$

$$\varphi_n=(n_o+\delta n-1)\mathrm{A}-(n'_o+\delta n'-1)\frac{dn_o}{dn'_o}\mathrm{A}; \text{ whence}$$

$$\varphi_o-\varphi_n=\delta\varphi=(\delta n-\frac{dn_o}{dn'_o}\delta n')\mathrm{A}.$$

But in the paper of vol. xviii, cited above, it was shown that the refractive index of one species of glass can be expressed as a simple trinomial function of that of another with practically absolute accuracy, whence

$$n'=\alpha+\beta n+\gamma n^2$$

$$\delta n'=(\beta+2\gamma n)\delta n+\gamma\delta n^2; \text{ also}$$

$$\beta+2\gamma n=\frac{dn'}{dn}=\frac{dn'_o}{dn_o} \text{ nearly, and } \gamma=\tfrac{1}{2}\frac{d^2n'}{dn^2}.$$

Substituting the value of $\delta n'$ in the expression for $\delta\varphi$, we have

* This Journal, vol. xxiii, p. 167.

$$\delta\varphi = -\tfrac{1}{2}A \frac{dn_o}{dn'_o} \frac{d^2n'}{dn^2} \delta n^2, \qquad (3)$$

which is the measure for the secondary chromatic abberration for a binary lens of materials n and n' and power φ. Although it is, as appears from the method in which it was derived, an approximation, it is found to be perfectly accurate to three significant figures from the wave-lengths A to H inclusive.

If we already have the constants of the equation expressing the relation between n' and n the calculation of $\delta\varphi$ is easy and the method obvious. For the Crown 1219 and Flint 1237 of my paper on double objectives cited above, which may be taken as typical specimens of the crown and flint glasses used in the construction of astronomical telescopes during the last half century, the value of $\delta\varphi$ is $-27{\cdot}1$; but if we have not sufficient data to enable us to calculate the values of α, β and γ, or if we wish to avoid the labor of determining them, we may content ourselves with three indices for each kind of glass employed and be confident of a useful approximation to the true solution if the corresponding wave-lengths are well distributed through the spectrum. Thus if the indices for the Fraunhofer lines C, D and F, are given, we may substitute in the above equations, n_D for n_o, $\frac{n_F - n_C}{n'_F - n'_C}$ for $\frac{dn_o}{dn'_o}$, and for $\frac{d^2n}{dn^2} = 2\gamma$ the value deduced from the equations:

$$n'_F - n'_D = (n_F - n_D)\beta + (n_F - n_D)^2\gamma$$
$$n'_D - n'_C = (n_D - n_C)\beta + (n_D - n_C)^2\gamma.$$

Such a ready approximation gives $\delta\varphi = -30{\cdot}0$ for the glasses above mentioned.

In the catalogue of the Jena manufacturers are given the approximate indices of refraction for the line D, and to a much greater degree of precision, the differences of the indices for various intervals in the spectrum including the intervals C to F and D to F. Since the color characteristics of a combination depend upon the differences far more decidedly than upon the absolute value of the indices, as has already been stated, we have in this list all the data necessary to secure an approximate solution to the problem by the method described. We may most conveniently proceed by selecting some one from the list and then find the value of $\delta\varphi$ for each combination of the others with it for a definite change of wave-length of light; or, what is far better for our end in view, calculate the value of the coefficient of δn^2 in the expression for $\delta\varphi$. If we call this coefficient k its value will be $-\tfrac{1}{2}A \frac{dn^o}{dn'_o} \frac{d^2n'}{dn^2}$. Such tabulated values of k would give us a notion whether a combination was subject to a large secondary chromatic aberration or to a small one, but the numbers would not be proportional to the aberrations because of the variable factors δn^2; but if we multiply the number k by $\left(\frac{dn}{dn_1}\right)^2$, where n is the index for the glass which is to be combined with that common to the whole series of pairs, and n_1 is the index for another glass arbitrarily assumed to have the standard dispersion, we shall have a series of numbers all of which are to be multiplied by the same quantity, namely, δn_1^2, to find the secondary chromatic aberration for a binary objective of each pair. These numbers we will designate by k'. In order to make the comparison with an objective of the ordinary type, I have chosen No. 37 of Schott and Co.'s catalogue, an ordinary flint of the kind generally employed in telescope objectives, for the negative lens of all the combinations, and No. 13, which is an ordinary crown glass, as the material of standard dispersive power. The following table contains the results of the computations thus indicated. The first column contains the catalogue number of the glass combined with No. 37; the second column contains A, the sum of the curvatures of the two surfaces of the positive lens, and the third, under B, the sum of the curvatures of the two surfaces of the flint lens; finally, the fourth column contains k', which may be regarded as the true measure of the secondary chromatic aberration. In short, if r_1 and r_2 are the radii of the positive lens, r'_1 and r'_2 those of the flint No. 37 lens, we have for a binary lens of focal length unity,

$$A=\frac{1}{r_1}+\frac{1}{r_2},\quad B=\frac{1}{r'_1}+\frac{1}{r'_2},\quad k'=k\left(\frac{dn}{dn_{13}}\right)^2.$$

Inspection of the table shows—First: that only one of the binary combinations having "ordinary dense flint" as one component is practically free from secondary chromatic aberration, namely, No. 30. This is described in the catalogue as a silicate flint with relatively high refractive power. Although the combination demands rather deep curves for the lenses, it is in my opinion by far the best which the present resources of practical optics affords, and is sensibly perfect. The inconvenience of excessive curvature could be reduced by making the objective of three lenses, the flint 37 being a double concave between two positive lenses of flint 30, or, perhaps better, in the case of large telescopes, increasing the ratio of focal length to aperture. This conclusion stands or falls with the accuracy of the data supplied by the catalogue, for, although there are strong reasons for supposing the data good, I have not seen either of the materials in question.

Second: that there are only two combinations for which k' is positive, those of 66, an "ordinary light flint," and rock salt. The first of these is of no practical interest on account of the large numerical values for A and B, but the case of rock salt is worthy of a moment's discussion. The numbers show that it is possible to make a telescope objective of rock salt and ordinary telescope flint which, with moderate curvatures, shall give a *negative* secondary chromatic aberration, that is, which would show the center of a stellar-image purple inside of the focal plane instead of outside as in the familiar case. This peculiarity of rock salt I discovered a long time since. It is of interest since it enables us to eliminate all secondary chromatic aberration by combining a relatively strong binary lens of rock salt and flint with a weak binary of crown and flint, or, in short, to make an absolutely achromatic combination of the three materials named. I had calculated such an objective and commenced making a pair for spectroscopic work, when the publication of the Jena catalogue suggested combinations of more practical value.

Table of constants of binary objectives composed of various substances combined with flint, No. 37.

No.	A	B	$-k'$	No.	A	B	$-k'$
1	3·97	−1·68	25·5	24†	5·91	− 3·83	36·4
2*	3·85	−1·84	20·0	25	6·62	− 4·23	34·4
3	3·86	−1·96	19·8	26	7·06	− 4·46	21·1
4†	3·84	−2·04	22·3	27	7·58	− 5·29	33·2
5	4·46	−2·04	25·3	28†	8·64	− 6·81	34·5
6	4·68	−2·21	25·4	29	10·48	− 7·98	21·5
7	4·71	−2·30	27·1	30	10·6	− 8·61	0·5
8	4·77	−2·35	23·6	53	5·02	− 2·94	23·3
9	4·80	−2·40	23·0	54	5·65	− 3·06	24·1
10†	4·91	−2·37	35·8	55	5·45	− 3·35	17·2
11	4·99	−2·41	25·7	56	6·31	− 3·71	18·2
12	4·67	−2·43	26·2	57	5·84	− 3·72	20·5
13	4·92	−2·48	28·7	58	6·09	− 3·90	19·9
14	5·00	−2·58	17·0	59	6·03	− 3·92	18·9
15	4·93	−2·59	25·6	60	6·42	− 4·24	15·4
16	4·63	−2·64	21·6	61	7·03	− 4·65	14·2
17	5·21	−2·70	24·4	62	7·53	− 5·42	18·8
18	5·29	−2·76	22·5	63	10·7	− 8·10	11·0
19	5·21	−2·77	26·9	64	13·0	−10·4	12·3
20	4·70	−2·95	22·2	65	12·9	−10·2	5·8
21†	5·17	−2·96	35·5	66	25·8	−23.4	−13·3
22†	5·42	−3·19	32·2	Rock Salt	11·67	− 8·52	− 6·5
23	6·21	−3·74	18·5				

* That in my possession not permanent. † Not permanent.

Third: that it is easy to select from the table triple combinations such that the secondary dispersions shall be completely eliminated. The process would be the following:—Take a *negative* binary lens of some materials of which the value of $-k'$ is large and of such a power, φ', that $\varphi' k'$ equals $-k'$ for a binary having a small value of this constant. These two binaries combined will form a system of power $\varphi - \varphi'$ without chromatic aberration. Other things being equal those materials having the smallest numbers under A and B would be preferable. To illustrate: suppose we take combinations 3 and 37 and 10 and 37, the first having a small, and the second a large, secondary aberration. Take a negative binary of the second pair of power $-0·553$, which will give

$$A_{10}=-2·72 \quad B_{10}=1·31 \quad k'_{10}\varphi_{10}=19·8 \quad \varphi_{10}=-0·553\,;$$

add to this a binary of the first pair of which

$$A_3=3·84 \quad B_3=-2·04 \quad k'_3\varphi_3=-19·8 \quad \varphi_3=1·$$

and we have a triple lens for which

$$A_3=3·84 \quad A_{10}=-2·72 \quad A_{37}=-0·73 \quad k'\varphi=0 \quad \varphi=0·447.$$

The meaning of A_{37} is obvious when we remember that B_3 and B_{10} both express curvature sums for the same material, flint 37. To find the curvature sums for a focal length of one, we should have only to divide throughout by 0·447, which yields 8·59 $-6·09$ and $-1·63$. These are moderate curvatures, but in view of the fact that 10 is not a permanent glass I should prefer 3, 25 and 37, or 3, 27 and 37, although there are a considerable number of such triple combinations which may be useful and which may be gathered from a study of the table.

Fourth: that by means of the table we may also find the value of the secondary chromatic aberration for a binary composed of any two materials entered in it. For example, suppose we desire the color characteristic of a binary composed of Nos. 1 and 22, which is one of the combinations recommended by the makers as yielding an objective of notably diminished secondary aberration. Take a negative binary of 22 and 37 with a power of $-0·527$; its constants are:

$$A_{22}=-2·85 \quad B_{22}=1·84 \quad k'\varphi'=17·0.$$

Combining this with the binary of 1 and 37 of power one, we have a binary lens of the two glasses in question (since the 37 eliminates) the constants of which are:

$$A_1=3·97 \quad A_{22}=-2·85 \quad k'\varphi=-8·5 \quad \varphi=0·473\,;$$

or, reduced to focal length of unity,

$$A_1=8·39 \quad A_{22}=-6·02 \quad k'=-18·0,$$

whence we conclude that by this construction we only reduce the secondary dispersion one-third at a cost of permanence in one of the lenses.

Other combinations recommended for the end in view are 2 and 24, and 3 and 28. The first of these is optically by far the best, reducing the dispersion about five-sixths, but both the materials are perishable; the second pair is practically the same as 1 and 22, but 28 is not permanent. If we are content with a combination containing a glass which is not permanent we can find much better pairs than those suggested in the catalogue. For example, 2 and 22 reduce the secondary aberration

80 per cent with moderate curves; 3 and 24 by 90 per cent with still smaller curvatures; 3 and 22 form a combination without chromatic aberration, but requiring rather deep curvatures; 55 and 28 are also practically perfect, reducing the secondary aberration 98 per cent, but demanding somewhat deeper curves than the last pair.

If, however, we impose the condition that only permanent glasses shall be employed, which is an obviously imperative condition for a telescope which is to be used out of doors, the range of choice is very greatly reduced. The only pair suggested in the catalogue which is useful from this point of view is of Nos. 8 and 25. These give an improvement of 65 per cent over the ordinary objectives, but require the values $A_8=10{\cdot}7$ $A_{25}=-8{\cdot}29$; this combination would without doubt be very useful if we had nothing better. The above table, however, suggests at least two combinations which are better, one, that of 30 and 37, which, like 8 and 25, requires undesirably deep curves, but which gives an improvement of 98 per cent, and the other Nos. 14 and 27 which yields an improvement of 94 per cent and demands the somewhat more manageable curvature sums of 9·78 and −7·24.

The trustworthiness of the data of the catalogue is the only further element which we need to consider, since all the above conclusions rest upon them. There are three excellent reasons for placing the highest confidence in them. In the first place, emanating from so eminent a physicist as Professor Abbe they can hardly, by any possibility, be subject to systematic errors, which alone we have to fear. Secondly: If we arrange the materials according to their optical properties as given in the table above we find that they fall into groups suggested already by their chemical composition. Thirdly: In the various glasses which I have accurately determined the data of the catalogue are exactly what they pretend to be, that is, the errors of the indices of refraction are confined to the fourth place of decimals, and the differences of the indices to the fifth place.

Among the glasses in my possession are the Nos. 14 and 27, which, according to what appears above, form a most advantageous combination. Of these I made prisms, determined the optical constants with great precision, and then calculated an achromatic objective. There were two questions of interest which could only be answered by trying the objective. They were, first, whether secondary chromatic aberration reduced to about one-twentieth of its ordinary value could be detected by the eye; and second, how much the defining power of such an objective would surpass that of the familiar type. Thus, although after studying the prisms and computing the objective no doubt as to the validity of the conclusions from the table remained, it was highly desirable to try a telescope so constructed before publishing this paper. The largest objective which could be made of the pieces in my possession was of $2\frac{3}{4}$ inches clear aperture. This, though smaller than desired, was sufficient to give a fairly satisfactory answer to the questions. Accordingly the glasses were worked accurately to the curvatures and thicknesses corresponding to the computations and mounted for use. The astonishing beauty of the images in the new telescope was its most surprising feature at first. The familiar purple was wholly wanting, or at least, could only be recognized with the closest attention, with magnifying powers greater than forty to the inch aperture, and on objects most suitable to its exhibition. But the moment that the instrument was applied to astronomical use it was also evident that its defining power was remarkable. The companions to Polaris and Rigel, instead of being objects which require somewhat careful looking, as is the case with my eye and an ordinary achromatic of the same aperture, were strikingly plain. More difficult, but certainly seen, was the fifth star in ϑ Orionis. The binary star η Orionis was so well elongated that its position angle was estimated to within 5° of its true value; on the other hand ξ Ursai Maj. which I suppose to have at present a separation of $1''\cdot 7$, was divided only with difficulty on a fairly good evening though it was supposed that it would be easy. Saturn showed all that I have seen with an admirable telescope of considerably greater apertures, including more than half of Ball's division, the ring C, a single belt and five satellites though Tethys and Dione have not been seen unless they had an elongation equal or greater than that of the end of the ring. Rhea has been seen in conjunction. By reference to the records of many observations which I have made with various telescopes the power of the new telescope was estimated as equivalent to a $3\frac{1}{2}$ inch objective of the ordinary construction. The powers used varied from 53 to 265 diameters with 194 as the most satisfactory for Saturn and for double stars.

Another method of determining the relative power of the telescope was by comparing the distances at which a table of logarithms could be read with it and a very perfect telescope of $2\frac{5}{8}$ inches aperture made a number of years ago, and with which I have observed a great deal. Allowing for the 5 per cent increase in size in the new instrument, the mean of five tolerably accordant determinations indicated a gain of 23 per cent, or that the new objective was equivalent to a $3\frac{3}{8}$ inch objective of the ordinary construction. This ratio of improvement is doubtless higher than would generally be admitted as possible by most opticians, but it must stand for the present as the best value attainable.

Yale University, March, 1889.

ART. XXXII.—*The distribution of Phosphorus in the Ludington Mine, Iron Mountain, Michigan;* by DAVID H. BROWNE. With Plates VIII–XIII.

[Paper read before the American Institute of Mining Engineers at its New York Meeting, February, 1889.]

ONE of the most difficult problems in the chemistry of iron ore, and one, so far as I am aware, the solution of which has never been attempted, has been the distribution, throughout the vein, of Bessemer ore, and its relation to the formation of the deposit. In those hematite mines in which both Bessemer and non-Bessemer ores occur, the sorting of the ore, as it lies in the deposit, becomes a problem of much economic as well as scientific interest. It would seem from a superficial examination, or indeed from any examination not conducted for this especial purpose, as if high and low phosphorus ores were mixed in inextricable confusion; and a mining chemist is very apt to fall into a system of adventitious analyses, taking first-class ore wherever he can find it, and overlooking its relation to the formation and position of the vein. I hope that a few notes, which I shall present on this subject, may be found worthy of consideration, as throwing a new light on this obscure topic.

During the last three years, while acting as chemist of the Lumberman's Mining Co., I have made some 3000 analyses of ore from the Ludington Mine, at Iron Mountain, Mich. These analyses were necessary in order to separate Bessemer and non-Bessemer ore which occurred intermixed in the deposit. During the last year I attempted in several ways to find some reason or method in the distribution of phosphorus; and have finally become cognizant of the arrangement herein outlined. I have been obliged to confine my attention to one mine, and of that, to that portion wherein the commercial quality of the ore was such as to demand systematic sampling and analysis. The analyses, therefore, and the conclusions drawn therefrom, are given merely as facts found to exist, and I do not claim that such sequence as I have noticed will obtain in all or every case. I simply state what results I have obtained in an investigation carefully conducted, and I give some conclusions toward which the data seem to lead.

The Ludington mine, like most on the Menominee Range, consists of several lenticular deposits of soft blue hematite. These deposits are contained between clay slates, which conform with the Huronian strata represented in the district. The main deposit is about 700 feet in length and perhaps 60 feet in width. It strikes N. 75° W., pitches 45° west, and dips from 70° to 80° N. The ore is a very rich, soft, friable, bluish-black hematite, occurring in thin laminæ, which cleave very readily from each other in the direction of the strike. These layers alternate in places with thin seams of calcium-magnesium carbonate. The ore analyzes from 65 to 68 per cent in iron, in silica from 1 to 4 per cent, and in phosphorus from ·005 to ·200. The ore is separated into Bessemer and non-Bessemer; about one-half falling below ·035 phosphorus; the rest averaging about ·075. At first sight, the ore upon analysis, seemed to have no regularity whatever in percentage of phosphorus. A room as stopped up, would change from Bessemer ore to non-Bessemer, or *vice versa* in a way at first totally inexplicable.

The fact that phosphorus exists as calcium phosphate led me to infer that some proportion between the percentage of lime and phosphorus might be found to exist; but such inference was not verified in practice. An ore containing 2 per cent of lime may contain almost no phosphorus, or may run high above Bessemer limit. Nor was any proportion manifest between the percentages of iron or silica and phosphorus. I have noticed jasper vary as much in percentage of phosphorus as any iron ore, and similarly a lean ore is just as likely to be Bessemer as non-Bessemer. The only difference I could find between Bessemer and non-Bessemer was this: As a rule a soft blue hematite high in phosphorus, has a brighter and more specular appearance than non-Bessemer ore of the same value in iron. This distinction, slight as it is, will not always hold good, and the separation of such ores must be guided solely by chemical analysis.

The fact that a bright ore was high in phosphorus, and that such ore was generally found near the hanging wall led me to search for some regularity of phosphorus distribution, dependent upon the position of the ore. After making analysis of the ore from any room, drift or winze, I marked the percentage of phosphorus in a map of that portion of the mine. Having thus obtained a chemical map of each room, I noticed in each a certain regularity which seemed to me to throw considerable light both upon this problem of phosphorus distribution, and upon the vexed question of the method of formation of the hematite ore deposits.

In order to give a clear idea of this relation I must first state a few facts with regard to the physical features of the deposit. As previously stated, the so-called "veins" of the Ludington mine stand nearly vertical, dipping north and pitching west. A horizontal cross section of the ore-body shows it to form an elongated lens about 65 feet in thickness at the center, tapering to an acute point at both ends (fig. 1). A vertical cross section shows the dip to the north, and also the fact that the hanging wall is more curved than the foot. A cross section of the Chapin Mine, which possesses the same physical features, shows this very plainly (fig. 2). A horizontal cross section of several small veins shows that the hanging wall curves toward the foot. On large veins the strata have been subjected to so much flexion that this curvature is not clearly seen, but on small veins it is unmistakeable (see fig. 1, *a*). I must here state that in the greater number of veins on the Menominee Range the dip is to the south, and hence what is called the hanging wall in the Chapin and Ludington Mines answers in them to foot wall. If we attempt to make an ideal vertical longitudinal section of the ore deposits it seems to have the shape given in figure 3. A study of the eastern and western limits of the Chapin Mine seems to verify this idea. Figure 18 shows a vertical longitudinal section of a small vein in which this shape is very noticeable. The ore will now be understood to lie in the form of lenticular deposits dipping north, and pitching west.

With regard to the content of phosphorus: the first thing noticeable was that if a room, in stoping up, changed from non-Bessemer to Bessemer ore, such change was liable to occur at the footwall side of the room. In making maps of those rooms in which change occurred it was also noticeable that the ore at the eastern end of the rooms was higher in phosphorus than that at the western end. The most typical room was No. 7 Room, 2 Shaft, 5th Level, which is outlined in figure 4. This room was, if I remember aright, about 3½ sets from east to west and four sets from footwall to hanging. A set, I may say, is a space 8 by 8 by 8 feet, outlined by the timbers used to support the back. From the ground plan of this room it will be noticed that the ore showed a marked regularity of formation. Follow the course of the hanging wall, and trace the increase of phosphorus from ·068 at the west hanging wall set to ·078, ·086, ·100 and finally ·156 on the east hanging wall set. Such increase is also noticeable in the ore in entry from ·060 to ·096 and, though less plainly on the footwall from ·020 to ·032. Beside this regularity there is a corresponding increase from footwall to hanging. Notice the gradual change from ·032 and ·028 on the foot, to ·045 and ·040 in the middle and ·156 and ·068 on the hanging wall. On inspection, figures 4 to 16 will also show the same peculiarity and a large number of average analyses corroborate the conclusion that in this mine, as a rule, the ore increases in percentage of phosphorus from footwall to hanging wall, and generally speaking from west to east. It frequently happens, however, that a streak of high or low phosphorus ore crosses a room from west to east, as in figures 4, 14, and 15. This seems to be due to the fact that one or more individual layers of ore were originally very high or very low in phosphorus, and such individuality has not been observed by subsequent changes. Moreover irregularity is very frequently noticed in the direction from west to east. Sometimes a decrease is manifest, and sometimes an increase, these being both easily accountable for. The analyses taken from west to east are not nearly so regular and uniform as those taken from foot to hanging wall; nor is this to be wondered at; for since the layers of ore present smooth surfaces in the direction of the walls, analysis taken along a series of sets on the footwall will represent roughly analyses of at most a very few layers of ore. In driving a drift, or stoping a room, or sinking a winze, on the other hand, where analyses are made, averages are taken of a large number of separate deposits, and as these deposits are much flexed and broken, the analyses show little correspondence. In the breast of a drift 8 feet wide, supposing each layer of ore has a thickness of half an inch, there will present themselves for analysis the edges of no less than 192 layers; and in consequence more confusion is liable, and does occur, in analyses taken east and west than in those taken north and south.

Having obtained thus a general idea of how the lines of phosphorus tend in two directions; the next question naturally is, what would be the lines of equal phosphorus content in any individual layer of ore. These, for want of a better term I have herein been obliged to term "isochemic lines." It is evident that analyses of ore in the breast of a drift, or in the bottom of a winze, would not give any clue to the isochemic lines in a particular stratum of ore, but would show the average of several hundred separate strata. It is also evident that no analysis would accurately represent the composition of a particular layer, unless this layer, in no case over half an inch, and rarely over one-quarter inch in thickness, could be followed by chemical analysis along drifts, and up slopes, and down winzes and shafts, for a distance in some way proportionate to the extent covered by the deposit of which it forms an infinitesimal thickness. This would be, and for me was, practically impossible. For analyses to be of commercial value, must show, not the amount of constituents in any particular stratum of ore, but the average of that amount of ore which a gang of men, working under contract, can take out of a given room, before other analyses be made. For this reason I have been obliged to confine myself to analyses which represent averages of a large number of layers; and from these analyses I have endeavored to outline the probable distribution of phosphorus in the separate strata. It is plain that if any single layer of ore shall have its percentage of phosphorus in some way modified by its method of deposit, every other layer subjected to the same conditions will be in similar manner modified, and consequently, analyses representing average of a large number of strata will show the characteristics common to each individual stratum.

In sinking a winze in No. 1 Room, 5 Shaft, 5½ Level, the following facts were noticed. The drift running east from the winze showed ore running from ·015 phosphorus to ·030; the winze as sunk passed through ore running from ·015 to ·029. Lines drawn from the point in the drift where a certain percentage of phosphorus was noticed to a corresponding point in the winze showed an angle of about 45° with the horizon. Also in sinking a winze in No. 2 R., 5 Sh., 5½ Level, similar lines of equal chemical composition were noticed. (See fig. 20.) In sinking 5 shaft from the 7th to the 8th Level, and in sinking the winzes in No. 1 and No. 2 Rooms it was noticed that the winzes passed through ore previously met with in drifts and winzes to the east. These isochemic lines will be easily seen in figure 21. If now we take a small vein as that composing No. 4 and No. 5 Rooms, A shaft, 6 Level, and attempt to outline the isochemic lines in the plane of the winzes the regularity is at once patent. On the entry the first-class ore was confined to the last set west in the room. As the room stoped up, this first-class ore was thrown more to the center of the room. The course of the isochemic lines is very plainly indicated by the average analyses marked in the map of this room. (Fig. 18.) The first-class ore continues steadily along the western boundary of the room, and the high phosphorus ore as steadily follows the course of rock to the east. A winze sunk in the room showed all the changes from low to high phosphorus, previously met with east of the winze in the entry. Analyses taken from a small and very characteristic lens of ore forming No. 4 Room, 1 Shaft, 6 Level, shows very clearly the tendency of isochemic lines to run in the same direction as the pitch of the ore, and also the tendency of phosphorus to increase toward the upper part of the deposit. (Figs. 10 and 11.)

In attempting to draw up a vertical longitudinal section of the western end of the deposit, the principal difficulty lay in reducing so many analyses to the same plane. In consequence of the impracticability of attempting to represent every analysis taken, and its relation to others in the same vein, I have been obliged to select those analyses which represent averages; and in the vertical longitudinal sections of various rooms the figures entered in the map represent average percentage in phosphorus of the ore in that particular place covered by the figures, and in the plane through which section is made. Fig. 19 gives the detail of various averages in 1 and 2 Rooms, 5 Shaft. While the ore left in the pillars has not been subjected to analysis, I have for the sake of clearness drawn through the pillars the isochemic lines indicated by the percentages in phosphorus in the rooms which they support. Figure 23 is an attempt to outline the curvature of isochemic lines in the course of 5 shaft from the surface to the 8th level. I have in my possession detail maps of the chemistry of the entire course of No. 5 shaft, showing the percentage of phosphorus in every eight feet cube of ore removed. As it would be impossible to reduce this map to the size of the engravings required for an octavo page and preserve at the same time the clearness of the figures therein, I have been obliged in drawing Maps 18, 19, 20 and 21, to omit more than two-thirds of the figures in the original drawings. Figure 23 will be understood then, simply as an outline sketch. By actual measurement the distances along various levels, through which certain average percentages of phosphorus obtained, have been carefully ascertained, and the exact points where change from Bessemer ore to non-Bessemer occurred located upon the section map to correspond. The curvature of the isochemic lines, therefore, is in accurate correspondence with the course of high and low phosphorus throughout the western end of the Ludington mine. The drawing of various rooms and pillars is in this map omitted. The curving lines, when close together, represent high phosphorus ore; the arrows indicate direction of Bessemer ore; and the figures represent averages of several hundred analyses for phosphorus taken in the immediate neighborhood indicated thereby.

From this figure (23) it will be noticed that on the upper levels the greater portion of the ore is non-Bessemer. At the west end of the mine, a small streak of Bessemer ore follows the shaft, gaining toward the west until the 4½ and 5th levels are reached, where the Bessemer ore flexes toward the east and merges into the broad current of first-class ore which flows upward and eastward from the lower levels of 5 shaft. The non-Bessemer ore follows the western boundary of rock, and seems to accumulate also in shoals outlined by projections or intrusions of jasper, which break the flow of the current.

On stoping up No. 1 Room, 7th Level, through ore gradually increasing in phosphorus, a seam of rock was encountered. As analysis of the drift over head had shown low phosphorus, and the shaft 50 feet to the left had passed through Bessemer ore, I concluded that the ore above this rock would be of first-class quality. This prediction was made entirely on the supposed consistency and continuity of isochemic lines, as no ore had been taken from above this rock for analysis. I was at this point called to New York on business, and before leaving, left word with the mining captain that any ore found above this rock should be sent up for first-class ore. On returning to the mine three weeks later I found that this rock had been pierced and some 200 tons of ore from over head sent up and dumped upon the Bessemer stock pile. Analysis of this ore showed it to be from ·011 to ·027 phos. which will be seen to agree with other analyses along this isochemic line. (Fig. 21.)

Below this 7th Level the intrusion of rock seems to have caused an inflow of non-Bessemer ore. It appears as if the rock had formed in shoal water on its lower side, and into this shallow the calcium phosphate had drifted. I have noticed in a large number of instances this tendency of rock occurring as vein matter to alter the percentage of phosphorus in the adjoining ore. In fact I do not know of any case wherein a horse of jasper did not in some way alter the proportion of phosphorus in the ore penetrated thereby. The statement that high phosphorus follows rock is one which will be corroborated by any one familiar with the mine under consideration.

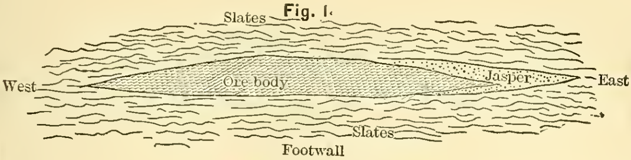
Another fact I must state is this: On the upper levels of No. 5 shaft almost all the ore was exceedingly high in phosphorus. The ore found on the lower levels shows a greater uniformity, the difference between Bessemer and non-Bessemer ore being less evident than on the upper levels. It was no uncommon occurrence on the third and fourth levels to find streaks of ore as high as ·350 phosphorus. Now such ore is very rarely met with. The average of non-Bessemer ore in the west end of the open pit and the upper levels of No. 5 shaft was somewhere near ·150 phosphorus. The averages of non-Bessemer at present obtained is probably ·075 or ·080. Again, on the upper levels the greater part of the ore near No. 5 shaft was non-Bessemer; at present the converse is the case, the first-class ore occupying the greater portion of the deposit. To state in general terms, the tendency of the phosphorus on this vein seems to be to increase with the distance from the lower point of the deposit. This is not true of the eastern end of the deposit, at No. 1 shaft, in which the upper levels are largely Bessemer ore. This seems due to the fact that a horse of rock splitting up the deposit has thrown the current of Bessemer ore to the east. This Bessemer ore, occurring on the upper levels of No. 1, is of the same content in phosphorus as that on the 5th and 6th levels of No. 5 Shaft, and the high phosphorus ore on the lower levels of No. 1 is the same as that now being met with on the 7th and 8th levels of No. 5 shaft. Fig. 23.

In endeavoring to correlate these isochemic lines with the physical phenomena of the deposit, the only theory which will, to my mind, furnish adequate explanation, is that of aqueous deposition. The easy longitudinal cleavage of the laminæ of ore, the curvature in small veins of the hanging wall toward the footwall, and the hydrated muddy look of the ore next the footwall, all seem to indicate that the ore was deposited in hollows of the exposed slates which now form the hanging wall. Furthermore since it is well understood that the almost uniform tendency of all deposits east of the Mississippi River is in a line from southwest to northeast, it is very probable that this deposit, as originally laid down, was no exception to the general rule. If we suppose that the ore was formed in hollows in the hanging wall, and was covered by the footwall slates, and that this bed has been tilted up from the north side, through an angle of 100° to 110°, it will be readily understood that the original trend of the deposit becomes the complement of the present pitch of the ore. This supposition explains also the strike of N. 75° W., and the fact that what is now the hanging wall seems to have been the original bed of deposit. It is improbable that the tilting has been from the south side upwards through an angle of 70° to 80°; for if this had been the case the ore would pitch east at the same angle at which it now pitches west.

In the American Journal of Science for January, 1889, Professor Van Hise suggests that the soft ores of the Gogebic range have been formed by the action of percolating waters containing carbonic acid, which, acting upon previously deposited carbonate of iron, has dissolved iron therefrom; and this dissolved iron has been precipitated by oxygen-bearing, or alkaline waters from the surface. This theory, while seeming to explain the formation in the Gogebic mines studied, seems less probable as applied to the mines on the Menominee Range. Here the ore rests directly upon clay slates containing none of the unaltered carbonates found in the Gogebic Range. The ore also lies not in trough-like formations, but in regular basins of lenticular shape. The ore exhibits none of the nodular form spoken of in Professor Van Hise's paper, and the stratification is remarkably even and regular.

The suggestion made by Mr. R. D. Irving in the American Journal of Science for Oct., 1886, that the ore has been washed into its present position from previously precipitated beds of carbonate, seems to me very plausible, and is borne out in a large measure by the chemistry of the ore body. I should, however, suggest this change, that the original deposits of iron and lime were not as crystallized siderite and calcite, but as hydrous oxide and carbonate of iron with intermixed calcareous deposits. This finds analogy in the formation of beds of bog iron ore in the present day. It is worthy of note that such beds of altered bog ore do exist in the Huronian strata represented in the upper Peninsula of Michigan. Any one familiar with the non-Bessemer ores of the western end of the Menominee Range must have been struck with the remarkable

Fig. 1.



HORIZONTAL SECTION

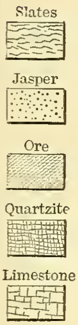
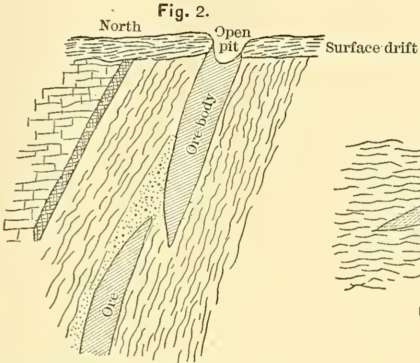
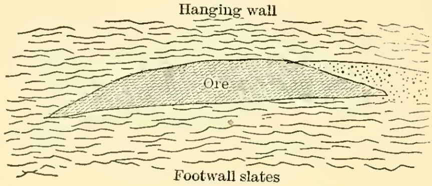


Fig. 2.



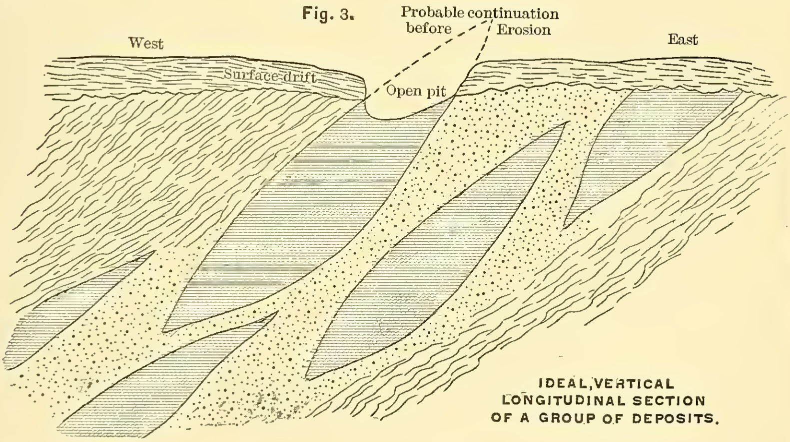
VERTICAL CROSS SECTION

Fig. 1a.



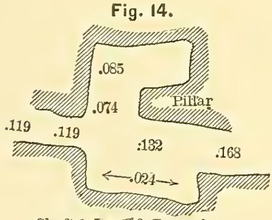
HORIZONTAL CROSS SECTION

Fig. 3.



IDEAL VERTICAL LONGITUDINAL SECTION OF A GROUP OF DEPOSITS.

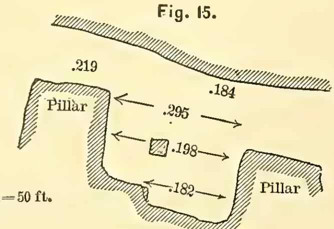
Fig. 14.



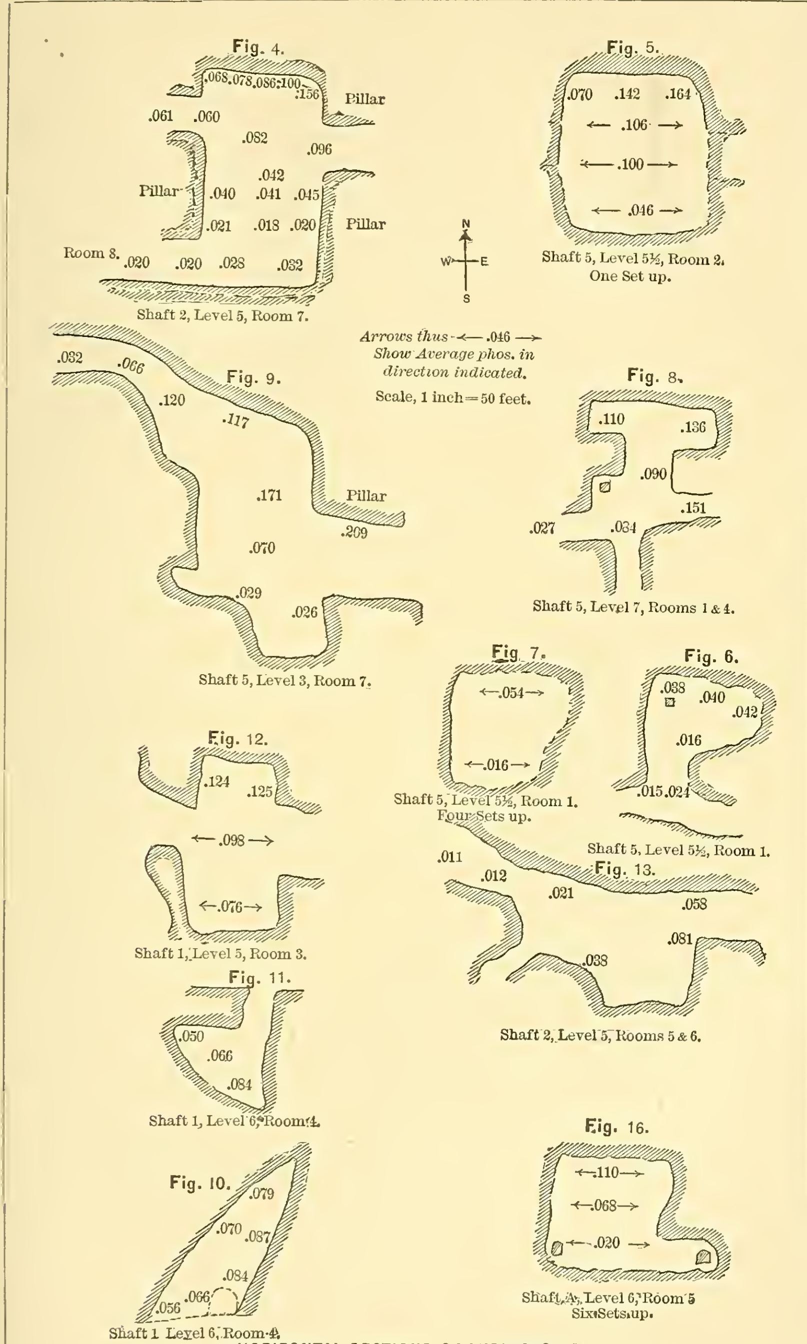
Shaft 2, Level 3, Room 6.

Scale, 1 inch = 50 ft.

Fig. 15.

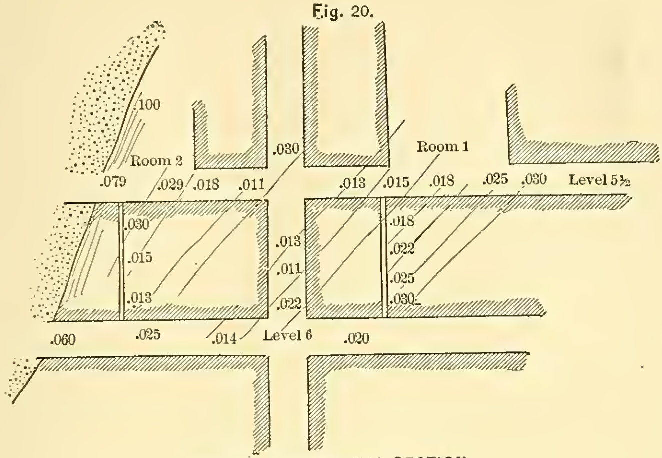


Shaft 5, Level 4, Room 1.



HORIZONTAL SECTIONS OF LUDINGTON MINE.
EXCEPT FIG. 10. WHICH IS A VERTICAL SECTION.

Fig. 20.

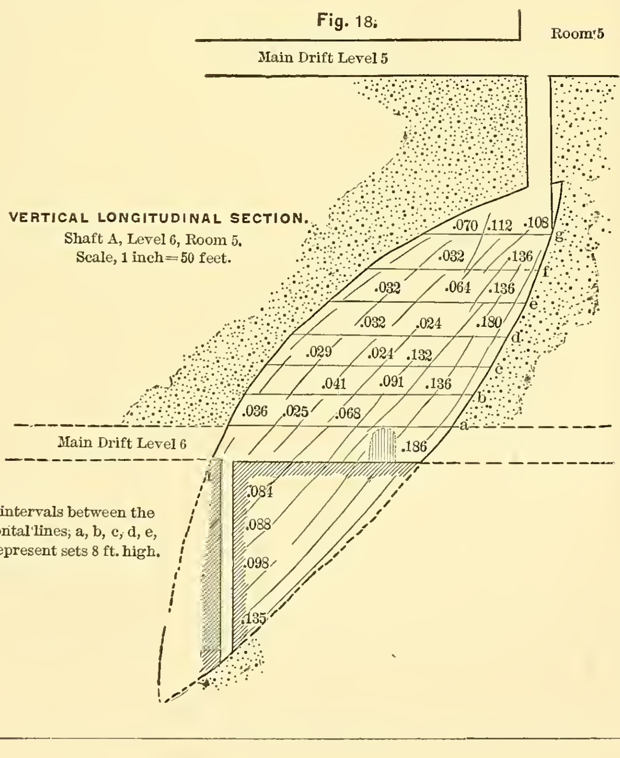


VERTICAL LONGITUDINAL SECTION

Levels 5½ & 6, Rooms 1 & 2.

Scale, 1 inch = 50 feet.

Fig. 18.



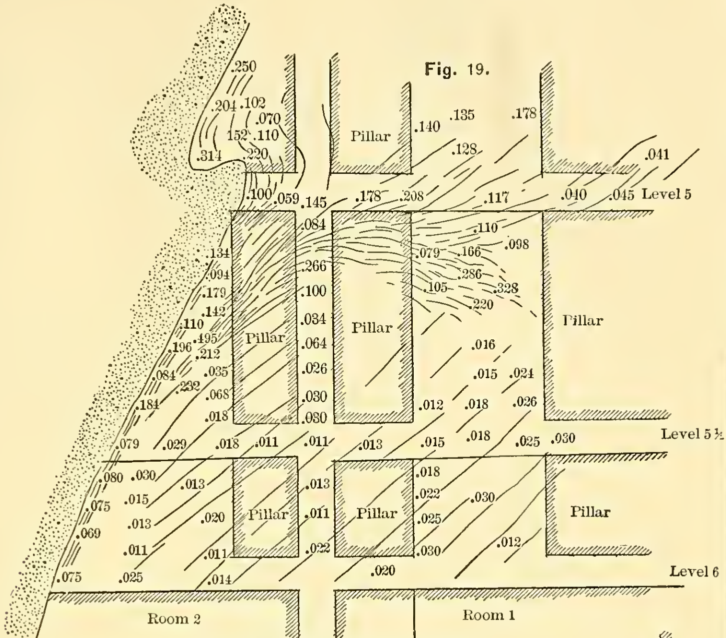
VERTICAL LONGITUDINAL SECTION.

Shaft A, Level 6, Room 5.

Scale, 1 inch = 50 feet.

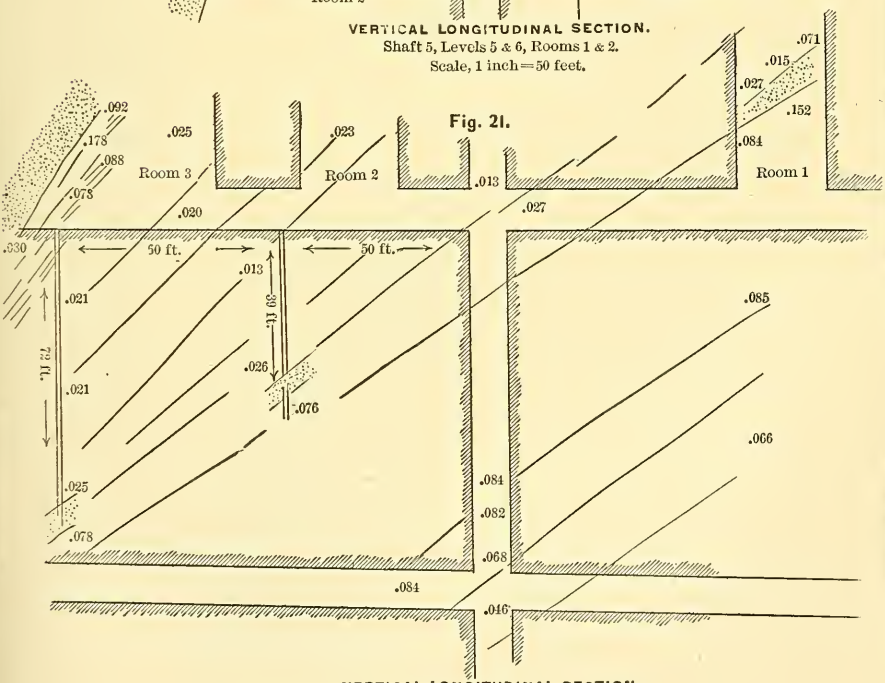
The intervals between the horizontal lines; a, b, c, d, e, f, g, represent sets 8 ft. high.

Fig. 19.



VERTICAL LONGITUDINAL SECTION.
Shaft 5, Levels 5 & 6, Rooms 1 & 2.
Scale, 1 inch = 50 feet.

Fig. 21.



V.ERTICAL LONGITUDINAL SECTION.
Level 7, Rooms 1, 2, & 3.
Showing depth of winzes.

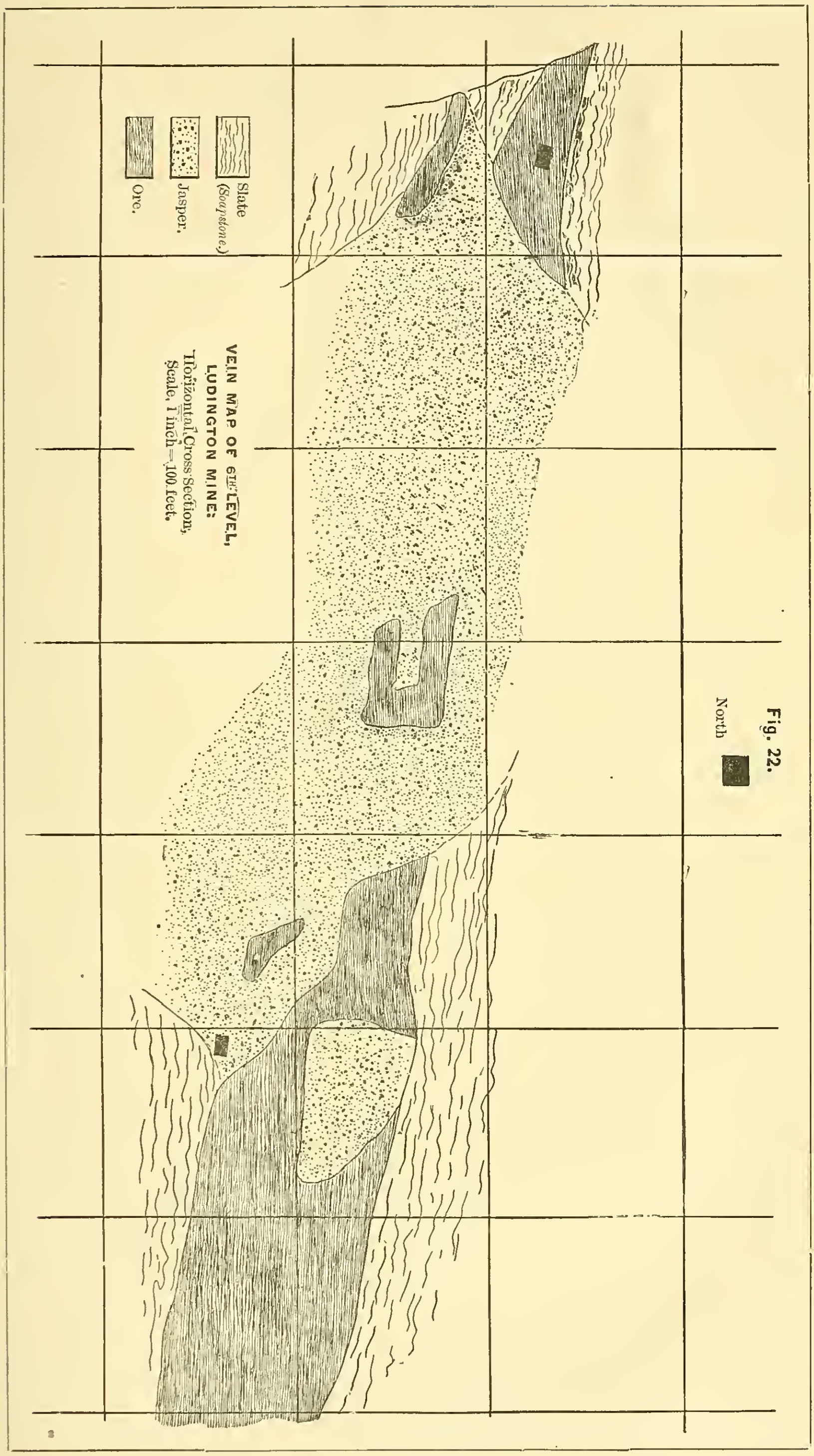
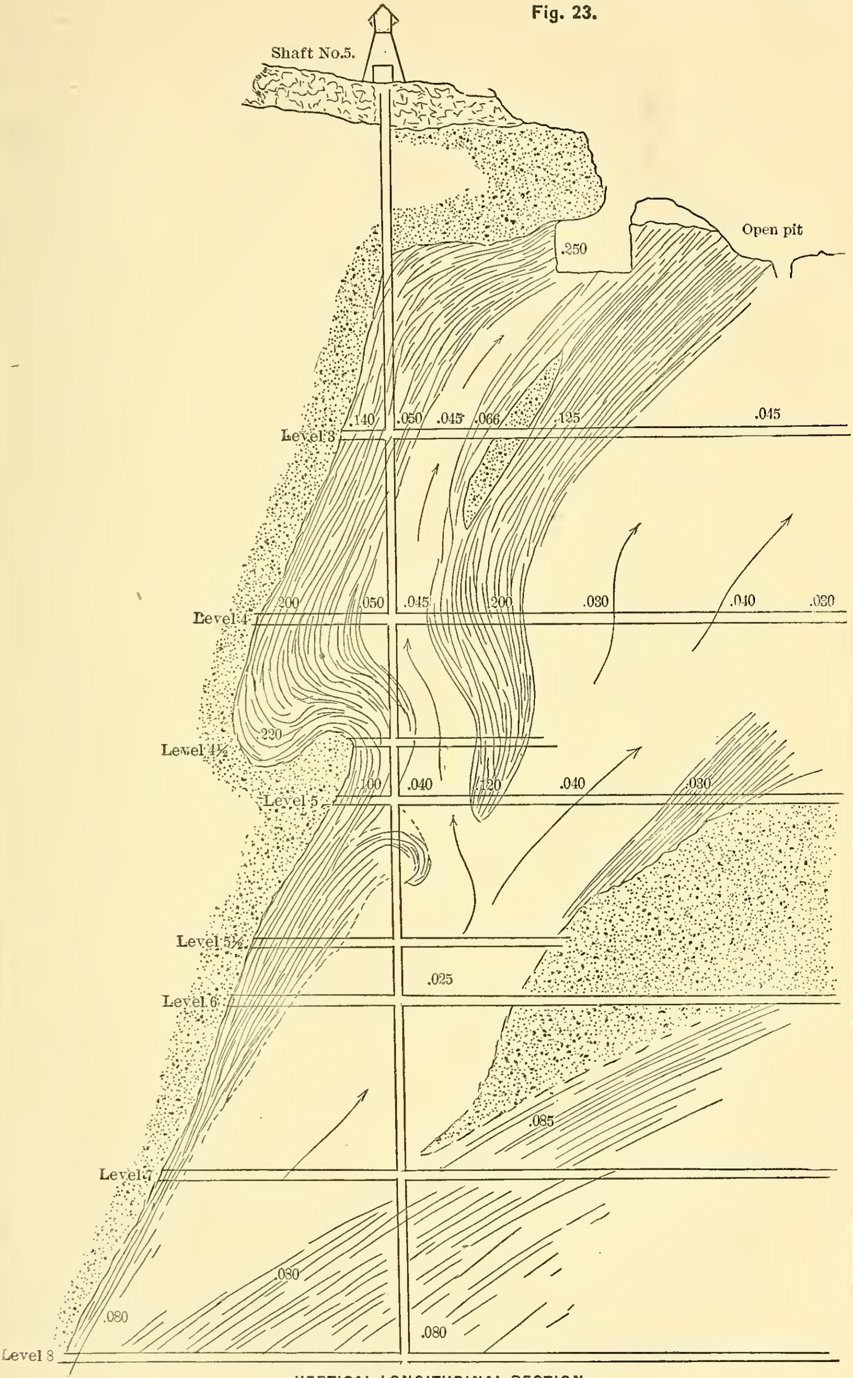

Slate (Soapstone.)
Jasper.
Ore.
VEIN MAP OF 6TH LEVEL,
LUDINGTON MINE:
Horizontal Cross Section,
Scale, 1 inch = 100 feet.
North

Fig. 22.

Fig. 23.



VERTICAL LONGITUDINAL SECTION.
West End of Main Deposit.
Ludington Mine.
Scale. 1 inch = 100 feet.

difference between these ores and the soft blue hematites occurring east of the Menominee River. The ore taken from the Nanaimo, Paint River, Iron River, and other non-Bessemer mines has all the non-laminated, massive, porous, reddish-yellow appearance of an altered bog ore. With this also the frequent occurrence of graphite, the high phosphorus, the intermixed calcareous matter, and the low percentage of iron seem to agree. From such beds as these, I incline to think the iron of our soft blue hematite mines has been carried. It is interesting to notice how this supposition is strengthened by chemical proofs. I have often noticed that very dilute solutions of hot acids will dissolve from an ore almost all of its phosphorus, with only a slight percentage of iron. Indeed it is possible, in this way, to remove and estimate the phosphorus without bringing the ore into solution. Nor is acid always necessary, for in a large number of instances also verified by experiment I have found that ore exposed for several years to the weather will have appreciable amounts of phosphorus dissolved and removed. Now if water acidulated by carbonic acid acts on a bed of bog ore, it will carry therefrom a large amount of phosphorus in proportion to the amount of iron removed. If such thermal water flows into a shallow valley or lake, the acid will be lost by evaporation, and precipitation of phosphorus and iron will take place.

The theory of aqueous deposit of these ore bodies, as drawn from chemical evidence, is then briefly as follows. From previously deposited beds of bog iron ore, by the action of acidulated water, iron, lime, silica and phosphorus were dissolved. The first solution contained a large amount of phosphorus in proportion to the amount of iron dissolved. On coming into hollows in the surface of the exposed slates, the acid solution, losing acid by evaporation, deposited iron, as hydrated oxide, which carried down an amount of phosphorus proportionate to the amount of iron precipitated. As the acid became still weaker crystals of carbonate of lime and magnesia settled out, forming a layer of carbonates. A second inflow of water would tend to dissolve these carbonates and precipitate another layer of iron. In similar manner by successive inundations the depression became filled with alternating layers of iron ore and calcium-magnesium carbonates, each layer being as a rule lower in phosphorus than the preceding one. As the carbonates were more soluble than iron, the probability is that the greater portion was replaced by iron ore. Moreover as both calcium and iron phosphate are of lower specific gravity, and more soluble than the hydrated oxide of iron, the tendency of the water was to carry these phosphates toward the lower end of the lake, and to deposit them in shallow water, along banks of previously precipitated silica, and in places where evaporation was most rapid. By reference to fig. 23, it will be seen that those parts of the deposit where the current must have been deep and unbroken are low in percentage of phosphorus, while the high phosphorus as a rule occurs where the deposit is shallow or the ore pinched out by rock. After the deposition was complete, further action of the water would stir up the upper layers of ore, and mix them with suspended sand or clay, while the iron and phosphorus were carried farther along to be deposited in other depressions to the northeast. As jasper occurs as vein matter, and in laminæ cleaving in the same line as the ore, it would seem, either that the jasper had been produced by precipitation with the iron, or that subsequent action of water has eroded the beds of iron thus formed and substituted silica for the iron removed.

A study of the vein map of the 6th level at the Ludington mine, on which level almost the entire deposit was replaced by jasper, and in consequence the formation of the jasper was most evident, seems to show that the jasper is a later formation than the ore. It will be seen by reference to fig. 17 that the jasper deposit widens toward the footwall. A large horse of jasper occurring in the ore at the eastern end of the vein shows this very plainly. This would seem to indicate that at a time when the ore deposit was about half its present width an inflow of silica-bearing water eroded the ore deposit and deposited silica in place of the iron abstracted. The greater width of the jasper at the footwall also suggests an erosion of the original ore bed and a subsequent deposition of silica. Had the silica been the primary deposit the ore would be widest at the footwall instead of at the hanging.

The explanation, however, of the deposits of silica bedded in the same plane with the ore, in some cases stopping sharply against ore, in others merging gradually into it, is at present a very difficult problem. The explanation suggested by Prof. Van Hise seems to me more satisfactory than any other, with the provision, however, that subsequent erosion must be taken into consideration. Whatever explanation of the horses of jasper be adopted, it is evident that both ore and jasper after formation were covered by the slates and other superincumbent strata, and in some local upheaval tilted up from the north and brought into their present position.

The erosion of the Glacial period removing several hundred feet of the outcropping strata has cut away a large part of the original deposits, and from the ore thus eroded have been formed the surface deposits or washes of ore found at Keel Ridge, Quinnesse and Norway mines.

The subsequent action of water upon the upturned edges of the eroded deposit would of course in large measure modify the chemical peculiarities of the ore. This is proved by the fact that the greatest regularity of isochemic lines is manifest where the ore is shielded from surface water by the overhang of the western jasper; and by the fact that at the eastern end of the mine where the ore has been exposed under the drift, this regularity is not so manifest. That the original direction of deposition was from west to east is shown by the occurrence underground of strong streams of water flowing from the rock at the western extremity of the ore deposit.

The theory of aqueous deposit will explain, as will no other, the marked regularity of isochemic lines and their peculiar curves, the regular decrease of phosphorus from hanging wall to foot, the alternation of carbonate of lime and oxide of iron, the ripple-marked hanging wall, the uniform lamination of the ore and the hydrated muddy deposit next the footwall. It also suggests explanation of the general features of the Menominee Range, and the gradual change from high phosphorus and low iron ores resembling altered bog ores at its western extremity, through regular deposits of high iron and lower phosphorus, to the immense washes and surface deposits of exceedingly low phosphorus ore which mark its eastern termination.

The conclusions herein given are not intended as general and applicable to all cases. They are intended simply as an explanation of certain chemical phenomena noticed in a careful study of the Ludington mine. Whether such tendencies would be found in other mines I am not prepared to say; but the fact that irregularity of chemical composition has been often noticed does not preclude the possibility of a method or law of irregularity existing. I incline to think that careful and systematic chemical research applied to the soft ore deposits of the upper Peninsula would bring to light many interesting facts with regard to their manner of deposit, and would lead to a more thorough understanding of one of the most practical and interesting problems of economic geology.

EXPLANATION OF FIGURES. PLATES VIII TO XIII.

Fig. 1. Horizontal cross section of small vein.

Fig. 1*a*. Horizontal cross section of vein showing curvature.

Fig. 2. Vertical cross section of same, showing curvature of hanging wall.

Fig. 3. Vertical longitudinal section showing form of hollows in which ore is deposited. This section is ideal, but corresponds with several known sections.

Figs. 4–16. Horizontal cross sections of various rooms in the Ludington mine. In all figures the hanging wall is toward the top of the plate, and the west end toward the left, as shown in fig. 4. Figures indicate percentages of phosphorus in the ore removed.

Fig. 18. Vertical longitudinal section of No. 5 room, A shaft, 6 level, in the plane of the winzes, showing curvature of isochemic lines. The figures show percentage of phosphorus in the ore at the points indicated.

Fig. 19. Vertical longitudinal section of 5 shaft between the 5th and 6th levels. Dotted lines are lines of equal chemical composition.

Fig. 20. Vertical longitudinal section of 5 shaft between 5½ and 6 levels, showing ore in winzes and its relation to ore in drifts.

Fig. 21. Vertical longitudinal section of 5 shaft between the 7th and 8th levels, showing depth of winzes and distances along drifts, and method of establishing an isochemic line.

Fig. 22. Vein map of 6 level, Ludington mine.

Fig. 23. Sketch map of the isochemistry of 5 shaft from surface to the 8th level. The dark lines represent high phosphorus ore, the open spaces and arrows low phosphorus ore and its direction of increase. The space covered by these lines and the figures is the ore deposit in part worked out. The jasper at the left shows the western limit of the ore deposit. The jasper occurring to the right of this constitutes what is known as horses of rock splitting up the vein and breaking the regularity of the deposit.

These figures are drawn from maps made by Mr. Chas. N. Snow, engineer of the Ludington mine, Mr. Per Larson, engineer of the Chapin mine, and Mr. E. Everett of Ishpeming, to whom I am much indebted for their kind assistance in the preparation of this paper.

Art. XXXIII.—*Palæohatteria* Credner, *and the Proganosauria;* by Dr. G. Baur.

One of the most important discoveries in Paleontology has just been made by Professor H. Credner of Leipzig, well known by his publications on the Stegocephalia of the Permian of Saxony.*

This discovery consists of a series of nearly complete skeletons of a reptile from the lower Permian (Rothliegendes). This reptile, with the exception of *Stereosternum* Cope, from the Carboniferous (?) of Brazil, is the oldest yet known. Professor Credner calls it *Palæohatteria* from the close resemblance to *Hatteria* from New Zealand, the only living member of the Rhynchocephalia. But since *Hatteria* is preoccupied by *Sphenodon*,† this new form really ought to be called *Palæosphenodon.* It is placed by Professor Credner among the Sphenodontidæ, but it has to be considered as the type of a distinct family, which may be called the *Palæohatteriidæ*, or *Palæosphenodontidæ*, in case the name *Palæosphenodon* shall be admitted by Credner.

Characters of the Palæohatteriidæ.—Skull resembling *Sphenodon;* lacrymal free from præfrontal; bones showing centers of ossification, like those of Stegocephalia; interclavicle

* Credner, Hermann: Die Stegocephalen und Saurier aus dem Rothliegenden des Plauenschen Grundes bei Dresden, vii Theil. *Palæohatteria longicaudata* Cred. Zeitschrift Deutsch. Geol. Gesellsch., 1888.

† *Sphenodon* Gray, 1831; *Sphenodon* Lund, 1839 (Mamm.); *Hatteria* Gray, 1841; *Sphenodon* Agass. 1843 (Fish.) Baur, G., Erwiderung an Herrn Dr. A. Günther. Zool. Anz., No. 245, 1887.

rhomboidal with long distal process, nearly of the same form as that of *Belodon*, *Aetosaurus*, and *Proterosaurus;* ilium expanded at the upper end ; claws well developed.

One of the most important characters of *Palæohatteria* consists in the presence of five distinct tarsal bones in the second row, one for each metatarsal. In this it agrees with *Stereosternum* Cope, which I placed in a new order, *Proganosauria.**

The *Mesosauridæ*† are a specialized family of this order. The *Palæohatteriidæ* on the contrary are a generalized group ; *they are Proganosauria, which gave origin to the Rhynchocephalia.*

I give now a new definition of the *Proganosauria.*—Humerus with entepicondylar foramen ; five distinct tarsal bones in second row, one for each metatarsal ; condyles of limb-bones not ossified ; pubis and ischium broad plates ; each set of abdominal ossicles consisting of numerous pieces.

1. *Palæohatteriidæ.*

Characters given above.

2. *Mesosauridæ.*

Skull elongate, with numerous very sharp and slender teeth ; first metatarsal the shortest, fifth metatarsal the longest bone. No claws.

The *Proganosauria* are Reptiles with many characters of the Batrachians ; the *Palæohatteriidæ* is the most generalized group among the *Monocondylia* (Sauropsida).

Some points in Professor Credner's paper need correction :

1. There are two not three or more sacral vertebræ.
2. The bones called "hyoids" may just as well be the epipterygoids (columellæ). If they represent hyoids, they resemble these elements in *Belodon* and *Ichthyosaurus.*
3. There is no free lacrymal in *Sphenodon* as figured by Credner.
4. The quadratojugal of *Sphenodon* is overlooked.
5. The so-called basisphenoid is probably the parasphenoid.
6. The foramen in the humerus is *entepicondylar* not ectepicondylar.
7. The carpal bones of *Proterosaurus* are wrongly determined ; the bone called radial represents the first central bone.
8. The figure of the embryo of "*Monitor*" is erroneously explained, by both Hoffmann and Credner ; the bone called tars. 5 is the metatarsal 5.

* Baur, G. On the Phylogenetic Arrangement of the Sauropsida. Journ. of Morphol., vol. i, No. 1, Sept, 1887.

† I use the family-name *Mesosauridæ.* It is probable that *Mesosaurus* Gervais is the same as *Stereosternum* Cope.

Some important results can be reached from the study of this ancient form:

1. The antorbital foramen or fossa is a secondary formation; all forms of Reptiles having this fossa descended from forms without it.

2. The peculiar short bone in the hind foot of the Reptilia, which some consider as a metatarsal 5, others as a tarsal 5, certainly represents the *metatarsal* 5.

3. The bones called epiplastra and endoplastron in the Testudinata are doubtless the clavicles and interclavicle. The clavicles and interclavicle of the Amniota represent the "mittleren und seitlichen Thoracalplatten" of the Stegocephalia and other Batrachia. These elements must be considered as dermal ossifications; the connection with the shoulder-girdle is secondary.

4. *The origin of the so-called "Abdominal ribs."* The *abdominal ossicles* or "ribs" are found to-day only in *Sphenodon* and the Crocodilia; the "abdominal ribs" of *Chamæleo*, *Polychus*, etc., are entirely different elements. There are no abdominal ossicles like those in *Sphenodon* found in *Palæohatteria*, *Proterosaurus*, *Hyperodapedon*. In these we have bundles of scale-like pieces. These we have to consider as the homologue of the same elements in the Stegocephalia and as the abdominal ossicles in the Rhynchocephalia, Ichthyosauria, Plesiosauria, Pterosauria, Crocodilia, Dinosauria, Saururæ. In nearly all these forms each set of abdominal ossicles consists of one or two median pieces and one lateral one on each side; but in the Ichthyosauria we find very often one median piece and *two* lateral ones on each side.

The idea, at first pronounced by Owen, that the plastron of the Testudinata has developed from abdominal bones is very probable.

5. *The foramina in the humerus of the higher Vertebrata.*—*a. No foramen:* Batrachia.

b. Foramen entepicondyloideum: Proganosauria, Theromora,† Mammalia.*

c. Foramen entepicondyloideum and foramen ectepicondyloideum: Sphenodontidæ, some humeri from the Permian of Russia.

d. Fossa entepicondyloidea and foramen ectepicondyloideum: Atoposaurus, Sapheosaurus, Nothosauridæ, part.

e. Foramen ectepicondyloideum: Testudinata, Lacertilia. Nothosauridæ part, Rhynchocephalia, part.

f. Fossa ectepicondyloidea: Belodon, Champsosaurus, Testudinata, part, etc.

g. No foramen: Crocodilia, Dinosauria, Pterosauria, Plesiosauria, Pythonomorpha, Birds, etc.

* If not lost by specialization.

† The name Theromorpha has been changed by Professor Cope to Theromora.

The oldest Reptiles, the *Proganosauria*, had only the foramen entepicondyloideum; from those the *Theromora* and *Mammalia* took their origin.* Some of the *Proganosauria*, which we do not know yet, probably developed also the foramen ectepicondyloideum; such forms connected the *Rhynchocephalia*. Then the entepicondylar foramen was lost again and later also the ectepicondylar foramen.

New Haven, Conn., March 5th, 1889.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Presence of a New Metal in Nickel and Cobalt.*—KRÜSS and SCHMIDT have discovered a new metal in both nickel and cobalt. These chemists had undertaken to determine the atomic mass of nickel and of cobalt, using for the purpose the pure material prepared by Zimmermann, the method of Winkler and the atomic mass of gold as corrected by Krüss, 196·64. When the solution of sodium-gold chloride was treated with metallic nickel or cobalt, the precipitated gold was found to be mixed with a small quantity of one or the other of these metals thrown down apparently by a secondary action. By dissolving the weighed precipitate in aqua regia, precipitating the gold with sulphur dioxide, subtracting its mass from that of the precipitate, the excess of nickel or cobalt was ascertained and allowed for. But still the method did not give concordant results. Finally it was noticed that in washing the gold precipitate obtained by sulphur dioxide from a solution of a previous precipitate thrown down by cobalt, the red color of the filtrate, due to cobaltous chloride, became gradually paler and finally acquired a pale greenish color. This portion of the wash water was collected and evaporated in a platinum dish, and left after ignition a slight residue which dissolved in concentrated hydrogen chloride solution on warming, with a beautiful green color, the color disappearing on cooling. A similar result was obtained when nickel was used to precipitate the gold. A chloride solution was obtained on evaporating the wash-water and dissolving in hydrogen chloride in which no nickel or other known element could be detected. In order to obtain a larger quantity of the new substance, nickel sulphide was treated with ammonium sulphide so long as the solution became brown. The new element became concentrated in the residue. So an increase of the new chloride in the mother liquors was obtained by crystallizing the double chloride of mercury-nickel or mercury-cobalt from a

* Baur, G. Ueber die Kanaele im Humerus der Amnioten. Morph. Jahrbuch, vol. xii, 1886, pp. 299–305. On the Phylogenetic Arrangement of the Sauropsida. Journ. of Morphology, vol. i, No. 1, Sept., 1887.

solution containing equivalent quantities of both chlorides. Finally it was observed that the new oxide was soluble in fused caustic alkali, in which cobalt and nickel oxides are insoluble; and thus it was obtained pure, 50 grams nickel oxide yielding about one gram of the white oxide. Its properties are as follows: The acid chloride solution is not precipitable by hydrogen sulphide, but ammonium sulphide produces in neutral solutions a blackish sulphide. Ammonia throws down a voluminous white flocculent precipitate, not soluble in excess. Potassium hydrate acts similarly. On igniting the oxide moistened with cobalt solution, only a weak brown color results. Even after strong ignition, the oxide is soluble in the cold in a 27 per cent hydrogen chloride solution. With excess of acid, the chloride is green, but the neutral chloride is white and gives with water a colorless solution. The oxide does not change its weight when ignited in hydrogen. The metal can be obtained, however, by electrolyzing the chloride solution or by reducing the chloride in a current of hydrogen. It is black, brownish-black in thin layers, dissolves readily in acids when produced electrolytically, more difficultly when produced at a high temperature. Further researches on the new metal are in progress by the authors.—*Ber. Berl. Chem. Ges.*, xxii, 11., January, 1889. G. F. B.

2. *On the Atomic Mass of Tin.*—BONGARTZ and CLASSEN have undertaken a redetermination of the atomic mass of tin. For this purpose they employed four methods: 1st, the oxidation of the tin to stannic oxide; 2d, the electrolysis of ammonium stannic chloride, $SnCl_4(NH_4Cl)_2$; 3d, the electrolysis of potassium-stannic chloride; and 4th, the electrolysis of stannic bromide. The mean of eleven experiments by the first method gave the value 118·7606 for the atomic mass of tin; the difference between the maximum and the minimum values being 0·459. The mean of sixteen experiments by the second method was 118·8093, the difference between the greatest and least value being 0·228. The mean of ten experiments by the third method was 118·7975, the difference between the extreme values being 0·163. And the mean of ten experiments by the fourth method was 118·7309, the difference being 0·144. The final mean of the 47 experiments was 118·7745; or taking the 26 experiments in which the difference between maximum and minimum was least, 118·8034; taking oxygen at 15·96.—*Ber. Berl. Chem. Ges.*, xxi, 2900, October, 1888. G. F. B.

3. *Studies from the Laboratory of Physiological Chemistry, Sheffield Scientific School of Yale University for the years* 1887–88. Volume III. Edited by R. H. CHITTENDEN, Ph.D. 157 pp. 8vo. New Haven, January, 1889.—The present volume of this series, like those already issued (noticed in vols. xxxii and xxxiii of this Journal) contains a series of important papers upon different subjects in physiological chemistry. They embody the results of work done in the Sheffield Laboratory and show the high position that it occupies as a school of research as well as one of training.

4. *On the divergence of Electromotive forces from Thermo-Chemical data.*—Professor E. F. HERROUN, sums up his research as follows:—

(1.) The primary factor in determining the electromotive force of a Voltaic cell is the relative heat of formation of the anhydrous salts of the two metals employed.

(2.) That the E. M. F. may set up chemical changes of a different direction and character from those predicable from the heat of formation of the dissolved salts.

(3.) That the E. M. F. set up by (1) may be, and usually is supplemented by the energy, or a portion of the energy, due to the hydration or solution of the solid salts, and may have values which accord with the heat of formation of the dissolved salts.

(4.) That in those cases in which there is no chemical attraction, or a very feeble attraction between the water and the salt, the negative heat of solution is derived from sensible heat, and is not supplied by the free energy of the chemical change. All cells in which such salts are employed opposed to zinc should have negative "Thermo voltaic constants" and evolve heat when they send a current forward.

(5.) That when metals, whose salts have purely negative heats of solution, are oppposed to metals whose salts they can replace, the E. M. F. set up is in excess of the total thermal change. Such cells therefore, absorb sensible heat when worked forward.

(6.) That, taking the foregoing facts into consideration, no cell exists which can furnish an E. M. F. in excess of the free energy of the chemical change: i. e. which can convert sensible heat into electrical energy working at uniform temperature (negatives the supposition concerning mercury and other salts.)

(7.) That certain metals have a tendency to form films of sub-salts on their surfaces, the formation of which giving rise, as it does, to a different thermo chemical reaction, naturally furnishes an E. M. F. which does not correspond with the values calculated from the heats of formation of their normal salts (*ex. gr.* copper in cupric chloride, mercury in mercuric chloride, probably silver in most soluble chlorides).

(8.) That the electromotive force of a voltaic cell furnishes a more accurate measurement of this free energy, and therefore of true chemical affinity, than data derived from calorimetric observations."—*Phil. Mag.*, March, 1889, pp. 209–233. J. T.

5. *Behavior of Metals to Light.*—At a meeting of the Physical Society, held in Berlin, Jan. 11, KUNDT gave an account of his experiments on the refraction of light by metals. Metals whose refractive index is large, showed an increase of the angle of deviation of light as the temperature rises; thus proving that the author was dealing with true refraction. A further outcome of his experiments was to show that the velocity of light in metals is dependent on changes of temperature in a way exactly similar to that in which their electrical conductivity is dependent.—*Nature*, Feb. 7, 1889, p. 360. J. T.

6. *Hertz's experiments on Electro-magnetic Waves.*—Professor FITZGERALD and Mr. F. T. TROUTON have repeated Hertz's experiments. Ordinary masonary walls were found to be transparent to electrical waves of ten meters in length, with an apparatus suitable for dealing with definite angles of incidence. With a wall three feet thick reflection was obtained, when "the vibrator" was perpendicular to the place of reflection; "but none, at least at the polarizing angle, when turned through 90° so as to be in it." This decides the point in question, the magnetic disturbance being found to be in the plane of polarization, the electric at right angles.—*Nature*, Feb. 21, 1889, p. 391. J. T.

7. *Electrified Steam.*—"HELMHOLTZ has shown that if an invisible jet of steam be electrified or heated it becomes visible with bright tints of different colors according to the potential or the temperature."—*Nature*, Jan. 24, 1889.

8. *Viscosity of gases at high temperatures and a new Pyrometric method.*—The subject of the viscosity of gases has been investigated by Maxwell, O. E. Meyer, S. W. Holman and others. Dr. Barus in a very exhaustive paper reviews the work of previous observers, and adds valuable results on viscosity at high temperatures. Obermayer had investigated the subject up to 280°, Holman with carbonic acid to 224° and with air to 124°, E. Wiedeman at 100° and 185°. Dr. Barus has carried his observations to 1000°. Temperature was measured by the combination of a porcelain air-thermometer and a thermal junction of platinum and platinum-iridium. Further details of this method of measuring high temperature are reserved for the forthcoming bulletin No. 54, of the U. S. Geological Survey. The observations suggest to Dr. Barus a method of measuring high temperatures which is based upon Meyer's equation of gas transpiration. He entitles the method transpiration pyrometry and gives a comparison of the temperatures measured by this method with those obtained by a direct method, and believes that greater precision in the measurement of high temperature can be obtained by this method than by any other method, not even excepting the method of the porcelain air-thermometer. The paper concludes with a careful discussion of the results upon viscosity which the author has obtained; a plate giving diagrams of the apparatus and the curves which represent the results accompanies the paper. —*Ann. der Physik und Chemie*, vol. xxxvi, 1889, pp. 358–398.

J. T.

II. GEOLOGY AND NATURAL HISTORY.

1. *Brachiospongidæ: On a Group of Silurian Sponges, by Charles Emerson Beecher.* 28 pp. 4to, with 6 plates. Mem. Peabody Mus., Yale Univ., Vol. II, Part 1. New Haven, Conn., 1889.—The first known specimen of the Brachiospongidæ was described and figured, as Mr. Beecher states, by Troost in 1839, but not named. It was from Tennessee. The same species and prob-

ably the same specimen was described by Prof. O. C. Marsh in this Journal in 1867, and named *Brachiospongia Rœmerana.* In 1858, in vol. ii of the Kentucky Geological Survey, the species was named *Scyphia digitata*, by D. D. Owen, from Kentucky specimens, and afterward *Scyphonia digitata.* Mr. Beecher, in his memoir, after presenting further facts respecting the synonymy of the species and describing its geological position as in the Trenton limestone, gives a detailed account of the species under the name *Brachiospongia digitata*, and illustrates it with excellent figures on plates I to IV, showing its various forms, its external and internal structure and its hexactinellid spicules. The number of arms or lobes is shown to be a variable character, the extremes observed being 8 and 12, and the extremes in diameter, 3¼ and 11 inches. Specimens with 12 arms, the maximum number, vary in size from 6 to 10½ inches.

Besides the full account of the Brachiospongia, Mr. Beecher describes and figures also two species of a new genus of Hexactinellid Sponge, named by him *Strobilospongia*, based on specimens collected by himself with the Brachiospongia in Franklin County, Kentucky. The sponge has irregularly rounded lobes grouped about the surface of a stout central mass or stem. The species are *S. aurita* Beecher and *S. tuberosa* Beecher. The memoir is a very important contribution to the science of American Paleozoic Sponges.

2. *On the Waverly Group of Ohio.*—In a paper on the Geology of Licking Co., Ohio, contained in the Bulletin of the Denison University (Granville, Ohio), Vol. IV, Parts 1 and 2, dated December, 1888, Prof. C. L. Herrick continues, from the preceding number, an enumeration of the fossils obtained from the Waverly group and describes and figures (Plates I to XI) some new species. His papers occupy 85 pages of the number. He arrives at the following arrangement of the Waverly series, beginning below:

(1.) Berea or Transition Series, *the western equivalent of the Upper Chemung:* (1) Cleveland shale (local), 50 feet; (2) Bedford shale, 50 ft.; (3) Berea grit, 50–60 ft.; (4) Berea shale (including, besides the Black shale, the greater part of the shale below the Kinderhook), 200–400 feet; (5) Waverly shale, 40 feet.

(2.) Cuyahoga or Waverly Series, *Subcarboniferous:* (1) Kinderhook, Conglomerate I, 50 to 60 feet (not represented in the northern and eastern counties of Ohio); (2) Logan, or the Burlington and Keokuk, Conglomerate II, 100 to 150 feet.

The fossils from the Bedford shale leading to a reference of it to the Chemung are: *Lingula melie* H., *Orbiculoidea Newberryi* H., *Orthis Vanuxemi* H.,* *Chonetes scitula*,* *Ambocoelia umbonata*,* *Hemipronites* sp., *Macrodon Hamiltonæ* H.,* *Microdon bellistratus* Con.,* *Leda diversa*, var. *Bedfordensis*,* *Palæoneilo Bedfordensis* Meek (= var. of *P. constricta*), *Pterinopecten* sp., *Bellerophon Newberryi*,* *B. lineata* H.?, *Loxonema* resembling *L. delphicola*,* *Orthoceras* resembling *O. tintcum*, *Gonia-*

tites resembling a Portage species, *Pleurotomaria* cf. *P. sulcomarginata*. The names marked with an asterisk are Hamilton species, or near them. The Trilobite tribe has its species through the series instead of being absent as in the Chemung and Catskill of New York.

3. *Saccamina Eriana* (Communicated).—I observe that this little fossil has again come under the notice of naturalists.* When specimens from Sandusky were kindly sent to me some years ago by my friend Dr. Newberry, I was, as a paleontologist, naturally disposed to refer them to *Characeæ*, but a comparison with specimens from the French Tertiaries convinced me that this was untenable, and as I found that in form and texture, though not in material, the fossil corresponded to the well-known *Saccamina* of the Carboniferous, I placed it provisionally in that genus.† Subsequently, and apparently without knowing what I had done, Ulrich ("Contributions," Vol. I, 1886), described the Ohio Falls specimens, and referred them to Foraminifera as I had done, but with the new name *Mœllerina Greenei*. I may say that I still hold to my original opinion that these organisms are foraminiferal tests, for the reasons fully stated in my paper in the Canadian Naturalist, 1883, and which I think have not yet been controverted.

I have no other objection to Dr. Williamson's name, *Calcisphæra*, except that it seems certain that the organisms from Kelley's Island are of entirely different nature from those from Wales, and therefore should not bear the same name. I also consider it probable that the specimens described by Ulrich are specifically distinct, though it is not unlikely that the double wall described by him may be a result of difference of preservation rather than original structure. In my specimens the wall seem continuous and granular, having in fact a similar structure to that of other fossil Foraminifera whose tests are composed of calcareous grains. My specimens show some indications that the test was finely porous. This caused me to suggest a possible affinity with *Lagenidæ*, which I find Ulrich also suggests.

J. WM. DAWSON.

Montreal, March 8, 1889.

4. *Ueber eine durch die Häufigkeit Hippuritenartiger Chamiden ausgezeichnete Fauna der oberturonen Kreide von Texas; von Ferdinand Roemer in Breslau. Paleontologische Abhandlungen*, Viertes Band, Heft 4. Berlin, 1888. 4to, 15 pp. 3 plates.—In this valuable paper Dr. Roemer describes with his usual skill, a most interesting fauna from Barton's creek, a few miles west of the city of Austin. The descriptions are excellent and the figures beautiful. Twenty-one species are figured and described, of which eighteen are alleged to be new. As the reviewer has made a special study of the faunal and stratigraphic horizons of these fossils, he would here correct one or two mistakes in the otherwise excellent publication. Instead of being

* Knowlton, this Journal, March, 1889.

† Canadian Naturalist, 1883.

from the Austin Chalk of Shumard (Niobrara of M. & H.) as the author asserts, all of these forms came from an entirely different and lower horizon, separated by four distinct subfaunas, a complete stratigraphic and paleontologic non-conformity, and four hundred feet of strata below that horizon, and hence the deductions and correlations of Dr. Roemer are unfounded. The twenty-one species mentioned, together with a half dozen or so in the writer's possession, which escaped Dr. Roemer's attention, are mostly non-criterional genera (except the aberrant bivalves), which range in European terranes from Jurassic to present, but which are especially numerous in the upper Jurassic and Lower Cretaceous, all being found in the European Neocomian, especially the peculiar aberrant bivalves and the Nerineas—the varieties described of the latter having especial Jurassic affinities. Hence, Dr. Roemer's assignment of this fauna to the Upper Turonian horizon is not based upon sufficient evidence either stratigraphical or paleontological. They belong to the Hippurites Limestone of Shumard, whose stratigraphic place as given in my section is in the middle of the Lower American Cretaceous. R. T. HILL.

5. *Shall we teach Geology? A discussion on the proper plan of Geology in modern education;* by ALEXANDER WINCHELL. 217 pages, 12mo.—Prof. Winchell makes in this volume a strong plea for the study of geology in schools and higher institutions of learning, treating at length of its educational value as compared with other subjects of study, its ethical influence, and the bearing of its developments on modern civilization. His large experience enables him to bring forward in illustration, a wide range of facts with regard to the science, and the best methods of instruction.

6. *The Descending Water-current in Plants and its Physiological Significance.* J. WIESNER (*Botanische Zeitung*, Jan. 4, 1889).—In an earlier paper the author gave an account of the supposed existence of a downward movement of water in the branches and stems of plants. In the present communication he points out the bearing of his discovery upon the coördination of the various organs. Experimental proof of the existence of the descending current of water is thought by the author to be afforded in the following way. When a severed leafy shoot of fresh grape-vine is immersed in water, the tissues are more turgescent than before they are covered by water, indicating absorption through the epidermis. If, now, the middle portion of such a shoot is lifted into the air, so that transpiration can go on rapidly, the upper part of the shoot, which is still immersed, will soon become wilted, showing that it is furnishing water to the parts lower down the stem. Assuming that this experiment shows the existence of a downward current, the author passes at once to the application of this fact to the explanation of the development of various parts. He believes, for instance, that the opening of many flowers and flower-clusters is caused largely by the movement of water in the branch or stem, and especially

by the so-called downward current. Other examples cited by the author are the following: (1) Sympodial leafy shoots, (2) Terminal buds, (3) Axillary buds, (4) Acaulescent plants and clusters of radical leaves. All of the cases to which the author applies his hypothesis seem to be perfectly explicable upon the older view that the water in a plant moves in lines of least resistance toward points of consumption or outflow. Thus in the well-known instance of the flow of sap from a maple tree which is tapped, there is undoubtedly, for the time, a descending current; but that there is, under normal conditions, anything answering to this, is not shown by the experiment in question. It should be said, however, that the author promises a more extended communication upon this subject. G. L. G.

7. *Certain Coloring Matters in Fungi.* W. ZOPF (Botan. Zeit., Jan. 4, 1889).—The author adds to the long list of pigments found in fungi a few of great interest. He points out the close similarity which exists between the yellow coloring matters in a few fungi and the yellow colors which are derived from some of the higher plants. From some of the tissues of the fungi in question a fatty coloring matter can be isolated by the process of saponification which was suggested by Kühne, and has been successful in other cases; but from certain bacteria which he studied, although the pigment could be obtained, it could not be procured in a condition of purity.

In order to settle the question of the relations of light to the formation of this yellow color, the author cultivated for control, the organism in different nutrient liquids and on different nutrient solids in the light, using the same organisms on precisely the same substances kept in absolute darkness. After the lapse of about a fortnight, the color was found to be as dense in the latter as in the former case. For completeness in nomenclature the author suggests that these substances, so similar in their relations as regards absorption spectra, a series of terms should be given as *anthoxanthin*, *mycoxanthin* and *bacterioxanthin.* The coloring matters of plants are, so far as their physiological significance is concerned, to be regarded as waste products (see Vine's Physiology of Plants, p. 242), which chemically are allied to the aromatic series. Since the fungi have no chlorophyll to begin with, and since, further, these organisms studied by Zopf have the power of producing coloring matters, akin to those of the higher plants, out of colorless substances like gelatin, or agar-agar, some of the pigments must be excluded from the series formerly believed to be products of the degradation of chlorophyll-pigment. G. L. G.

8. *The Bacterial Forms found in Normal Stomachs.*—J. E. ABELOUS (Comptes rendus, cviii, 310, Feb., 1889) reports the results of his studies in the laboratory of Professor Lannegrace. Besides seven forms of microbes previously known, the author adds nine as occurring in the juices of the healthy stomach upon which experiments were conducted. Proper care appears to have been exercised to exclude all foreign germs from the apparatus used

for withdrawing the liquids of the stomach, and the subsequent cultures seem to have been carried on with care. The conclusions are the following: (1) In the stomach in the normal condition, there are very numerous microbes, some of which can live in strongly acid liquids, and a few of them can exist without air. (2) All of these microbes, when under the conditions of experiment, were found to produce prompt effects on alimentary substances. (3) Taking into account the long time required for some of these microbes to act on the alimentary substances in which they were placed, the author thinks that they must exert their principal effect upon the food after it has passed from the stomach into the intestinal tract. (4) In the intestines, the microbes play a very important part in digestion, since in the experiments, that is to say, under what he calls comparatively unfavorable conditions, many of them can decompose alimentary matters. The author regard his results as confirmatory in all respects of the views expressed by Pasteur and Duclaux. G. L. G.

9. *Mr. Morong's Journey in South America.*—Mr. Walter Deane, of Cambridge, Mass., sends us the following communication:—"I have received a letter lately from the Rev. Thomas Morong which will interest his friends. The letter is dated Asuncion, Paraguay, Dec. 28, 1888, where he is at present located. Mr. Morong left Boston, July 30, 1888, in the bark Eric J. Ray bound for Buenos Ayres. He went under the auspices of the Torrey Botanical Club, to collect and study the flora of South America, and reached his destination Oct. 8 in just 70 days, after a delightful passage with 'clear days and nights, balmy air and soft breezes.' He has just published a sketch of 'First Glimpses of South American Vegetation' in the February number of the Torrey Bulletin. He writes in excellent spirits and says, 'My health has been first rate ever since I stepped on South American soil and I have not had to take a drop of medicine once.' Ever since he reached Asuncion, which was about the first of November last, he has been most diligently collecting the rich and varied vegetation of that tropical country. He makes the following curious statement:—'The water vegetation disappoints me, not a Potamogeton, or Naiad, or Chara, to be found. But I have seen and collected the Victoria regia, and that makes up in a measure for my disappointment.' Mr. Morong says that he has some 2500 specimens, including about 250 species, already dried and ready to send north. At Asuncion nobody ventures out of doors between the hours of 11 A. M. and 3 P. M. 'for the sun at 115° is a little too much for flesh and blood.' So his botanical tours are made at 5 A. M. about the time when the business of the city begins. 'Botanizing stops when they have a downpour of rain characteristic of that region, for then a regular river runs through the streets, nobody goes out, schools close, stores shut up and all stay at home.' Asuncion is to be his headquarters at present, as he finds that he can accomplish more there than at Buenos Ayres."

10. *The Botanic Garden at Buitenzorg, Java.*—Dr. TREUB (Comptes rendus, cviii, 211, Feb., 1889) says that the Garden comprises three parts. (1), the Botanic Garden, properly so-called, at Buitenzorg, consisting of a collection of between eight and nine thousand species of plants, (2), that at Tjibodas, situated in one of the most mountainous districts, at an altitude of 1500 meters, and (3), the Experimental Garden in the Tjikeumeuh quarter, where are the plantations for raising the plants which possess economic use in the tropics. In the Garden at Buitenzorg, besides the Bureau of Administration, there is a museum, together with an herbarium. There is also a laboratory equipped for physiological and phytochemical research. A photographic studio completes the outfit. The whole institution is now so arranged that botanists can carry on their investigations under the most favorable auspices. In fact, it is the design of the direction to make it as useful to Botany as the zoölogical station at Naples, is to zoölogy. For the support of the establishment, the Government of the Dutch East Indies grants annually the sum of 150,000 francs. G. L. G.

11. *The Structure of the "Crown" of the Root.*—LÉON FLOT (Comptes rendus, cviii, 306, Feb., 1889) gives the results of his examination of the histology of the zone where the stem joins the root. He regards this tissue system as a special structure. Morphologically speaking, this part may be said to possess, besides stem proper, a larger or smaller section of the epicotyledonary axis, and it appears to be derived directly from the nodal portion previously existing in the embryo. G. L. G.

OBITUARY.

Mr. U. P. JAMES, long and well-known to geologists and paleontologists as a student of the fossils of the Cincinnati Group, died at his residence near Loveland, Clermont County, Ohio, on February 25th in his 78th year. He was born December 30th, 1811, in Goshen, New York and went to Cincinnati in 1831 where he has since resided. He established himself in the book-selling and publishing business in connection with his brother Joseph A. James, but afterwards continued the business by himself. As a recreation he interested himself in the sciences of conchology and paleontology and amassed a very large collection of the shells and fossils of the locality in which he lived. Many of the latter were described by himself while others were described in volumes of the Geological Survey of Ohio by Meek, Hall and Whitfield. He published the first catalogue of fossils of the Cincinnati Group, contributed papers to the Cincinnati Quarterly Journal of Science, the Journal of the Cincinnati Society of Natural History, and published the Paleontologist in seven issues. The study of conchology occupied his earlier years, but in later life he devoted his time to paleontology. He was married in 1847 and leaves a widow, two sons and three daughters. The older son manages the business affairs in Cincinnati, while the younger is connected with the U. S. Geological Survey.

APPENDIX.

Art. XXXIV.—*Comparison of the Principal Forms of the Dinosauria of Europe and America;** by Professor O. C. Marsh.

The remains of Dinosaurian reptiles are very abundant in the Rocky Mountain region, especially in deposits of Jurassic age, and during the past ten years, the author has made extensive collections of these fossils, as a basis for investigating the entire group. The results of this work will be included in several volumes, two of which are now well advanced towards completion, and will soon be published by the United States Geological Survey.

In the study of these reptiles, it was necessary to examine the European forms, and the author has now seen nearly every known specimen of importance. The object of the present paper is to give, in few words, some of the more obvious results of a comparison between these forms and those of America which he has investigated.

With this purpose in view, it will not be necessary to discuss here the classification of the Dinosauria, their affinities, or their origin. These topics will be treated fully in the volumes in preparation. For the sake of convenience, however, the ordinal names proposed by the author, and now in general use, will be employed.

* Abstract of a paper read before Section C, of the British Association for the Advancement of Science, at the Bath Meeting, Sept. 8th, 1888.

Sauropoda.

The great group which the author has called *Sauropoda*, and which is represented in America by at least three well-marked families, appears to be rare in Europe. Nearly all the remains hitherto discovered there have been found in England, and most of them, in a fragmentary condition. The skull is represented only by a single fragment of a lower jaw and various isolated teeth, and, although numerous portions of the skeleton are known, in but few cases have characteristic bones of the same individual been secured.

Quite a number of generic names have been proposed for the remains found in England, and several are still in use, but the absence of the skull, and the fact that most of the type specimens pertain to different parts of the skeleton, render it difficult, if not impossible, to determine the forms described.

In the large collections of *Sauropoda* secured by the author in America, which include the remains of more than one hundred individuals, both the skull and skeleton are well represented. On this material, his classification of three families, *Atlantosauridæ*, *Morosauridæ*, and *Diplodocidæ*, has been based. The *Pleurocœlidæ*, also, appear to be distinct, but the remains at present known are less numerous and characteristic than those pertaining to the other divisions of this group.

In examining the European *Sauropoda* with some care, the author was soon impressed by three prominent features in the specimens investigated :

(1) The apparent absence of any characteristic remains of the *Atlantosauridæ*, which embrace the most gigantic of American forms.

(2) The comparative abundance of another family (*Cetiosauridæ*), nearly allied to the *Morosauridæ*, but, as a rule, less specialized.

(3) The absence, apparently, of all remains of the *Diplodocidæ*.

A number of isolated teeth, and a few vertebræ of one immature individual appeared to be closely related to the *Pleurocœlidæ*, but this, for the present, must be left in doubt.

Among the American forms of *Sauropoda*, the skull is now comparatively well known in the principal families and genera. *Brontosaurus*, *Morosaurus*, and *Diplodocus*, typical of their respective families, are each represented by several skulls, some of which are nearly complete, and characteristic portions are known of the skulls of other genera.

The vertebræ, also, and especially the pelvic arch, afford distinctive characters. By the latter alone, the *Atlantosauridæ* and *Morosauridæ* may be readily distinguished. In the absence of the skull, this is a point of importance in a comparison of European with American forms.

In the *Atlantosauridæ*, the ischia are nearly straight, and when in position, extend downward and inward, meeting on the median line by a symphysis of the two ends, as in crocodiles. In the *Morosauridæ*, the ischia are twisted, and extend inward and backward, with the inner margins alone meeting each other on the median line, the ends being free.

All the ischia of *Sauropoda* known from Europe appear to be of the latter type, although proportionally broader and more massive than those of the corresponding American forms. The ilia and pubes associated with these ischia agree in their main features with those of the American genus *Morosaurus*, so that there can be little doubt that the same general form is represented in both countries.

A striking difference between the *Cetiosauridæ* and the allied American forms is that, in the former, the fore and hind limbs appear to be more nearly of the same length, indicating a more primitive or generalized type. Nearly all the American *Sauropoda*, indeed, show a higher degree of specialization than those of Europe, both in this feature and in some other respects.

The identity of any of the generic forms of European *Sauropoda* with those of America is at present doubtful. In one or two instances, it is impossible, from the remains now known, to separate closely allied forms from the two countries. Portions of one animal from the Wealden, referred by Mantell to *Pelorosaurus* under the name *P. Becklesii*,* are certainly very similar to some of the smaller forms of *Morosaurus*, especially in the proportions of the fore limbs which are unusually short. This fact would distinguish them at once from *Pelorosaurus*, and until the skull and more of the skeleton are known, they cannot be separated from *Morosaurus*, and should be known as *Morosaurus Becklesii.* During the examination of this specimen, which is in the collection of its discoverer, Mr. S. H. Beckles, of St. Leonards, England, the author found, attached to the humerus, portions of the osseous dermal covering, the first detected in the *Sauropoda*, and known only in the present specimen.

A dozen or more generic names have been proposed for the European forms of *Sauropoda*, and of these, *Cetiosaurus*,

* Morris' Catalogue of British Fossils, p. 351, 1854.

Owen, 1841, is the earliest, and must be retained. The remains on which this genus was based are from the Great Oolite, or Middle Jurassic. *Cardiodon*, Owen, 1845, is from nearly the same horizon, and there appears no evidence that the two forms are not identical. *Pelorosaurus*, Mantell, 1850, is from the Wealden, and may be distinct, but, at present, the proof is wanting. *Oplosaurus*, Gervais, 1852, also from the Wealden of England, cannot well be separated from *Pelorosaurus. Gigantosaurus*, Seeley, 1869, from the Kimmeridge of the Upper Jurassic, may prove to be different from the above, but the type specimens alone do not indicate it. *Bothriospondylus*, Owen, 1875, is also from the Kimmeridge, and, although the type specimen pertains to a very young, if not fœtal individual, it seems to be distinct, and may be nearly allied to the American genus *Pleurocœlus.* The author failed to find conclusive evidence in the type specimens themselves for the use of the other generic names proposed, namely: *Ornithopsis*, Seeley, 1870, from the Wealden; *Eucamerotus*, Hulke, 1872, Wealden; *Ischyrosaurus* (preoccupied), Hulke, 1874, Kimmeridge; and *Chondrosteosaurus*, Owen, 1876, Wealden.

Æpyosaurus, Gervais, 1852; *Macrurosaurus*, Seeley, 1876; and *Dinodocus*, Owen, 1884, all represent forms from the Cretaceous, but their relations to each other cannot yet be determined.

Discoveries of more perfect specimens may establish the fact that the forms in the different geological horizons are distinct, but as long as the known remains are so isolated and fragmentary, this point must be left in doubt.

The European *Sauropoda* at present known are from deposits more recent than the Lias, and none have been found above the Upper Greensand. In America, this group apparently has representatives in the Trias, was very abundant in the Jurassic, but, so far as now known, did not extend into the Cretaceous.

STEGOSAURIA.

Another group of Dinosaurian reptiles, which the author has called the *Stegosauria*, from the typical American genus *Stegosaurus*, is well represented in European deposits. The remains already discovered are more numerous, and in better preservation, than those of the *Sauropoda*, and the number of distinct generic forms is much larger. The geological range, also, is greater, the oldest forms known being from the Lias, and the latest, from the Cretaceous.

These reptiles, although very large, were less gigantic in size than the *Sauropoda*, and were widely different from them in their most important features. Their nearest allies were the *Ornithopoda*, to which they were closely related.

All the known members of the group appear to have had an osseous dermal armor, more or less complete.

One of the best preserved specimens of the *Stegosauria* in Europe was described by Owen, in 1875, as *Omosaurus armatus*, and the type specimen is in the British Museum. It is from the Kimmeridge Clay (Upper Jurassic), of Swindon, England. The skull is wanting, but the more important parts of the skeleton are preserved. Various portions of the skeleton of several other individuals have also been found in England, but the skull and teeth still remain unknown.

A recent examination of these specimens by the author disclosed no characters of sufficient importance to separate them from the genus *Stegosaurus*, and, as the name *Omosaurus* is preoccupied, they should, for the present, at least, be referred to *Stegosaurus*. The discovery of the skull and the dermal armor may not unlikely prove them to be distinct, but the parts now available for comparison do not alone authorize their separation.

The type specimen of *Anthodon serrarius*, Owen, a fragment of a jaw from South Africa, and now in the British Museum, has teeth so very similar to the American forms of *Stegosaurus*, that, judging from these alone, it would naturally be referred to that genus. *Hylæosaurus*, Mantell, from the Wealden, has teeth of the same general type, but most of those referred to it, by Mantell and others, pertain to the *Sauropoda*. This genus, as well as *Polacanthus*, Hulke, from the same formation, *Acanthopholis*, Huxley, from the Cretaceous, and *Scelidosaurus*, Owen, from the Lias, are known from English specimens, but have not yet been found on the continent. No American forms of these genera have yet been discovered.

An interesting Cretaceous member of this group is the *Struthiosaurus*, Bunzel, 1871, apparently identical with *Danubiosaurus* of the same author, 1871, and *Cratæomus*, Seeley, 1881. It is from the Gosau formation of Austria. Although only fragments of the skeleton and dermal armor are known, some of these are very characteristic. One specimen of the latter, figured by Seeley, and regarded as a dermal plate, bearing a horn-like spine "exactly like the horn-core of an ox,"* is very similar in form to some problematical fossils from America, the exact horizon of which is in doubt.†

* Quarterly Journal of the Geological Society of London, vol. xxxvii, Plate XXVIII, fig. 4, 1881.

† Additional remains secured during the past season prove conclusively that some of these "horn-cores," if not all, were attached to the skull in pairs, and one specimen found in place has since been described by the author as *Ceratops montanus* (This Journal, vol. xxxvi, p. 477. December, 1888). It is from the Laramie formation of Montana. Others have been found in Colorado and in Wyoming. These are all much larger than the European specimens.

Palæoscincus, Leidy, 1856, from the Cretaceous, and *Priconodon* of the author, 1888, from the Potomac formation, are, perhaps, allied forms of the *Stegosauria*, but, until additional remains are found, their exact affinities cannot be determined. Apparently, the oldest known member of this group in America is the *Dystrophæus*, Cope, 1877, from the Trias of Arizona. In Europe, none have yet been found below the Jurassic. The *Euskelesaurus*, of Huxley, 1867, from the Trias of South Africa, is apparently a member of this group.

Ornithopoda.

The great group which the author has called the *Ornithopoda* is well represented in Europe by *Iguanodon* and its allies. The remarkable discoveries in the Wealden of Belgium, of a score or more skeletons of *Iguanodon*, have furnished material for an accurate study of the genus which they represent, and, indirectly, of the family. The genus *Iguanodon*, founded by Mantell in 1824, is now the best known of European forms, and need not here be discussed. *Hypsilophodon*, Huxley, 1870, from the Wealden, is likewise well represented, and its most important characters fully determined. The other genera of this group, among which are *Mochlodon*, Bunzel, 1871, *Vectisaurus*, Hulke, 1879, *Orthomerus*, Seeley, 1883, and *Sphenospondylus*, Seeley, 1883, are described from less perfect material, and further discoveries must decide their distinctive characters.

None of these genera are known from America, but allied forms are not wanting. A distinct family, the *Hadrosauridæ*, is especially abundant in the Cretaceous, and another, the *Camptosauridæ*, includes most of the Jurassic species. The latter are the American representatives of the *Iguanodontidæ*. The nearest allied genera are, apparently, *Iguanodon* and *Camptosaurus* for the larger forms, and *Hypsilophodon* and *Laosaurus* for those of small size. A few isolated teeth from each country suggest that more nearly related forms may at any time be brought to light.

Many generic names have been proposed for members of this group found in America and in Europe, but, in most cases, they are based on fragmentary, detached specimens, which must await future discoveries before they can be assigned to their true place in the order.

As a whole, the European *Ornithopoda* now known seem to be less specialized than those of America, but additional discoveries may modify this opinion. The geological range of this group, so far as known, is essentially the same on each continent, being confined to the Jurassic and Cretaceous.

There is some evidence, from footprints, at least, that, in America, the order was represented in the Trias.

Theropoda.

The carnivorous *Dinosauria* have all been included, by the author, in one order, *Theropoda*, although there are two or three suborders quite distinct from each other. This great group is well represented both in Europe and America in the Trias, is especially abundant in the Jurassic, and diminishes in the Cretaceous, at the close of which, it apparently becomes extinct.

The typical genus is *Megalosaurus*, Buckland, 1824, the type of which was the first Dinosaurian reptile described. Although its remains are comparatively abundant in Europe, they have been found only in a fragmentary condition, and many important points in the structure of the skull and skeleton are still in doubt.

The oldest representatives of this group in Europe are *Thecodontosaurus*, Riley and Stutchbury, 1836, and *Plateosaurus*, von Meyer, 1837, both from the Trias. The former genus is from the lower horizon, near Bristol, England; the latter, from the Keuper of Germany. *Zanclodon*, Plieninger, 1846, is from the same horizon as *Plateosaurus*, and appears to be the same thing. *Massospondylus*, Owen, 1854, from the Trias of South Africa, is apparently a form allied to *Thecodontosaurus*. The nearest American genus is *Anchisaurus*, two species of which are known from the Connecticut River sandstone.

The most interesting member of the *Theropoda* known in Europe is the diminutive specimen described by Wagner, in 1861, as *Compsognathus longipes*. The type specimen, the only one known, is from the lithographic slates of Solenhofen, Bavaria, and is now preserved in the museum in Munich. Fortunately, the skull and nearly all the skeleton are preserved, and as it has been studied by many anatomists, its more important characters have been made out. It is regarded as representing a distinct suborder, and no nearly related forms are known in Europe Its nearest ally is probably the specimen from Colorado, described by the author, in 1881, as *Hallopus victor*. This animal was about the same size as *Compsognathus*, and resembles it in some important features. It is probably from nearly the same geological horizon, but may be somewhat older. Each of these specimens appears to be unique, and until a careful comparison of the two is made, their relations to each other can only be conjectured.

The American representative of *Megalosaurus* is apparently *Allosaurus*, a genus established by the author, in 1877. The type specimen is from Colorado, from a higher horizon in the Jurassic than that of *Megalosaurus.* Nearly every part of the skeleton of this genus is now known, and the more important portions have been described and figured by the author. *Creosaurus*, also from the Jurassic, is an allied form, and *Dryptosaurus*, from the Cretaceous, is, perhaps, also closely related. A very distinct form in the Jurassic is *Labrosaurus*, described by the author, in 1879. It is known from detached specimens only, but these, especially the jaws, edentulous in front, show it to represent a distinct family.

The most perfectly known of American *Theropoda*, and by far the most interesting, is the genus *Ceratosaurus*, founded by the author, in 1884. This is the representative of a very peculiar family, which differs in some important respects from all other known Dinosaurs. The skull and nearly all the various parts of the skeleton are known. When found, they were entire, and in the position in which the animal died. The skull and some of the more interesting parts of the skeleton have been figured by the author; and all will soon be fully described.

The skull bears a large elevated horn-core on the median line of the nasals. The cervical vertebræ differ in type from those of any other known reptiles, having the centra plano-concave. All behind the axis have the anterior end of each centrum perfectly flat, while the posterior end is deeply cupped. This genus, moreover, differs from all known Dinosaurs in having the elements of the pelvis (ilium, pubis, and ischium) coössified, as in all existing birds. The metatarsals, also, are firmly united, as in birds. No representatives of the *Ceratosauridæ* are known in Europe.

In conclusion, it may safely be said that the four great groups of *Dinosauria* are each well represented both in Europe and America. Some of the families, also, of each order have representatives in the two regions, and future discoveries will doubtless prove that others occur in both.

No genera common to the two continents are known with certainty, although a few are so closely allied, that they cannot be distinguished from each other by the fragmentary specimens that now represent them. It must be remembered that the great majority of genera have been named from portions of skeletons, of which the skull was unknown, and until the latter is found, and definitely associated with the remains described, the characters and affinities of the genus can be only a matter of conjecture, more or less definite, in proportion to the perfection of the type specimens.

From Asia and Africa, also, a few remains of Dinosaurs have been described, and the latter continent promises to yield many interesting forms. Characteristic specimens, representing two genera, one apparently belonging to the *Stegosauria*, and one to the *Theropoda*, are already known from South Africa, from the region so rich in other extinct Reptilia.

From Australia, no *Dinosauria* have as yet been recorded, but they will undoubtedly be found there, as this great group of Reptiles were the dominant land animals of the earth, during all Mesozoic time.

ART. XXXV.—*Notice of New American Dinosauria;* by O. C. MARSH.

IN the large series of Dinosaurian remains brought together by the writer, in the last few years, and now under investigation, there are a number of new forms, some of which are briefly noticed below. These will all be fully described and figured in the memoirs now in preparation, by the writer, for the United States Geological Survey.

Anchisaurus major, sp. nov.

The remains of this reptile are from the sandstone of the Connecticut River valley, which has long been known for the great variety of footprints it contains, especially those supposed to have been made by birds. The extreme rarity of any bones in these beds is equally well known, not more than half a dozen finds having yet been made, and only a few of these of much scientific interest. A portion of a skeleton found near Springfield, Mass., and described by Hitchcock, in 1865, as *Megadactylus*, has hitherto been by far the most important of these discoveries. It is a typical member of the order *Theropoda*, and has apparently for its nearest allies in the old world, *Thecodontosaurus*, from the Trias of England, and *Massospondylus*, from the same formation in South Africa.

The remains here described represent a later discovery, in 1884, near Manchester, Conn., in essentially the same horizon as the Springfield specimen. They indicate an animal of larger size, but in many respects nearly allied to the one described by Hitchcock. Both apparently belong to the same genus, which the writer has called *Anchisaurus*, as the name first given was preoccupied.

The present specimen is part of a skeleton which was probably complete, and in position, when discovered, but for want of proper appreciation at the time, only the posterior portion was secured. This consists of the nearly entire pelvic arch, with both hind limbs essentially complete, and in position. As this was one of the animals that are supposed to have made the footprints, one of the hind feet is figured below.

FIG. 1.

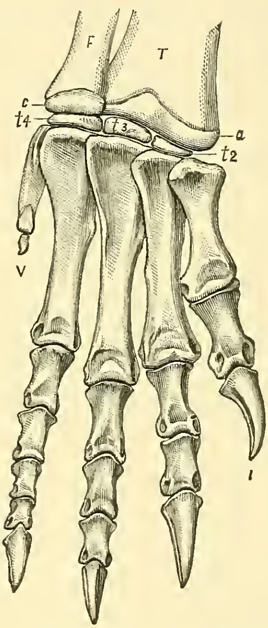


FIGURE 1.—Right hind foot of *Anchisaurus major*, Marsh; front view. One-fourth natural size.

In the present specimen there are only three sacral vertebræ. All the dorsal vertebræ preserved have their articular ends biconcave, or nearly plane.

The ilium has a slender preacetabular process, thus differing from most of the other *Theropoda*. The ischia are very slender, and are directed backward. For the posterior half of their length, they are closely adapted to each other.

The known remains of this species indicate an animal about six or eight feet in length.

Morosaurus lentus, sp. nov.

One of the most interesting specimens of *Sauropoda* in the Yale Museum pertains to a species of *Morosaurus* much smaller than *M. grandis*, the type, and differing materially in other respects. The skull is not known, but nearly all the important parts of the skeleton are well represented, and in excellent preservation. The individual was not fully adult, and hence, the elements of the vertebræ and sacrum are, in most cases, separate, thus affording special facilities for investigation.

The limb bones and feet show that the fore and hind legs were much shorter than those of the other species of the genus. The vertebræ, also, are shorter, more massive, and the cavities in them, smaller. All parts of the skeleton preserved are of similar density, indicating that the whole osseous structure of the animal was more solid than any other of the known *Sauropoda*. The vertebræ of the cervical and dorsal regions have their centra more depressed than in the other species of this genus, and may easily be distinguished by this feature alone. The neural arch rests directly upon the centrum, instead of being elevated on pedestals above the articular faces. This feature is well shown in the figure below.

FIG. 2.

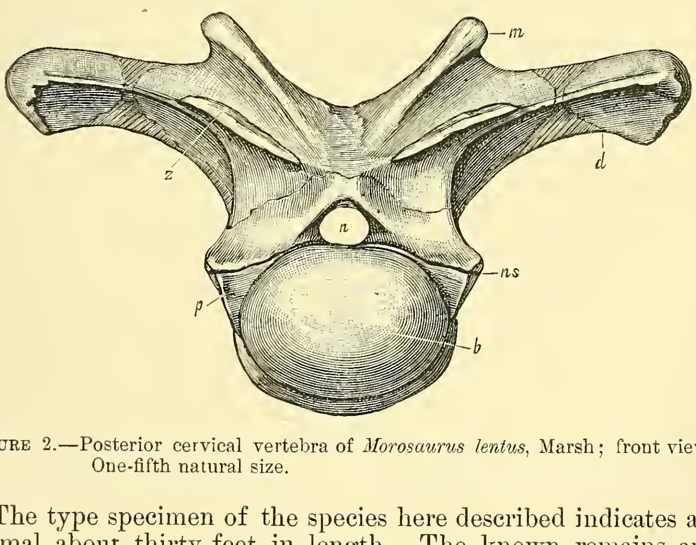


FIGURE 2.—Posterior cervical vertebra of *Morosaurus lentus*, Marsh; front view. One-fifth natural size.

The type specimen of the species here described indicates an animal about thirty feet in length. The known remains are from the Atlantosaurus beds of the Upper Jurassic, in Wyoming.

Morosaurus agilis, sp. nov.

A second new species, which apparently belongs to the same genus, is represented by the posterior half of the skull, the anterior cervical vertebræ, and other parts of the skeleton. This animal was in direct contrast with the one last described, the skull and skeleton being especially light and delicate in structure for one of the *Sauropoda*. It was also much smaller in size, being the most diminutive known member of the genus, probably not more than fifteen feet in length.

The figure below represents the back of the skull with the atlas attached, and the postoccipital bones in place. The axis and third cervical were also found in position. These will serve to distinguish the present species from the others of the genus, as they are proportionally much longer, and of lighter structure.

FIG. 3.

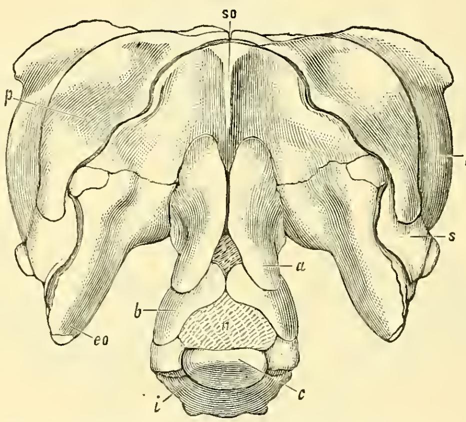


FIGURE 3.—Skull of *Morosaurus agilis*, Marsh; posterior view. One-half natural size.

The hind feet of the present specimen agree in general structure with those of *Morosaurus grandis*, but differ in having the first digit unusually large and massive in comparison with the others. The third, fourth, and fifth, are especially slender.

This interesting specimen was found in the Upper Jurassic beds of Colorado, by Mr. M. P. Felch, whose researches have brought to light so many important remains of the *Dinosauria*.

Ceratops horridus, sp. nov.

The strange reptile described by the writer as *Ceratops montanus** proves to have been only a subordinate member of

* This Journal, vol. xxxvi, p. 477, Dec., 1888. *See also* p. 327 of the present number. The specimen figured in vol. xxxiv, p. 324, may prove to belong to the same genus.

the family. Other remains received more recently indicate forms much larger, and more grotesque in appearance. They also afford considerable information in regard to the structure of these animals, showing them to be true *Stegosauria*, but with the skull and dermal armor strangely modified and specialized just before the group became extinct.

The vertebræ, and the bones of the limbs and of the feet, are so much like the corresponding parts of the typical *Stegosaurus* from the Jurassic, that it would be difficult to separate the two when in fragmentary condition, as are most of those from the later formation. The latter forms, however, are of larger size, and nearly all the bones have a peculiar rugosity, much less marked in the Jurassic species. In the form here described, this feature is very conspicuous, and marks almost every known part of the skeleton.

In the type specimen of the present species, the posterior horn-cores are much larger than these appendages in any other known animal, living or extinct. One of them measures at the base, no less than twenty-seven inches, and about sixteen inches around, half way to the summit. Its total height was about two feet. In general form, these horn-cores resemble those of *Ceratops montanus*, but the anterior margin is more compressed, showing indications of a ridge.

The top of the skull, in the region of the horn-cores, is thick and massive, and strongly rugose.

This skull as a whole must have had at least fifty times the weight of the skull of the largest *Sauropoda* known, and this fact will give some idea of the appearance of this reptile when alive.

As previously stated, the posterior pair of horn-cores of this family are hollow at the base, and in form and surface markings are precisely like those of the *Bovidæ*. The resemblance is so close that, when detached from the skull, they cannot be distinguished by any anatomical character. This accurate repetition, in later and still existing forms, of the highly specialized weapons of an extinct group of another class is a fact of much interest.

The present specimen is from the Laramie formation of Wyoming, but fragmentary remains, which may be referred provisionally to the same species, have been found in Colorado.

Hadrosaurus breviceps, sp. nov.

An interesting specimen in the Yale University Museum, from Montana, indicates a large Dinosaur, apparently belonging to the genus *Hadrosaurus*, and hitherto unknown. It is the dentary portion of the right maxillary, and is so characteristic, that it is here briefly described and figured. Its main features are well shown in figures 4 and 5 below.

The teeth are very numerous, and form a tessellated surface, as in *Hadrosaurus Foulkii*, Leidy, but they are more elongate, and the outer enamelled faces ard less distinctly rhomboid in form. The grooves, also, in which the inner surfaces of the fangs were inserted, are less regular, than in that species.

FIG. 4.

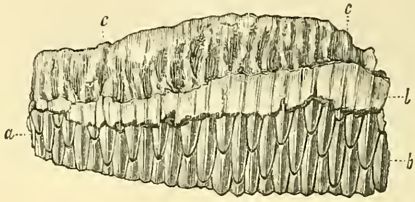


FIG. 5.

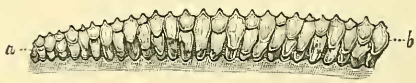


FIGURE 4.—Right maxillary of *Hadrosaurus breviceps*, Marsh; outside view.
FIGURE 5.—The same jaw; showing worn surface of teeth.
Both figures are one-fourth natural size.

The present specimen is from the Laramie formation of Montana.

Hadrosaurus paucidens, sp. nov.

In strong contrast with the species above described is another from the same region and same formation. The best preserved specimen that now represents it is a left maxillary, nearly complete. With this was found some other portions of the skull, but the maxillary affords the best distinctive characters. All, however, indicate a skull of extreme lightness and delicacy of build for one of the *Ornithopoda*. The maxillary is especially slender, and the anterior and posterior extremities are pointed. The middle of the bone is more massive, but yet very light for this portion of the skull. The teeth are of the general type of those in this genus, but are comparatively few in number, and only one row appears to have been in service.

The maxillary preserved is about ten inches in length, and three inches high near the center. The row of teeth in use contains about thirty.

The remains on which the present species is based were found in 1888, in the Laramie formation of Montana, by Mr. J. B. Hatcher, of the United States Geological Survey.

New Haven, Conn., March 25, 1889.

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THE

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[THIRD SERIES.]

ART. XXXVI.—*The Electrical Resistance of Stressed Glass;* by CARL BARUS.

THE thermal relations of the resistance of glass, originally studied by Buff,* have more recently been made the subject of research in memoirs by Beetz,† Foussereau,‡ Perry,§ Thos. Gray,‖ and others. Warburg's¶ experiments, however, throw new light on the inquiry, by showing that the apparent polarization evoked by the passage of current, is due to a layer of non-conducting silica depositing at the anode. If this be continually dissolved by an electrode of sodium amalgam, the apparent polarization is so far removed that an almost constant current may be kept up indefinitely. If the film be not removed, conduction soon ceases and the glass behaves like a condenser of measurable capacity.

The effect of temperature on the conductivity of glass has thus been mapped out with considerable detail, and it will be superfluous to add new data in the following paper. I purpose therefore to confine myself narrowly to the effects of

* Buff: Lieb. Ann., xc, p. 257, 1854.
† Beetz: Pogg. Ann., Jubelband, p. 23, 1874.
‡ Foussereau: Journ. de phys., II, xi, p. 254, 1883.
§ Perry: Proc. Roy. Soc., xxiii, p. 468, 1875.
‖ T. Gray: Proc. Roy. Soc., xxxiv, p. 199, 1883.
¶ Warburg: Wied. Ann., xxi, p. 622, 1884; ib., xxxv, p. 455, 1888.

stress* on electrolyzing glass, kept as nearly as practicable at different constant temperatures between 100° and 360°.

2. The apparatus with which most of my definite experiments were made† are shown in figures 1 and 2, and are differential in kind. The resistances across equal parts of the walls of two nearly identical glass tubes, respectively stressed and

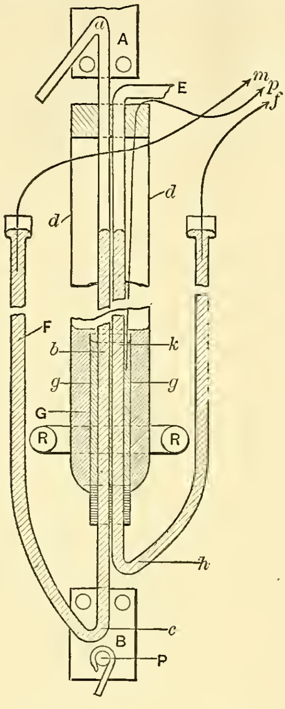

Figure 1.—Apparatus for 200°.

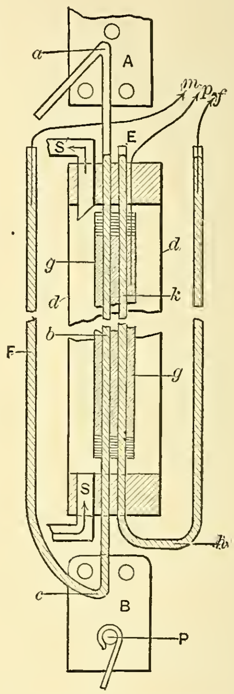

Figure 2.—Apparatus for 100°.

unstressed, are compared. These tubes are shown at *abcF* and *Ekhf*. The ends proper are bent hook-shaped; and those of the glass tube to be operated on, fastened by aid of screws and cement, between slabs of wood *A* and *B*. *A* is fixed; *B* provided with a hook, *P*, from which a scale pan may be hung;

* Reference may here be made to J. and P. Curie (C. R., xci, pp. 294, 383; xcii, p. 350, 1881; xciii, p. 1137, 1881), and to Hankel (Wied. Ann., p. 640, 1881), who show that in certain hemihedral crystals longitudinal compression is accompanied by the manifestation of electromotive force. Curie's very recent work is summarized in the Beiblätter, xii, p. 857 to 867, 1888.

† The earlier experiments were made with single tubes alternately stressed and unstressed, inserted in a simple galvanic circuit. In such a case, however, fluctuations of temperature often obscured the effect to be observed, beyond recognition. Cf. § 7.

or with a lever arrangement for twisting. In the experiments made the load was gradually increased as far as 20 kg., but the tubes were strong enough (theoretically) to sustain about three times this weight. The remainder of the figure shows the devices for heating and for passing the currents. Figure 1 is adapted for high boiling points (aniline, etc.), figure 2 for steam. An apparatus similar to figure 1 was used for mercury. In figure 1, *G* is the ebullition liquid, heated by a Gibb's ring burner *RR* surrounding the wide glass tube *dd*. A narrower glass tube *gg*, closed below with a perforated cork through which pass the experimental tubes *abc* and *ekh*, is partially filled with sodium amalgam. This is practically one terminal of the battery, the wire connecting at *p*. The other terminal, after passing through the respective coils of a differential galvanometer, connects at *m* and *f* with the sodium amalgam contained in the experimental tubes *abc* and *ekh*.

The notation in figure 2 is the same as that in figure 1. The two forms of apparatus are essentially identical, except that in figure 2 it is expedient to pass steam through *dd*, the vapor entering at *S* and leaving the apparatus at *S'*. For reasons stated below, § 5, it is desirable that the menisci of the amalgam contained in *abcF* and *ekhf*, figure 1, be visible above the level of the upper cork of the tube *dd*. The amalgam in *gg*, figure 1, should be submerged below the level of *G*. Inasmuch as sodium amalgam is only necessary at the anode, ordinary mercury may be used at cathodal parts; and these may therefore be exposed to hot air or steam without annoyances. To summarize: current arriving at *m* and *f* passes into the sodium amalgam core of the tubes, *abc* and *ekh*, thence across the walls of the hot parts of these tubes into the mercury surrounding them, and finally via *p* back to the battery. Regarding other apparatus, cf. § 7.

3. I commenced work with torsion experiments of which I may indicate something here. A battery of 10 Grove cells was used and the aniline at *G*, figure 1, kept both below and at the temperature of ebullition. The deflection of each coil alone being 16·4^{cm}, it was found that the differential action (nearly zero) could not be modified by twisting more than ·02^{cm}. Hence the specific electrical effect of twisting can not be greater than about ·1 per cent. The resistances encountered in these cases were about 200,000 ohms. Profiting by this preliminary experience however I was ultimately able to detect and measure the effect of torsion on electrolytic conductivity, using a different and more sensitive method to be indicated below, § 7.

4. In case of traction, the data decisively indicated an increase of conductivity proportional to the pull. But this

result is necessarily complex in kind, and must be carefully scrutinized before its true signification can be stated. I will therefore give my experiments in chronological order, the first series being made at 185° (aniline), the second at 100° (steam), the third series finally at 360° (mercury).

One remark may be made at the outset: inasmuch as the electrical effect of traction is persistant with the traction, and is an *increment* of conductivity, it can not be due to temperature. For the extension of an elastic solid like glass* produces temporary cooling, § 8.

5. The resistance across the walls of the experimental tube at 190° was about 100,000 ohms. In case of intense ebullition, the temperature is not fully constant. It is therefore desirable to use the apparatus, figure 1, just below the boiling point of aniline, and to bring the plane of the ring burner slightly below the plane of the ebullition liquid *G*. Parts of the apparatus which are not to be heated are screened with asbestos. In this way a nearly stationary distribution of temperature is reached.

Under these circumstances, when a weight of 18 kg. is alternately placed on the scale pan and removed from it by mechanism, thus subjecting the tube to periodic pulls of the force given, a definite and persistent oscillation of the galvanometer needle ensues synchronously with the period of stress. The amount of this oscillation was found to be equivalent to a resistance-decrement of 1500 ohms for the stressed tube. In other words the effect of the pull of 18 kg. is a diminution of the resistance of the stressed tube amounting to about 1·4 per cent. These experiments were repeated many times with practically the same results, e. g.

P = 2 kg.,	resistance	reduced	.4	per cent.
P = 15 kg.,	"	"	1·2	"
P = 20 kg.,	"	"	1·4	"

data in which the oscillation of the needle was made the basis of comparison. They betray a somewhat wide margin of error, because glass at 190° is exceedingly sensitive even to trifling changes of temperature. Nevertheless the data are sufficient for the present purposes; and work of a more precise character with high temperature vapor baths seemed to me to be superfluous. By using a more sensitive galvanometer such measurements can be repeated at 100° with facility and much greater precision.

6. The result obtained is clearly a superimposed effect, being due in part to the elastic change of dimensions during stretching, and in part to the direct action of stress in promoting

* Cf. Sir William Thomson's collected papers, vol. i, p. 308.

molecular break-up. It is therefore necessary to estimate the value of the former influence.

The radii of the tube being $\rho_1 = \cdot 26^{cm}$ and $\rho_2 = \cdot 19^{cm}$, the section is about $q = \cdot 1^{cm^2}$. Supposing the tenacity of glass to be $6 \cdot 5 \times 10^8$ dynes per square centimeter, this tube should bear 65 kg. Tubes are rarely free from imperfections, such as result from insufficient annealing, and it is moreover difficult to apply traction in an experiment like the present, without some flexural or other strain across the section (tendency to be crushed between the slabs, A, B, at the supports for instance). Hence I found it practically difficult to strain these tubes with more than a pull of about 25 kg., without producing rupture. But from all this it appears clearly that the longitudinal extension produced by 18 kg. is much *below* the maximum for the given dimensions and mean strength of tube.

If the tenacity of glass be $6 \cdot 5 \times 10^8$ and Young's modulus $5 \cdot 5 \times 10^{11}$, the values given by J. D. Everett,* then the maximum longitudinal extension is ·0012. Again since Poisson's ratio for glass is nearly $\frac{1}{4}$, it follows that the corresponding radial contraction is about ·0003.

Finally the resistance R of a hollow-cylinder, of length l, radii ρ_1 and ρ_2, and specific resistance s, to conduction across the walls of the tube is (M being the modulus of Brigg's logarithms); $R = \frac{1}{2\pi M} \frac{s}{l} \log \rho_1/\rho_2 = \cdot 3665 \frac{s}{l} \log \rho_1/\rho_2$ . . . (1).

To evaluate the resistance effect of elastic change of dimensions, R is to be regarded as a function of l, ρ_1 and ρ_2. In view of the symmetrical occurrence of the last two variables, and if the simplifying relation $4\delta\rho_1/\rho_1 = 4\delta\rho_2/\rho_2 = \delta l/l$, nearly, it follows that $\delta R'/R = (dR'/dl)\delta l/R + (dR'/d\rho_1)\delta\rho_1/R + (dR'/d\rho_2)\delta\rho_2/R = -\delta l/l$, where the accent has reference to elastic change.

Nevertheless radial contraction enters in case of an apparatus of the form figure 1, in which decrease of bore during traction lengthens the column of mercury contained. If λ be the length of this column before stretching, its length during stretching is $\lambda(1+2\delta\rho_1/\rho_1) = \lambda(1+(1/2)\delta l/l)$. Hence in consequence of elongation of the mercury column, $\delta R''/R = -(\lambda/2l)\delta l/l$, nearly, where l is the length of the hot part of the column. Hence the elastic discrepancy is

$$(\delta R' + \delta R'')/R = -(1 + \lambda/2l)\delta l/l \quad . \; . \; . \; . \; . \quad (2).$$

In none of my apparatus did λ exceed $2 \cdot 5\ l$. Moreover λ is always one shank of a U-tube. Therefore ·003 may be assumed as a decidedly superior limit of the numeric of equation (2).

* Everett: Units and Phys. Constants, p. 56. These data are reduced from Rankine's "Rules and Tables," p. 895.

Hence in an extremely unfavorable case, the resistance effect due to elastic change of dimension ($-\cdot 30$ per cent) is only about $\frac{1}{5}$ of the observed effect of traction ($-1\cdot 4$ per cent) produced by a pull much below the tenacity of glass, the said pull (18 kg.) being certainly not more than $\frac{1}{2}$ the maximum load. Hence these effects are very different, and it follows that the decrement actually observed is principally due to *decreased molecular stability* superinduced by stress. In equation (1), s is therefore the variable which chiefly responds to the action of stress.

To obviate the troublesome occurrence of $\delta R'' / R$, the column of mercury in most of my experiments was made so long as to extend far *above* the zone of conduction of the stretched glass tube (see figure 1). In the apparatus for steam, figure 2, the menisci of the column are advantageously raised quite above the cork. In such a case $\delta R''/R=0$, and the elastic discrepancy is simply $-\delta l/l$.

In one respect this reasoning is deficient. It does not take into account the changes of elastic behavior of glass due to the heating to 190°. Tabulated constants for this large interval are not available.* Hence special cathetometric measurements must be made. At 190° this is difficult, and for these and the other reasons given above, §5, it is expedient to refer to the complete set of measurements at 100°. §6.

6. At 100° the results can be made more accurate than the above chiefly for two reasons. In the first place the temperature is easily obtained absolutely constant; in the second elastic changes of dimensions can be directly measured with facility. In Table I, I have given the results obtained with the apparatus, figure 2. The method of measuring these large resistances (glass at 100°) is necessarily chosen more delicate than above. I used a high resistance Thomson's galvanometer read off by Hallock's short range telescope, and adjusted for differential work. The needle being practically ballistic in kind, the maximum deflections (swing) obtainable by alternately adding and removing the loads P, were used for comparison (method of multiplication). I then determined the amount of oscillation produced by inserting known resistances into one or the other coil of the differential galvanometer. Knowing the resistance of each tube (mean values) from special and preliminary measurements, I was able to deduce the percentage variation of the resistances of glass across the lines of stress. Table I contains four series of these experiments, i. e. two sets of results for each pair of tubes. R, the observed electrical resistance per tube was found to be about 7,500,000 ohms

* Kohlrausch and F. E. Loomis (this Journ., II, 1, p. 350, 1870), give low temperature data for metals.

per tube, of which the external and internal diameters were $2\rho_1 = \cdot 53^{cm} 2\rho_2 = \cdot 38^{cm}$ respectively. The table gives the oscillations for the divers loads P; the corresponding absolute decrement δR of R, and the relative value of this decrements in terms of R.

The amount of variation here given for glass is somewhat smaller than was found at 200° above. In the last case, however, the data are less accurate, and definite statements can not be made. In Table I the values for the 2d apparatus are smaller than for the first, a circumstance obviously depending on the tubes chosen, but which I will also leave without further comment.

TABLE I.—*Resistance of stretched glass at* 100°.

Tubes.	P	Maximum oscillation.	δR	$10^3 \times \delta R/R$.	Method.
	kg.	cm.	ohms.		Differential Galvanometer.
I and II	6	1·05	−21000	−2·8	
	10	1·63	−33000	−4·4	
	15	2·20	−44000	−5·8	
	19	2·90	−58000	−7·7	
I and II	6	·87	−17000	−2·2	
	10	1·50	−29000	−3·8	
	15	2·17	−42000	−5·4	
	19	2·91	−56000	−7·3	
III and IV	6	·29	− 6000	− ·9	
	10	·74	−15000	−2·2	
	15	1·05	−21000	−3·1	
III and IV	6	·33	− 7000	−1·0	
	10	·76	−15000	−2·3	
	15	1·11	−22000	−3·3	
IV	5	·56	--------	−1·2	Bridge.
	10	1·33	--------	−2·8	

This table proves conclusively, that within the given limits of variation, the resistance decrement experienced by glass is proportional to the applied stress. For the given conditions $(2\rho_1 = \cdot 53^{cm} 2\rho_2 = \cdot 40^{cm})$ it is as high as $380/10^6$ per kilo stress, and is not below $210/10^6$ per kilo stress. Since the section $q = \cdot 10^{cm^2}$ nearly, it follows that the mean relative variation of resistance due to stretching is about $30/10^9$ per gram load, per square centimeter of section. Mr. H. Tomlinson* who investigated the effect of stretching metals, finds that for steel, iron and brass the total variations are only about 1/15 as large as this, and of the opposite sign. §11.

7. When the temperature is sufficiently constant, for instance in the case of a steam bath, experiments may be made with a single tube. Let a bridge adjustment be so arranged that

* H. Tomlinson: Proc. Roy. Soc., xxv, p. 451, 1876; id. xxvi, p. 401, 1877.

$a/b=r/R$, where r is a known rheostatic resistance, and R the resistance of the tube, the current in the galvanometer being nearly zero. Then if $\delta r/r$ produce the same maximum oscillation of the needle as $\delta R/R$, it follows that $\delta r/r=\delta R/R$. An accurate chart or table of $\delta r/r$ considered as a function of the oscillation is therefore first to be constructed, by aid of the rheostat. This being in hand, the value of $\delta R/R$ corresponding to any oscillation produced by alternately adding and removing the load on the tube, is given at once. This method may be made very accurate, and I was able to obtain not only traction effects, but torsion effects as indicated by the following data. Here r is approximately 53000 ohms, R approximately 5900000 ohms. In case of torsion, P denotes the load acting during the alternate twisting and untwisting.

TABLE II.—*Resistance of stressed glass at* 100°.

Preliminary.		Torsion.			Traction.		
$10^3 \times \delta r/r$	Oscillation.	P	Oscillation.	$10^3 \times \delta R/R$	P	Oscillation.	$10^3 \times \delta R/R$
	cm.	kg.	cm.		kg.	cm.	
·76	·35	5	·59	−1·3	0	·22	−·5
1·89	·89	10	1·27	−2·8	5	·29	−·6
3.77	1·63	16	1·86	−4·1	10	·28	−·6

The traction data $\delta R/R$ are numerically larger than in Table I, and hence lend greater favor to the views just expressed. The torsion data $\delta R/R$ are of the same sign as the traction data. In other words torsion increases the electrolytic resistance. They are of smaller magnitude than traction data and are independent of the load which the tube sustains, so far as I could follow them.

TABLE II.—*Longitudinal extension of the tubes, Table 1st.*

Temperature.	Load.	L	$\delta L/L$	
° C.	kg.	cm	$10^{-6}\times$	
16°	2	77·53	0	
	6	77·53	0	
	10	77·54	130	
	15	77·55	260	
100°	2	77·58	0	Coefficient of expansion ·000008
	6	77·58	0	
	10	77·60	260	
	15	77·60	260	
100°	2	77·57	0	
	19	77·59	260	
100°	2	77·57	0	
	19	77·60	390	

8. To interpret the above data, special measurements of extension are necessary. These are given in Table II. They were

made cathetometrically, and are not intended to give more than a safe estimate of the elastic effect in question. The glass tube to be examined was surrounded conaxially by a second wide tube of glass, through which steam at 100° continually circulated. Measurements were also made at 16°. L is the length between fiducial marks.

Utilizing these values to obtain a superior limit of the elastic discrepancy in Table I, it appears that $\delta l/l < \cdot 0004$ and $\delta\rho/\rho < \cdot 0001$, these data being the largest obtained for the largest load, 18 kg. Hence by equation (2), $-\delta R'/R < 2\cdot 5 \times \cdot 0004 = \cdot 0010$. In other words the elastic discrepancy is numerically much less than ·1 per cent of R, whereas the corresponding mean value for the traction effect in Table I (apparatus with tubes I and II, low menisci) is ·75 per cent. Again for raised menisci (Tables I and II, tubes III and IV), $-\delta R'/R = \delta l/l = \cdot 0004$. In this case the corresponding mean value of the traction effect is numerically greater than ·50 per cent. In both instances it may be safely inferred that error introduced by elastic change of dimensions is at most about 1/10 of the decrement of resistance actually observed as the effect of stretching.

9. I will make a final consideration here, relative to temperature. The thermal effect of traction is negative, its influence on R must therefore be a resistance increment, i. e. opposite in sign to the effect observed. Nevertheless, it is desirable to obtain some estimate of its value, which will probably be found too small for direct measurement. Since $P = 20$ kg. and $\delta L/L < \cdot 0004^{cm}$, the total energy *elastically* potentialized per linear centimeter during stretching is $P\delta L/L < 10000$ ergs. Hence, even if all this energy were converted into heat, the increase of temperature resulting in case of the given tubes (section $\cdot 10^{cm^2}$, density <3, sp. heat $<\cdot 2$) would be about $10^4/240\text{x}10^4$; i. e. less than ·005°. This datum is too small to produce serious error even in consideration of the phenomenal sensitiveness of hot glass to temperature variations. Estimating that the resistance of glass decreases several per cent (5 to 20) per degree, between 100° and 200°, the thermal discrepancy can not be greater, numerically, than the elastic discrepancy.

10. I have now to communicate the data obtained at 360°. This case possesses some points of special interest, because the differential apparatus is itself a battery, the action of which enters in a complex manner. The electrolytes here are the hot glass tubes containing amalgam and surrounded by mercury. The actual apparatus was a simplified form of figure 1. Figure 3 presents a clearer diagram of parts, in which a and b are the hot glass tubes in question, E the battery and D the differential galvanometer. The electrical currents due to E are indi-

cated by the *inside* arrows; but these currents are considerably reënforced by the action of the element sodium amalgam / hot glass / mercury, as shown by the arrows crossing the tubes *a* and *b*. The electromotive force of this element is easily found by reversing the action of *E*. In an actual experiment I measured NaHg / hot glass / Hg = 1·4 volts, a datum somewhat affected by polarization and depending for its value on the strength of the amalgam and the purity of the mercury.

Besides this large electromotive force there is another of smaller value, due to the fact that the tubes *a* and *b* with appurtenances, represent two elements switched against each other. The currents are indicated by the *outside* arrows in the diagram, and they are necessarily so circumstanced as not to flow through the galvanometer *G* differentially. Their occurrence is therefore a serious and annoying disturbance, such that measurements at 360° can not, without unreasonable painstaking, be made with the same accuracy as measurements at 100°. I measured the electromotive force in question, as about ·2 volt; but it is necessarily variable even as to sign, containing as it does the polarization inconstancy of both elements.

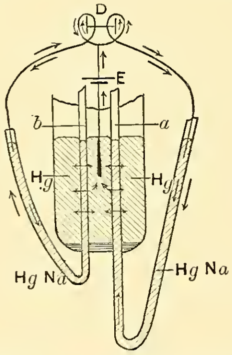

Figure 3.—Apparatus for 360°.

Since the resistance of glass near 360° is enormously low relative to its value at ordinary temperatures (in some practical cases the apparatus showed less than 1000 ohms), the extraneous electromotive force *E* can be withdrawn altogether. The present measurements of the electrical effect of traction are therefore made with the NaHg / hot glass / Hg element in the apparatus, figure 3. Notation being as above $2\rho_1 = \cdot 53^{cm}$, $2\rho_2 = 40^{cm}$. The small resistance at the boiling point is not available; owing to the formation of bubbles at the surface of contact between mercury and glass the resistance is too variable even for approximate measurement. Hence I observed at a lower temperature, encountering somewhat larger resistances *R*.

Even under favorable conditions these data are only qualitatively satisfactory. They are important, however, because they indicate that at 300°, the diminution of resistance due to traction is not larger in numeric value than at 100°; and since this would be the case if the decrements δR observed were due to elastic change of dimensions, I have here in hand additional evidence against this assumption.

TABLE III.—*Resistance of stretched glass at* 360°.

Apparatus.	P	Maximum oscillation.	R	δR	$10^3 \times \delta R / R$
	kg.	cm.	ohms.	ohms.	
I	6	·50	13000	−30	−2
	10	·50	----	−30	−2
	15	·70	----	−50	−4
	19	·70	----	−50	−4
III	6	1·00	17000	−15	−1
	10	1·40	----	−22	−1
	15	2·00	----	−31	−2

The present experiments are attended with much annoyance. As the load increases, the tube is apt to break in such a way as to spill the hot mercury; and with all reasonable care several tubes are usually sacrificed before a full series of observations can be obtained.

11. The above paragraphs summarized, prove that a solid electrolyte like glass is a better conductor of electricity (i. e. manifests smaller specific resistance), when in a state of strain (traction, torsion), than when free from strain. Inasmuch as the necessary concomitant of conduction in this case is molecular decomposition* and recombination, stress of the given kind must promote such decomposition. The rate at which molecular reconstruction occurs per unit of volume increases nearly proportionally to the intensity of stress; and it may in case of traction carried as far as the limit of rupture of glass amount to an increment of one per cent. In case of torsion the effect is not much larger than about 1/10 of this; and the increased break-up due to torsion is therefore studied with greater difficulty. The influence of temperature in changing the value of the electrolytic effect of stress is not marked. So far as observed the same pull per unit section does not increase the conductivity of glass more at 350° than at 100°, if indeed it increases it as much.

* It is best to avoid the term dissociation here. The term molecular reconstruction is used in preference.

Again the traction effect in case of electrolytic conduction, being a decrement of resistance, is of the opposite sign of the traction effect in cases of metallic conduction* (increment of resistance). The former is also of decidedly greater magnitude. If, therefore, conduction in metals is essentially the same phenomenon† as in electrolytes, then the soft metallic state must be singularly well adapted to promote molecular reconstruction. This fine adaptation of structure is destroyed by strains of dilatation, by heat, by alloying,‡ etc. In the data given, the electrical traction-coefficient, as well as the electrical temperature-coefficient (resistance), are similar in sign and in relative magnitude, both in metals and in electrolytes. They are positive in metals and small, negative in electrolytes and large. This is additional evidence in favor of a volume effect discussed at some length elsewhere.

12. The chief result of the present paper is the emphasis thrown on the fact that, independently of the passage of current, such a solid as glass must be conceived as undergoing spontaneous molecular reconstruction at all temperatures. For if the reconstruction in question were superinduced by the electric field, then the current passing would vary at a power higher than the first of electromotive force; whereas it may be taken for granted that currents of the intensity of those discussed above, pass through glass in accordance with Ohm's law.§ Recently J. J. Thomson‖ among many results of his development of the Lagrangian function, investigated an expression for the number of times, n, the electric field is discharged at any point, in case of conduction through either metals or electrolytes. If λ be the specific conductivity, K the specific inductive capacity of the medium, then $n=2\pi\beta\lambda/K$; where β is a coefficient the value of which is less than unity and depends on the relative time of destruction and existence of the electric field. Accepting provisional values for β and K, Thomson computes a table of values for the superior limit of n, in cases both of metals and of electrolytes. From this table it appears that n for mercury for instance, is less than 8×10^{16}. Similar values for the limit of n in case of glass at the above temperatures of observation, 100°, 200°, 360°, may be deduced. In round number the specific resistances of glass at the temperatures stated were, in ohms, 10^{8}, 10^{6}, and 5×10^{3},

* Mousson: Neue Schweizer, Zeitschr., xiv, p. 33, 1855; H. Tomlinson: Proc. Roy. Soc, xxv, p. 451, 1876; id., xxvi, p. 401, 1877.

† J. J. Thomson: Applications of Dynamics to Physics and Chemistry, p. 296; Macmillan, 1888.

‡ This Journal, xxxvi, p. 427, 1888.

§ Fitzgerald and Trouton (Rep. Br. Assoc., 1886, p. 312) show that electrolytes obey Ohm's law accurately.

‖ J. J. Thomson: l. c., p. 299.

respectively. From this it follows nearly, that for glass at 100°, $n=8\times10^7$; at 200°, $n=8\times10^9$; at 360°, $n=16\times10^{11}$. Thus it is fair to conclude that at temperatures quite as low as 100° the spontaneous chemical action, i. e. the continuous rearrangement of the molecules of glass is a pronounced occurrence.

The given value of the frequency of discharge of field, n, may be further expressed in terms of the number of molecules m, which break up per unit of volume, per unit of time, when the number of molecules q per unit of surface, whose disintegration just discharges the field, and the mean distance, x, over which they are urged by the field during the interval between break-up and recombination, are known. For $n=mx/q$; or $m=n\,(q/x)$. Here x is a very small quantity, not exceeding the centimeter numeric of the mean free path of the molecule of a gas; whereas q is a very large quantity. Hence m is larger than the given value of n, even if the above superior limits be 100 times the true value of n.

These approximate statistics are the nearest exact statement for the phenomenon of molecular break-up, which I can adduce; but they suffice for the present purposes. They show that even when glass is practically an insulator, the number of active molecules m, considered absolutely is very large; and that m need by no means be negligibly small even in comparison with the total number of molecules per unit of volume.

The above paragraphs prove that the rate at which molecular break-up takes place is appreciably greater when glass is under stress than when it is not. It is improbable that the system will pass from one state of molecular equilibrium to another, instantaneously. Hence, since even in case of very high resistance, such as that of glass at 100°, the number of unstable molecules per unit of volume must still be conceived to be very large, it follows that the species of molecular break-up in question may be looked upon as a fruitful cause of viscous deformation.*

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Art. XXXVII.—*On the Formation of Siliceous Sinter by the Vegetation of Thermal Springs*; by Walter Harvey Weed, of the U. S. Geological Survey.†

It is a well known fact that hot spring waters often contain considerable silica in solution, particularly those issuing from volcanic rocks, with which boiling springs are so frequently as-

* This Journal, xxxvi, pp. 178, 179, 183, 202, 208, 1888. Phil. Mag., V, xxvi, pp. 397, 398, 1888.

† Published by permission of the Director of the Survey.

sociated. Such waters, upon reaching the surface, deposit a portion of their burden of silica, as siliceous sinter, forming the white platforms, cones, and mounds which are a characteristic feature of the three geyser regions of the world. This material covers many square miles in the hot spring region of the Yellowstone National Park, occurring in beds of considerable thickness, which are of much geological interest, not only as chemical deposits but because they also afford evidence of the age of the hydrothermal forces which have played so important a part in the later history of the region and to which it owes its popular name of "Wonderland."

Although the formation of siliceous sinter has been noticed by many observers in connection with geyser and hot spring waters in Iceland and elsewhere, it is found that the causes advanced to account for the precipitation of the silica from the hot waters and its deposition as sinter do not offer a satisfactory explanation of the origin of many of the deposits of this material found about the hot springs of the Yellowstone. Such deposits are largely, sometimes wholly, due to a separation of silica by the vital growth of the algous vegetation of the hot spring waters. The present article is extracted from a paper in the Ninth Annual Report of the Director of the Survey, in which the work of this vegetable life of thermal waters is fully described.

The conditions governing the stability of a solution of silica are but imperfectly known, especially for such complex solutions as those of the Yellowstone hot springs, however the causes producing a separation of silica from these natural waters can be grouped under the following heads:

Relief of pressure.
Cooling.
Chemical reaction.
Evaporation.
Plant life.

The first four tend to produce a supersaturated solution of silica, and thus to cause its separation. So far as known the only waters in the Yellowstone Park in which cooling or relief of pressure are operative causes are those of the Norris Geyser Basin. If a highly heated underground water dissolves more silica from the lavas, whose fissures it traverses, than it can retain in permanent solution at the ordinary atmospheric pressure and temperature, it becomes supersaturated and deposits silica upon reaching the surface of the ground. The exact amount of silica which can be held in solution by the alkaline waters of the Yellowstone and similar hot springs is not known. The waters most highly charged with silica are those of the Norris Geyser Basin. That of the Opal Spring carries 0·7620 gms. of silica to the kilogram of water, and issues with a temperature of 199° F., one degree above the theoretical boiling point of pure water at this altitude. This water is perfectly clear and without sediment, and remains so upon cooling to 35° F. and after standing several days. Yet about the spring, sinter is deposited under such conditions that evaporation can have but little effect, though it is also deposited elsewhere through evaporation. It is possible that in this water as in that of the Coral Spring, the influence of the silica already deposited causes a separation from water that would not otherwise deposit silica.

Sinter deposition beneath the surface of the water is extremely rare among the hot springs of the Park and has never been observed at either the Upper or Lower Geyser Basins. The waters of the Coral Spring, Norris Basin, containing 0·6070 grams of silica to the kilogram of water, is opalescent from silica in suspension or "pseudo solution," but does not deposit silica after standing several years in the laboratory, and as in other siliceous waters cooling does not affect the silica, which only separates out after freezing (crystallization). Yet the water deposits silica freely upon the sides and bottom of the spring. The constitution of this water, its peculiar opalescence and the situation of the spring lead to the belief that the saturation of the solution is due to chemical reaction between an alkaline spring water and acid vapor. This accords with the theory of Damour regarding the deposition of silica by the waters of the Iceland hot springs.* Moreover, in such waters there is often a neutralization of the alkaline solution by *descending* acid waters, made acid by oxidation; this is the way in which LeConte and Rising explain the deposition of the gelatinous silica of Sulphur Bank, Cal.†

That the carbon dioxide of the atmosphere has any effect in producing sinter deposition‡ is disproven by the occurrence of free CO_2 in these waters.

Evaporation, partial or complete, certainly produces a deposition of silica from the siliceous waters of the Park, both acid and alkaline. It is, according to Bunsen, the only cause producing the deposition of sinter by the geyser waters of Iceland. Though evaporation is certainly an efficient agent, particularly in the dry air of the Park, producing some of the most beautiful and striking forms of sinter known, yet the deposits of the Yellowstone (excepting those of Norris Basin) are but partly due to this cause, and as already stated, are chiefly formed by a separation of silica by the vegetable life of the hot water.

* Phil. Mag., xxx, 1847, p. 405.

† This Journal. III, vol. xxiv. p. 33.

‡ Roscoe and Schorlemmer, Treatise on Chem., vol. i, p 571.

Algæ sinter.—This action of plant life consists in the abstraction of silica from the hot spring waters, by the vital processes of the algous vegetation, and in its deposition as a stiff gelatinous substance, occurring in a great variety of forms. This material, seemingly an inorganic deposit of gelatinous silica, consists of the siliceous filaments of various species of algæ, and their slimy envelope. Upon the death of the algæ this jelly loses part of its water, becoming cheesy in consistency and gradually hardening, and with a further separation of silica owing to the action of the decaying vegetable matter upon the water, it becomes a hard stony mass of sinter. If, however, a mass of the algous jelly be removed from the water and dried in the sun, it becomes a very light, pinkish material, containing about 94 per cent of silica, three to four per cent of water and one to two per cent of organic matter, with a little alumina—showing it to have the composition of a very pure siliceous sinter.

That vegetable life can exist in highly heated waters is well known to botanists. In the Yellowstone springs the maximum temperature at which vegetable life has been found is 185° F., only 13 degrees below the boiling point at this altitude, and algous growths are very common in the alkaline waters of the Geyser Basins—forming a brilliant and beautiful feature of the springs and their deposits. With rare exceptions the yellow and salmon tints of the geyser pools and the reds, orange, greens and browns of the hot springs are produced by algous vegetation.

The clearest case of sinter formation by algous life is that shown by a species of *Leptothrix*, forming thick masses of jelly, often assuming columnar, and vase-shaped forms, in the areas overflowed by the Black Sand, and Emerald Springs, at the Upper Geyser Basin. Here we have the conditions most favorable for the development of this form, viz: a constant volume and temperature of the overflow, and a gently sloping surface. Under such circumstances the overflow area is first carpeted with a membranous algous sheet, the color depending upon the temperature. From this flooring warty excrescences grow upward into pillar-like forms of soft jelly, until, reaching the surface of the water, their upward growth ceases, and a lateral development results in the formation of a cap, or "pileus" upon each pillar. These caps uniting, together with the growth of new, and the thickening of older pillars, fill up the channel and dam back the water, forming a little basin. Such growths thus form a series of terraced pools, in which the algæ thrive or die according to the supply and temperature of the water. In such basins one can see all gradations from the slender spikes of soft jelly to the hard firm sinter into which they pass. The larger columnar and vase-shaped forms result from a concurrent life and death of the vegetation, the inner layers dying and decaying as the outer coating of living algæ increases. This results in the formation of a hardened bony core, whose innumerable thin layers correspond to successive membranes of algæ. A pillar several inches in diameter consists of such a bony skeleton surrounded by a thin coating of green or red jelly. When by reason of changing conditions the algæ die, a different species of cooler habitat coats the surface with a fuzzy nap and adds its quota of silica, to which is added a further coating of silica by the action of the decomposing vegetation. The granular coating of silica thus formed rounds off and obscures the original outlines of the pillar, now a hard and solid mass of sinter. This conversion of soft algous jelly into stony material is going on in all the cooler pools, where the algous growth has itself dammed back the water, and diverted the supply. Where the basins are filled with algous forms whose tops uniting form a more or less continuous roof, supported by innumerable little pillars, the dull grayish surface of the sinter, shows no indication of the nature and origin of the sinter beneath, and may serve in turn as the floor of a new basin, and new growth.

Such is the origin of the sinter deposits of Specimen Lake, the Emerald Spring, north of the Grand Geyser, and numerous other parts of the Upper and Lower Geyser Basins. Similar to this in its origin and nature is the sinter, resulting from the growth of thick cushions of algous jelly, abundant during the past season in the area overflowed by the waters of the Beauty, Solitary and other springs, a sinter forming the greater part of the mound of the Solitary.

Another form of sinter, quite different from those mentioned, but also formed by algous vegetation, is common in all the geyser basins. It consists of fibrous layers, $\frac{1}{16}$ to $\frac{1}{2}$ inch thick, each layer resembling a thick and short white fur, and formed by the growth of a cedar-red (*Calothrix gypsophila*), or an olive green (*Mastigonema thermale*) alga—each formed of, and encrusted with, silica.

A bright red alga, *Leptothrix ochracea*, occurring in hot streams at 110° F. to 130° F., forms thatch-like layers of fibrous sinter, resembling interlacing straw. This sinter is very abundant about the Excelsior Geyser, and together with the variety last mentioned forms nearly the whole of the sinter platform of the Midway Geysers. A section of this plateau, exposed in the walls of the great pit of Excelsior, is twelve feet thick and shows 24 strata, each one composed of many layers of one variety of sinter. In this thickness of twelve feet, ten feet are formed of sinter produced by algæ, a striking illustration of the proportion of algous sinter of such deposits, while the remaining two feet consist principally of the cemented fragments of the same varieties of sinter. This preponderance of algous sinter in the deposits of all the geyser basins (save the Norris basin), is due to the greater rapidity with which it is formed.

Rate of formation.—Excepting the deposits formed by the highly charged waters of the Norris Basin, which deposit silica very rapidly, the hot spring and geyser waters deposit silica very slowly, by causes other than vegetable life. The beaded deposits which characterize the vents of the geysers, and to which the name *geyserite* is most properly applied, are formed entirely by evaporation. It is of course difficult to make any estimate of the average rate at which such deposits are formed about the older geysers. Quite recently, however, the development of a quiet "*laug*," a non-boiling spring, into a geyser named the Liberty has afforded an excellent opportunity for the study of the rate of formation of this class of sinters. A careful examination shows that an average thickness of $\frac{1}{20}$ of an inch has been formed in the eighteen months' activity of this vent. The laminated sinters about many of the springs are less rapidly formed. At the Model Geyser, under very favorable conditions for the formation of sinter by evaporation, i. e., alternate wetting and drying of the surface, a deposit formed over a name written upon the surface of the sinter nine years ago, and known to be authentic, is but $\frac{1}{120}$ of an inch thick, while more recent names are glazed with a coating of silica of extreme thinness. The salmon-colored floor of a channel near the Castle geyser is liberally inscribed with names of visitors, and although marring the beauty of the deposit they furnish a record of the rate at which the sinter forms at this place. In this case, moreover, the salmon-pink color is due to the presence of a fuzz of algæ, so that a coating of $\frac{1}{100}$ to $\frac{1}{60}$ of an inch a year, is not due wholly to evaporation.

The fibrous sinter forming the floor of the channels of Old Faithful is composed of layers, whose average thickness is $\frac{1}{20}$ of an inch, separated by lines of dense glassy silica. Each layer probably represents a summer's growth, and the annual thickness formed at this place can scarcely exceed $\frac{1}{20}$ of an inch.

The algous jellies, however, grow very rapidly—a thickness of four to five inches forming in several months under very favorable conditions, and a thickness of $1\frac{1}{8}$ inches in $2\frac{1}{2}$ months by actual experiment. Such jellies, deprived of the necessary supply of water, soon harden, and a crust forms on their surface by evaporation so that a considerable thickness of this form of sinter may be produced in a comparatively short time by this agency.

Moss sinter.—Siliceous sinters formed by algous vegetation are common at all the geyser basins of the Yellowstone Park, but so far as known the only places where mosses produce deposits of siliceous sinter are the Terrace Springs and the springs issuing from the slopes west of the Upper Geyser Basin. At the latter place the hot waters of the Hillside Springs, flowing down the steep slopes have deposited their carbonate of lime, and lost much of their silica, by the growth of those brilliant masses of red jelly, which can be seen when several miles distant, coloring the slopes with their brilliant tints. Near the foot of the slope, the water now cooled down to 80° F., fills a series of terraced basins suggesting those of the Mammoth Hot Spring, but covered with a bright green mossy growth. These basins are formed of a porous, buff-colored sinter composed of the stony forms of the moss covering its surface, which has been determined by Prof. Chas. R. Barnes, of the University of Wisconsin as *Hypnum aduncum* Hedw., var. *gracilescens* Br. and Sch. Specimens obtained by the writer show the green and living moss passing into the hard siliceous sinter—without break or interruption. Chemical analysis shows this sinter to have the composition of a typical geyserite; it is undoubtedly formed by the action of the moss—as the composition of the water shows that no silica would be deposited under ordinary circumstances.

In physical character, the sinters resulting from algous vegetation differ from those formed by evaporation or other inorganic causes by their greater lightness and opacity. They are often soft and easily crushed, and sometimes soil the fingers; their structure is readily distinguished from that of other forms of sinter.

Chemical analyses by J. Edward Whitfield of three varieties of siliceous sinter from the Upper Geyser Basin are given below. The first is a geyserite—a beaded deposit formed by the spray of the Splendid Geyser; the second an algous sinter from the Solitary Spring, the third the sinter formed by the *Hypnum* from the waters of the Asta Spring.

	Geyserite.	Algæ Sinter.	Moss Sinter.
SiO_2	81·95	93·88	89·72
Al_2O_3	6·49	1·73	1·02
Fe_2O_3	tr.	----	----
Na_2O	2·56	0·28	----
K_2O	0·65	0·23	----
CaO	0·56	0·25	2·01
MgO	0·15	0·07	tr.
SO_3	0·16	----	----
Cl	tr.	0·18	----
H_2O	7·50	3·37	7·34
Total	100·02	100·33	100·09

The numerous analyses of sinters, made in the Survey Laboratory, show that those formed by mosses and algous vegetation are generally purer than the true geyserite, the latter containing more or less clay, resulting from particles in suspension in the geyser waters. The algous sinter does not differ in composition from the opal sinters produced by the waters of the Coral and other springs at the Norris Basin, nor from the purer geyserites formed by evaporation.

Siliceous Sinter from New Zealand.

Through the courtesy of Prof. F. W. Clarke I have been enabled to examine a small collection of New Zealand "geyserites" and to compare them with the Yellowstone sinters. The specimens are mainly from the hot springs of Rotorua (or Ohinemutu), where the waters, long used by the Maori for cooking and bathing, are now utilized for a government sanitarium.

The collection embraces a number of varieties of sinters: true geyserites, formed by the evaporation of spattered drops of water; incrustation sinters, resembling a crushed handful of hay converted into silica; opal sinter and hot spring sandstones.

Besides these varieties there are two specimens whose structure indicates that the algous vegetation of the New Zealand waters produces siliceous sinter. These specimens are, however, quite unlike; the first resembles the sinter resulting from the growth of membranous sheets of red or green algæ, a form of vegetation resembling certain species of sea-weeds. Such algous sheets occur in hot waters all over the globe, and are described as "sheets of a slimy confervoid growth" * in the Rotorua waters. The sinter is creamy pink, showing a wavy, very thinly laminated structure, with occasional vesicular blisters lined with red and green patches, presumably the remains of algæ. It so very closely resembles sinters, whose algous origin is known, that a similar origin seems probable. An analysis of this specimen is given in the table following.

The second specimen is quite different in structure, consisting of several layers of fibrous silica, the fibers all perpendicular, and resembling a very fine, short and thick white fur. This sinter is exactly like the algous sinter forming the floor of the channels of the Old Faithful geyser and making one-half of the section of 12 feet of sinter exposed in the walls of the Excelsior, and there seems no reason for doubting that it has been formed in the same way.

The following analyses of New Zealand sinters have been made by Mr. J. Edward Whitfield, of the Survey Laboratory.

* Skey, Trans. N. Z. Inst., vol. x, p. 433.

	Geyserite.	Algous sinter?	Pulverulent deposit.
SiO_2	90·28	92·47	74·63
Al_2O_3	3·00	2·54	15·59
CaO	0·44	0·79	1·00
MgO	trace	0·15	trace
Na_2O	----	----	0·30
K_2O	----	----	1·02
Ignition	6·24	3·99	7·43
Total	99·96	99·94	99·97

The first is typical geyserite, undoubtedly an evaporation deposit; the second is the laminated sinter already alluded to. The third is a pure white pulverulent deposit resembling a block of diatomaceous earth, but composed of impalpable particles of glass. Its composition corresponds to that of rhyolite (the rock from which the Rotorua waters also issue) with the alkalies leached out and replaced by water.

Summary.

The study of the origin of the deposits of siliceous sinter found in the Yellowstone proves that they are largely formed by the vegetation of the hot spring waters. Waters too poor in silica to form sinter deposits by any other cause may be accompanied by beds of siliceous sinter formed by plant life. The extent and thickness of these deposits establishes the importance of this form of life as a geological agent.

Washington, D. C., Jan. 20, 1889.

Art. XXXVIII.—*Marine Shells and Fragments of Shells in the Till near Boston;* by Warren Upham.

[Read before the Boston Society of Natural History, Dec. 19, 1888.]

The fossils here described, occurring in drift deposits near Boston, and belonging wholly to species that are still living in Massachusetts bay, have been previously noticed by several observers, who have regarded them as evidence of a marine submergence within the Pleistocene or Quaternary period. Instead of this, my observations made during the past summer and autumn show that these fossils were transported from the bed of the sea on the north by the ice-sheet in the same manner as the materials of the drift, including its bowlders and rock fragments, large and small, have been carried various distances from north to south, being often deposited at higher elevations than the localities from which they were brought.

These glacially transported shells and fragments of shells cannot therefore be regarded as proof of the former presence of the sea at the height where they are found.

So long ago as during the Revolutionary war a fort was built on the top of Telegraph hill, in Hull, near the extremity of the peninsula of Nantasket, and a well was dug inside the fort, of which the commander, Gen. Benjamin Lincoln, wrote as follows.* "There is a large fort on the E. Hill, in which there is a well sunk 90 feet, which commonly contains 80 odd feet of water. In digging the well the workmen found many shells, smooth stones, and different stratas of sand and clay, similar to those on the beach adjoining to the hill. These shells and appearances were discovered from near the top of the ground to the bottom of the well."

Again, nearly forty years ago, Dr. William Stimpson collected fragments of shells, representing fourteen species, from the cliffs of drift which form the east and west sides of Winthrop Head, or, as it is more commonly called, Great Head on the Point Shirley peninsula of Winthrop, then a part of Chelsea.† This peninsula has two lenticular hills or drumlins of till, namely, Great Head which rises about 100 feet above the sea, and another, a third of a mile farther south, which may be more properly called the Point Shirley hill, about 60 feet high. It seems clear, from Stimpson's description of the sections where his shells were obtained, that they belonged to the higher one of these hills, which at the present time is being undermined by the sea. The southern hill, nearer to Point Shirley, is not sufficiently high to agree with his description, and moreover its eroded eastern cliff is separated from the ocean by a low tract of beach gravel and sand 20 to 40 rods wide, so that probably within the present century it has not presented any freshly exposed section.

Stimpson also reports that at some little distance from the place where he discovered these fossils, the digging of a well encountered shells in the drift at a depth of 50 feet below the level of high tide. Seventy years ago it was recorded that fragments of clam shells had been found 40 feet below the surface at Jamaica Plain, and at the depth of 107 feet in digging the well at Fort Strong, which was built in 1814 on Noddle's island, now East Boston.‡ About twenty years ago, in digging a well in Fort Warren, on George's island, shells

* Geographical Gazetteer of the Towns in the Commonwealth of Massachusetts, 1785, p. 56. (Only a small part of this work was published.)

† Proceedings of the Boston Society of Natural History, vol. iv, p. 9, January 15, 1851.

‡ Outlines of the Mineralogy and Geology of Boston and its vicinity, with a geological map. By J. Freeman Dana, M.D., and Samuel L. Dana, M.D., 1818. p. 96.

were found 100 feet below the surface and about 40 feet below the sea level.*

An article published last summer by Mr. W. W. Dodge,† describing the section of the sea-cliff of Great Head, Winthrop, and noting its fossil shell fragments, specially directed my attention to this subject. An examination of Great Head and of the lower drumlin at Point Shirley convinced me, as before stated, that the former was the locality of Dr. Stimpson's earlier and widely known observations. Mr. Dodge also informed me of the occurrence of similar shell fragments in Grover's cliff on the northeast shore of Winthrop, nearly one and a half miles north of Great Head.

My observations have included these drift sections and others in Winthrop, Revere, Chelsea, and thence southwest and south around Boston harbor, on several of the islands in the harbor, on the peninsula of Hull and Nantasket, and in Hingham, Cohasset, and Scituate. In only a small proportion of the whole number of sections examined were glacially transported shells and fragments of shells observed, these being found in Grover's cliff and Great Head, Winthrop, on Long island, Moon, Peddock's and Nut islands, in Quincy Great hill, in the drumlin forming the north shore of Hull close northwest of Telegraph hill, and in Sagamore Head, which rises from the Nantasket beach. All the other sections seen failed to yield any trace of organic remains, excepting that scanty fragments of lignite were found along an extent of two or three feet in the modified drift forming the base of the drumlin of Third cliff in Scituate by Prof. Crosby and Mr. Bouvé, who accompanied me in an excursion there. Without doubt, however, such transported shell fragments will be found in many other drumlins on islands in the harbor and on its eastern and southern shores, where they should be looked for in any deep section of the till, as in digging wells and in cliffs undermined by the sea.

The area where shells and fragments of shells are known to occur in the till has an extent of ten or eleven miles from northwest to southeast, reaching from East Boston and Grover's cliff to Sagamore Head, with a width of three or four miles, if not more, its eastern limit, which is the open ocean, being at a distance of four and a half miles east-northeast and eleven miles east-southeast of Boston. The fossiliferous sections are all in lenticular hills of till, like the drumlins of Great Britain, which name is now adopted for them. These hills have a very fine

* Reported by Mr. W. H. Niles in the Proceedings B. S. N. H., vol. xii, 1869, pp. 244 and 364. In commenting on this discovery, Mr. T. T. Bouvé read a letter from a gentleman in Hull, noting similar facts known to him in his own vicinity. (p. 364.)

† This Journal, III, vol. xxxvi, p. 56, July, 1888.

development upon most of the country in the neighborhood of Boston, rising with smooth, ovally rounded contour to heights from 50 to 200 feet, and have been the subject of several papers before this Society.* Approximate elevations of the drumlins in which fossils have been found are as follows: Grover's cliff, 60 feet above the sea; Great Head, 100 feet; Eagle hill, East Boston, 120 feet; north end of Long island, 75 feet; George's island, 60 feet; Moon island, 100 feet; north end of Peddock's island, 70 feet; Nut island, 40 feet; Quincy Great hill, 100 feet; on the north shore of Hull, 80 feet; Telegraph hill, 125 feet; and Sagamore Head, 65 feet. The cliffs eroded by the sea on most of these drumlins extend from 10 or 15 feet above mean tide sea level upward very steeply or often in part vertically to near their tops.

Excepting Great Head, which contains modified drift near its base, to be presently described, these sections consist wholly of till or bowlder-clay, the direct deposit of the ice-sheet, unmodified by the transporting and assorting action of water. Weathering has changed the small ingredient of iron in this deposit from the protoxide combinations which it still retains in the lower part of the till to the hydrous sesquioxide in its upper part for a depth of commonly fifteen or twenty feet from the surface, thereby giving to the latter a yellowish color in contrast with the darker gray or bluish color of the former. Both portions are very compact and hard till, an intimate unstratified commingling of bowlders, gravel, sand, and clay, and seem by these characters, and by their abundant striated bowlders and smaller fragments of stone, to be distinctly the ground moraine of the ice-sheet. The southeast and east-southeast trends of the longer axes of the drumlins in this vicinity, coinciding at least approximately with the direction of striation of the bedrock, further indicate that these oval hills of till were accumulated beneath the ice-sheet, this form being that which would oppose the least resistance to the glacial current passing over them. Though the till is destitute of stratification, its materials, coarse and fine, from boulders often several feet and occasionally ten feet or more in diameter to the finest rock-flour, being indiscriminately mixed in the same mass, it yet generally shows an obscure lamination in parallelism with the surface, having thus in the drumlins an inclination like that of their slopes. This structure is best displayed after some exposure of the section to the action of the weather. It seems to be an imperfect cleavage

*By Prof. N. S. Shaler, Proceedings B. S. N. H., vol. xiii, pp. 198–203; by Prof. C. H. Hitchcock, vol. xix, pp.63–67; and by the present writer, vol. xx, pp. 220–234. Also, see Geology of New Hampshire, vol. iii, pp. 285–309; "The Distribution and Origin of Drumlins," by W. M. Davis, in this Journal, III, vol. xxviii, pp. 407–416, Dec. 1884; and Illustrations of the Earth's Surface: Glaciers, by Professors Shaler and Davis, Plate xxiv.

resulting from the enormous pressure of the overlying ice, and also indicates that the accumulation of the drumlins took place by gradual addition of till over their surface. Only a thin layer of englacial till, with its numerous large bowlders, contained within the ice-sheet and allowed to fall loosely from it during its final melting, is observable upon these drumlins, its probable thickness in this vicinity being not usually more than one or two feet.

Plentiful fragments of shells, up to one or two inches in length and rarely of larger size, are imbedded, like the small fragments of rock, in the dark lower portion of the till. They were found most abundant in Grover's cliff, Great Head, Peddock's island, and the northern cliff of Hull, one or several shell fragments being usually seen on each square yard of the exposed surface, so that hundreds may be gathered in an hour. In all the localities a single species, the round clam or quohog, *Venus mercenaria* L., makes up probably ninety-nine per cent. of the specimens found ; but no entire valve of this shell was obtained among the thousands of its fragments. The species next in numbers is *Cyclocardia borealis* Conrad, which, like the foregoing, is thicker and stronger than most species and therefore better fitted to resist the grinding action of the ice. The smaller size of the latter has enabled some of its specimens to escape almost unbroken and with only slight abrasion of its margin. In no instance, however, have the two valves of this or any other species been found united. Some of the fragments show little wearing or none, their broken edges being sharp and the markings of their surface perfectly preserved ; but the majority are considerably worn, and pieces perforated by burrows, like the dead shells cast up on a beach, are frequently found. No glacial striation has been detected on any of these shell fragments, and indeed it is rarely observable on pieces of stone of so small size.

The cliff at the northeast end of Peddock's island, though not showing more of the large fragments than the other localities specially mentioned for their abundance, yet far surpasses these in its multitude of very small fragments and even minute particles of shells, from a quarter and an eighth of an inch in length down to the least speck visible to the eye. In one place, by no means exceptional, near the base of this cliff, the number of these particles and specks of shells, ground up in the process of formation and deposition of the till, averaged not less than forty to each square foot of the section. This locality, too, is the only one where the shell fragments were observed in the yellowish upper part of the till nearer to the original surface than a depth of ten or fifteen feet. Here small fragments of shells, an inch or less in length, were found in considerable numbers to a height only one or two feet below the sod forming the surface of the hill and brink of the cliff. The highest were in a soft and crumbling condition, and those found thence downward in the yellow till showed a gradation to the hard and strong character of the shell fragments in the dark blue till. These observations indicate that the transported and broken fossils were probably originally as plentiful in the upper as in the lower part of this drumlin, and perhaps likewise of all the others, but that they have been mostly dissolved out of the upper part by infiltrating water.

Great Head is a typical drumlin, the eastern third of which has been eroded by the sea, forming a cliff about 100 feet high. This consists of ordinary till, yellowish above and dark bluish below, from its top to within 20 or 15 feet above mean tide, where its base, exposed a few years ago during the construction of a railroad, was observed by Mr. Dodge to be a somewhat arched bed of "loose, clean, rather fine gravel filled with small fragments of shells. *Venus mercenaria* and *Cardium Islandicum* (?) were the only shells identifiable with any reasonable degree of certainty among the fragments." This was seen to be overlain by till, which exhibited traces of an imperfect stratification close to their line of separation but above is entirely unstratified. The till contains fragments of shells up to a height of about 80 feet. A similar structure of the drumlins of Third and Fourth cliffs on the east shore of Scituate, each of which includes extensive anticlinal beds of modified drift, overlain by a thick covering of till, and in Fourth cliff also seen to be underlain by till and interbedded with it, promises to contribute much to our knowledge of the mode of deposition of these remarkable drift hills, as I shall hope to show in a future paper.

Following the nomenclature and arrangement of the catalogue of the marine invertebrate animals of the southern coast of New England and adjacent waters, by Verrill, Smith, and Harger,* the species represented by these fragments of shells in the drumlins near Boston are noted in the following table.

Those marked by asterisks in the first column have been collected in Grover's cliff, the most northern section yielding these fossils. In the second column are those found in Great Head, mostly by Dr. Stimpson, to whose list Mr. Dodge has added, somewhat doubtfully, three species. An hour's search there by Mr. Q. E. Dickerman and myself was rewarded by fragments of *Venus mercenaria*, abundant; *Mya arenaria* and *Cyclocardia borealis*, frequent; *Astarte undata*, rare; and a

* United States Fish Commission, Report of 1871–72. This work and Gould's Invertebrata of Massachusetts give notes of the geographic range of our species, living and fossil, and of the situations and depths at which they occur.

columella, perhaps of *Chrysodomus decemcostatus.* In the third column are the species found in the cliff of Moon island; in the fourth column, those obtained from the well at Fort Warren; in the fifth, those of Peddock's island; and in the sixth, those of the northern cliff in Hull. At the other localities only *Venus mercenaria* was found in the limited time available for search.

List of Species in the Till near Boston.

Species.	1	2	3	4	5	6
Balanus crenatus, Bruguière		*				
Chrysodomus decemcostatus, Say		*				
Tritia trivittata, Adams		*				
Urosalpinx cinerea, Stimpson		*				
Lunatia heros, Adams				*		
Lacuna neritoidea, Gould (?)		*				
Saxicava arctica, Deshayes					*	
Mya arenaria, Linné		*				
Ensatella Americana, Verrill		*				
Mactra solidissima, Chemnitz		*				
Venus mercenaria, Linné	*	*	*	*	*	*
Tapes fluctuosa, Sowerby (?)		*				
Cardium Islandicum, Linné (?)		*				
Cyclocardia borealis, Conrad	*	*	*	*	*	*
Astarte undata, Gould	*	*				
Astarte castanea, Say		*				
Mytilus edulis, Linné		*				
Modiola modiolus, Turton		*				
Pecten Islandicus, Chemnitz					*	
Ostrea Virginiana, Lister		*				
Cliona sulphurea, Verrill	*	*	*		*	*

All these species, which remain from the marine fauna that existed before the formation of the last ice-sheet upon this area, excepting one whose determination is doubtful, are found living at the present time in the adjoining waters of Massachusetts bay. Stimpson wrote of his collection: "With the exception of *Venus mercenaria*, I have obtained all of them in a living state by dredging within a mile of the locality where they are now found fossil." Nor are any noteworthy differences observable between these fossils and the living shells, excepting that the *Venus mercenaria* belongs, like most of the fossils of this species in Sankoty Head, Nantucket, to the very massive and strongly sculptured form, probably not to be regarded as a distinct variety, which still survives in the waters of Nantucket.*

Four species in this list attain their southern limit at Cape Cod; and one, *Tapes fluctuosa*, is not reported south of Nova Scotia and the Fishing Banks. The remaining sixteen have a

* This Journal, III, vol. x, 1875, pp. 369, 371.

range beyond Cape Cod. In northward range, five extend only to the Gulf of St. Lawrence; and three of these, namely, *Urosalpinx cinerea*, *Venus mercenaria*, and *Ostrea Virginiana*, occur only in isolated colonies north of Massachusetts bay. Another, *Astarte castanea*, has its northern limits on the coast of Nova Scotia and at Sable island; while the burrowing sponge, *Cliona sulphurea*, is not reported beyond Portland. Fourteen are more boreal, of which four continue to Labrador, and ten to the Arctic ocean.

The great abundance of the round clam, *Venus mercenaria*, which is now scarce in Massachusetts bay but plentiful south of Cape Cod, indicates that the sea here during part of the epoch just preceding the last glaciation was warmer than at the present time.* Similarly, the colonies of this and associated southern species, scattered here and there northward to the Bay of Chaleurs, are evidence that since this last glacial epoch the sea has been again warmer than now along this coast, permitting these species to advance so far to the north. The intermingling of characteristic southern and northern forms in this assemblage of fossils from the till seems to be readily accounted for by the gradual refrigeration of climate which culminated in the formation of the ice-sheet. Before that time the round clam or quohog and other shells of chiefly southern range were doubtless succeeded by a wholly boreal and arctic marine fauna. In the Pleistocene beds containing fossil shells on Gardiner's island† and at Sankoty Head,‡ which are referable to the same epoch with these near Boston, namely, the interglacial epoch preceding the latest glaciation, the round clam occurs in abundance; but it has not been discovered fossil north of the sections here described, which indeed are the most northern yet found in northeastern America holding fossils of interglacial age. It has not been found in the plentiful fauna of the marine beds of modified drift deposited in southern Maine during the departure of the last ice-sheet, nor in the scantily fossiliferous continuation of these beds southward to Portsmouth, Gloucester, and Cambridge.

Nearly all the species of our list inhabit the shore or shallow water, from low tide to the depth of a few fathoms, though

* From the same evidence and the occurrence of other species elsewhere in the Pleistocene deposits of the eastern United States north of their present range, Desor announced in 1847 to the Geological Society of France (Bulletin, vol. v, p. 91) and in 1852 in this Journal, (II, vol. xiv, pp. 52, 53) that a warmer climate then prevailed throughout this whole district.

† Sanderson Smith in Annals of the Lyceum of Natural History of New York, vol. viii, 1867, pp. 149–151; F J. H. Merrill in Annals of the New York Academy of Sciences, vol. iii, 1886, p. 354, with sections on Plate xxvii.

‡ Desor and Cabot in Quarterly Journal of the Geological Society, London, vol. v, 1849, pp. 340–344, partly quoted by Packard in Memoirs B. S. N. H., vol. i, pp. 252–3; Verrill and Scudder in this Journal, III, vol. x, 1875, pp. 364–375.

some of these also range downward to considerable depths. Three, of which two are doubtfully determined, are probably restricted to comparatively deep water; but even these are often cast ashore in severe storms. Considering the outlines of our eastern coast and the direction of the motion of the ice-sheet, it seems probable that these fossils were living along the shore and in the shallow edge of the sea on the area between the mouths of the Charles and Saugus rivers. In that interglacial epoch the drumlins of this district had not been accumulated, and the greater part of Chelsea, Revere, and Winthrop, formed of these and other deposits of glacial and modified drift, may then have been sea of similar depth with the present harbor of Boston or the part of Massachusetts bay between Winthrop and Nahant. From this tract the southeasterly moving ice-sheet, plowing up the marine beds and their inclosed shells, with those then tenanting the sea, carried them forward to form a portion of the till of the drumlins. That the sea-bottom from which these shells were derived had been shallow is evident from the predominance of the round clam, which, according to Professor Verrill, is seldom found in any abundance below five fathoms.

Glacially transported shells and fragments of shells have been previously observed in till at Brooklyn, N. Y., where E. Desor and W. C. Redfield gathered fragments of the round and long clams, oyster, and other species, "imbedded in a reddish loam intermixed with pebbles and bowlders, many of which are distinctly scratched;"* and in till, or at least deposits of clay enclosing numerous stones and bowlders, on the lower part of the St. Lawrence river, from the vicinity of Quebec northeastward more than a hundred miles, chiefly on the southeastern shore, to opposite the mouth of the Saguenay.† But the descriptions of these beds containing shells and bowlders on the St. Lawrence indicates that they were mostly, if not altogether, deposited by water with floating ice during the recession of the ice-sheet, while these marine shells lived where they are now found, being thus comparable with the fossiliferous, bowlder-bearing brick-clay of Paisley, Scotland.‡ In the modified drift forming Cape Cod, derived from the melting ice-sheet in which it had been contained, I collected ten years ago fragments representing sixteen species of shells, all now living, eight of which appear also in the foregoing list.§

* Bulletin de la Société Géologique de France, second series, vol. v, 1847, pp. 89, 90; Quart. Journ. Geol. Soc., vol. v, p. 343; Am. Jour. Sci., II, vol. xiv, 1852, p. 51.

† J. W. Dawson's Notes on the Post-pliocene Geology of Canada, 1872, pp. 7, 45, and 50–53.

‡ T. F. Jamieson in Quart. Journ. Geol. Soc., vol. xxi, 1865, pp. 175–177.

§ American Naturalist, vol. xiii, 1879, p. 560.

Looking over the various lists of Pleistocene fossils found on Gardiner's island and in Sankoty Head under the drift of the last ice-sheet, in these drumlins of till near Boston, and in the modified drift of the glacial recession thence northward to Maine, New Brunswick, and the valley of the St. Lawrence, we cannot fail to be surprised that all these are still living in the adjoining ocean to-day. So recent was the glacial period* that none of them has become extinct, nor, with very rare exceptions, undergone any noteworthy change in form or size. But the vicissitudes to which they were exposed during the last of our two principal glacial epochs, when the ice-sheets east of the Alleghenies advanced farther than in the earlier glaciation, were doubtless well adapted to cause both extinctions and modifications of species. How vast then must be the duration of the time occupied in the evolution of the complex faunas and floras of our globe, and in the formation of all the fossiliferous groups of rocks since the dawn of terrestrial life!

In various parts of Great Britain such transported Pleistocene shells are found in the till, both in its low and smooth tracts† and in its hilly and knolly terminal moraines traced by Professor Lewis, as well as in the associated kames.‡ Some of these fossiliferous glacial deposits occur in Ireland, northern Wales and northwestern England at heights 1,100 to 1,350 feet above the sea, and have been generally considered as proof of marine submergence to that depth. Instead of this, Lewis has shown§ that the shells and fragments of shells found there were brought by the currents of the confluent ice-sheet which flowed southward from Scotland and northern Ireland, passing over the bottom of the Irish sea, there plowing up its marine deposits and shells, and carrying them upward as glacial drift to these elevations, so that they afford no testimony of the former subsidence of the land. This removes one of the most perplexing questions that glacialists have encountered; for nowhere else in the British Isles is there proof of any such submergence during or since the glacial period, the maximum known being 510 feet near Airdrie in Lanarkshire, Scotland.‖ At the same time the submergence on the southern coast of England was only from 10 to 60 feet,¶ while no traces of raised

* Compare Proceedings B. S. N. H., vol. xxiii, 1887, p. 446.

† Geikie's Great Ice Age, second ed., pp. 164–185, and 337–340.

‡ Quart. Journ. Geol. Soc., vol. xxx, 1874, pp. 27–42; xxxiv, 1878, pp. 383–397; xxxvi, 1880, pp. 351–5; xxxvii, 1881, pp. 351–369; and xliii, 1887, pp. 73–120; also, Geological Magazine, II, vol. i, 1874, pp. 193–197.

§ Report of the British Association for Adv. of Sci., Birmingham, 1886, pp. 632–635; Am. Naturalist, vol. xx, pp. 919–925, Nov., 1886; this Journal, III, vol. xxxii, pp. 433–438, Dec., 1886. Also, see the American Geologist, vol. ii, pp. 371–379, Dec., 1888.

‖ Quart. Journ. Geol. Soc., vol. vi, 1850, pp. 386–8; xxi, 1865, pp. 219–221.

¶ Quart. Journ. Geol. Soc., xxxiv, 1878, pp. 454–7; xxxix, 1883, p. 54. Geol. Mag., II, vol. ii, 1875, p. 229; II, vi, 1879, pp. 166–172.

beaches or of Pleistocene marine formations above the present sea level are found in the Shetland and Orkney islands.*

The occurrence of transported marine fossils in the till near Boston shows that during the epoch preceding the latest glaciation the North American coast in this latitude was not higher than now in relation to the sea; for in that case no marine deposits and shells would have existed here to be eroded by the southeasterly moving ice-sheet and incorporated in its drift accumulations. Conversely, we know that the land then was not appreciably lower than now, in other words, that there was no considerable submergence of the border of our present land area; for this would have led to the intermingling of such broken sea-shells with the glacial drift farther inland, where no trace of them is found. So it appears that the relative levels of land and sea here were closely the same before the last glacial epoch as at the present time.

The chief element of my interest in this subject has been a hope that its bearing thus on the oscillations of land and sea during the Quaternary period would contribute to the solution of the question whether the northward ascent of the beaches of the glacial Lake Agassiz, assigned to me for investigation in the United States Geological Survey, is to be explained mainly by northward attraction of the water of that lake in gravitation toward the ice-sheet, or mainly by a depression of the earth's crust beneath the vast weight of the ice and its re-elevation when the weight was removed. In this study of our Atlantic coast, I have therefore sought to connect these observations near Boston with the allied evidence supplied by other Pleistocene marine fossils both south and north of our latitude. Some of the conclusions to which this correlation seems to lead I will endeavor to state briefly.

As before noted, it is only toward the south that we find Pleistocene fossiliferous beds antedating the last epoch of glaciation, when an ice-sheet covered all New England. They occur in Sankoty Head and on Gardiner's island at elevations respectively about 30 and 15 feet above the sea, and in numerous localities on Long Island from the sea level up to elevations of about 200 feet. But at least the higher of these beds appear to have been "upheaved by the lateral pressure of the ice-sheet and thrown into a series of marked folds at right angles to the line of glacial advance," as shown by Merrill;† and he finds that this uplifting and folding is also very distinctly seen in the strata underlying the glacial drift on Gardiner's island, so that the fossiliferous layer there, though raised little above the sea level, is probably higher than its original position.

* Quart. Journ. Geol. Soc., xxxv, 1879, p. 810; xxxvi, 1880, p. 663.

† Annals of the New York Academy of Natural Sciences, vol. iii, 1886, pp. 341–364, with sections and map.

To such glacial thrust and uplifting I would attribute likewise the tilted condition of the beds forming the base of Sankoty Head and the elevation of the included layers of shells. More than this, I believe that the same cause will account for the elevation and folding of the wonderful section of steeply inclined Miocene strata which underlie the terminal moraine in Gay Head.* It may well be true, therefore, so far as paleontologic evidence can inform us, that this part of our coast, extending south to the farthest limit reached by the continental ice-sheet, held approximately the same relation to the sea level in preglacial and interglacial time as now.† During the final melting of the ice-sheet, however, the land was higher, or, as I would prefer to say, the sea was lower than now, as is shown by channels of drainage, which extend southward from the terminal moraines across the bordering plains of modified drift of Long Island, Martha's Vineyard, Nantucket, and Cape Cod, continuing beneath our present sea level.‡ Nor have we any proof in marine beds overlying the glacial drift that the sea there has stood higher than now at any time since the glacial period.

Near Boston and northeast to Cape Ann the coast seems to have been submerged to a slight depth, probably not exceeding 10 to 25 feet, when the ice-sheet retreated from this area.§ In New Hampshire this submergence amounted to 75 feet or more, and the fossils in the marine beds overlying the glacial drift, being partly of arctic and partly of temperate range, show that the severe climate of the glacial period was gradually changed until the ocean became as warm as now before it sank to its present level.‖ After this the ocean within recent times has held even a somewhat lower level than at present, and seems to be now very slowly rising upon this shore and indeed along the entire coast from New Jersey to the Gulf of St. Lawrence, as is shown by submerged stumps of trees in

* Hitchcock's Geology of Massachusetts, 1841; Lyell's Travels in North America in 1841–2, vol. i, pp. 203–6.

† The fossils in South Marshfield and Duxbury, Mass., which I once referred to the Pleistocene (Am. Naturalist, vol. xiii, p 557), extend back to the Miocene in the Southern States, and seem more probably to be of similar age with the beds of Gay Head (Hitchcock's Geology of Mass., 1833, pp. 199–201; do, 1841, pp. 91, 427).

‡ This Journal, III, vol. xiii, 1877, pp. 142–146, and 215; vol. xviii, 1879, pp. 89, and 198–205. Am. Naturalist, vol. xiii, 1879, p. 553.

§ Evidenced by layers of shells of the common or long clam, mussel, oyster, and other species at Lechmere Point in Cambridge (Outlines of the Mineralogy and Geology of Boston, before cited, p. 96), and by fossils discovered by Professor Shaler at Gloucester, Mass. (Proceedings B. S. N. H., vol. xi, 1868, pp. 27–30). In the same notice with the former of these localities, the authors mention a stratum of clam shells, observed on the side of a hill in Cambridge at the distance of a half mile from the Charles river, which seems from its description to be probably an aboriginal kitchen-midden.

‖ Geology of New Hampshire, vol. iii, pp. 165–7.

many localities, rooted in the ground where they grew, and by tracts of marsh and peat-swamps covered by the sea.* During part of the time of lower level of the sea, its temperature was apparently warmer, as indicated by the range of *Venus mercenaria* with other southern species northward to the Gulf of St. Lawrence, though now it is wanting along most of the shore of Maine, the Bay of Fundy, and Nova Scotia.

Proceeding from Boston toward the north and northwest, the elevation of fossiliferous marine beds lying on the glacial drift increases to about 225 feet in Maine, about 520 feet in the St. Lawrence valley at Montreal, and 440 feet at a distance of 130 miles west-southwest of Montreal; but eastward along the St. Lawrence it decreases to 375 feet opposite the Saguenay, and does not exceed 200 feet in the basin of the Bay of Chaleurs, while these marine deposits are wanting in Nova Scotia and Cape Breton island.† The changed condition in the relative heights of land and sea at the time of the recession of the ice-sheet thus caused the land to be submerged in increasing amount northwestward from a line drawn through Nova Scotia, Boston, and New York. This condition, due probably in part to depression of the land and in part to uplifting of the sea level by gravitation, seems to have been caused by the ice-sheet, which had its greatest thickness, estimated by Dana to be not less than two miles, on the highlands between the St. Lawrence and Hudson bay, where its influence to produce such changes of level would be greatest. The submergence seems to have been more than can be wholly attributed to gravitation of the sea toward the ice-sheet;‡ but it is much less than would be expected for agreement with the views advanced by Jamieson§ and Shaler,‖ that the ice-sheet must depress the earth's crust to a vertical extent approximately measured by a thickness of rock equal to the ice in weight.

* Outlines of the Min. and Geol. of Boston, p. 95; Memoirs B. S. N. H., vol. i, p. 324; Quart. Journ. Geol. Soc., vol. xvii, 1861, pp. 381–8; Geol. of N. H., vol. iii, p. 173; J. W. Dawson's Acadian Geology, third ed., 1878, pp. 28–32, and Supplement of do., pp. 13–17.

† A. S. Packard, jr., in Memoirs B. S. N. H., vol. i, pp. 231–262. J. W. Dawson in Notes on the Post-pliocene Geology of Canada; and Am. Jour. Sci., III, vol. xxv, 1883, pp. 200–202. C. H. Hitchcock in Proc., Amer. Assoc. for Adv. of Sci., Portland, 1873, vol. xxii, pp. 169–175; Geol. of N. H., vol. iii, pp. 279–282; and Geol. Mag., II, vol. vi, 1879, pp. 248–250. R. Chalmers in Transactions of the Royal Society of Canada, sec. iv, 1886, pp. 139–145.

‡ Sixth Annual Report U. S. Geol. Survey, 1885, pp. 291–300.

§ Quart. Journ. Geol. Soc., vol. xxi, 1865, p. 178. Geol. Mag., II, vol. ix, Sept. and Oct., 1882; and III, vol. iv, Aug., 1887. Also, see Fisher's Physics of the Earth's Crust, and Geol. Mag., II, ix, p. 526.

‖ Proceedings B. S. N. H., vol. xii, 1868, pp. 128–136; and xxiii, 1884, pp. 36–44. Memoirs B. S. N. H., vol. i, 1874, pp. 320–340. Am. Jour. Sci., III, vol. xxiii, 1887, pp. 210–221. Lowell Lectures, Nov. and Dec., 1888.

Besides the testimony of marine fossils, one further observation contributes greatly to our knowledge of the relation of land and sea on the south side of Massachusetts bay while this area was enveloped by the continential glacier. On the shore of a peninsula in Cohasset Little Harbor, fifteen miles southeast of Boston, pot-holes similar to those of water-falls on rivers are found in two localities, reaching from sea level to a height of fifteen feet. The contour of their vicinity precludes the possibility of referring their origin to any stream since the close of the glacial period; and they must doubtless be attributed to the action of a water-fall plunging down hundreds of feet through a *moulin* of the ice sheet.* To Mr. Bouvé, long the president of this Society, belongs the honor of first observing these pot-holes and appreciating their significance. It was under his guidance that my visit to them was made; and it is with his permission that I speak of them here, previous to the detailed description which he will later present before the Society. Such water-wearing of the bed-rock could not take place beneath the sea level, so that they prove that here during a part, probably the later part, of the time when this area was covered by the ice-sheet, the land stood at least as high as now, not being depressed under its vast weight.

Art. XXXIX.—*A Platiniferous Nickel Ore from Canada;* by F. W. Clarke and Charles Catlett.

During the autumn of 1888 we received, through two different channels, samples of nickel ores taken from the mines of the Canadian Copper Co. at Sudbury, Ont. From one source we obtained two masses of sulphides, to be examined for nickel and copper; from the other source came similar sulphides, together with a series of soil and gravel-like material, seven samples in all. In the latter case an examination for platinum was requested, and in five of the samples it was found, the gravel above mentioned yielding 74·85 oz. of metals of the platinum group to the ton of 2000 lbs. At the outset of the investigation we were decidedly incredulous as to the existence of platinum in such ores; but the discovery of sperrylite by Mr. Wells in material from the same mines gave our work a wholesome stimulus, and the assays were carefully carried through.

The sulphide ores submitted to us from Sudbury were all of similar character. They consisted of mixed masses, in which a gray readily tarnishing substance was predominant, with

* Compare Quart. Journ. Geol. Soc., vol. xxx, 1874, pp. 750–771.

some chalcopyrite, possibly some pyrite, and a very little quartz. Two samples were examined in mass; one gave 31·41 per cent of nickel with a little copper, the other gave 35·39 per cent of nickel and 5·20 of copper. The nickel mineral itself proved to be a sulphide of nickel and iron, and as ores of that composition are not common, it was thought desirable to examine the substance further.

As above stated, the nickel mineral is the predominating constituent of the masses submitted for examination. It is steel-gray, massive, and exceedingly alterable in the air, and its specific gravity, determined by pycnometer, is 4·541. An analysis of carefully selected material gave the following results:

Ni	41·96
Fe	15·57
SiO_2	1·02
Cu	·62
S	40·80
	99·97

Neither cobalt nor arsenic could be detected.

The foregoing figures work out sharply into the ratio R : S :: 4 : 5; and approximately into the formula Ni_3FeS_5. If we deduct silica, together with the copper reckoned as admixed chalcopyrite, and recalculate the remainder of the analysis to one hundred per cent we have the following figures:

	As found.	Calc. as Ni_3FeS_5.
Ni	43·18	44·6
Fe	15·47	14·4
S	41·35	41·0
	100·00	100·0

In short, the mineral has the composition Ni_4S_5, with *about* one-fourth of the nickel replaced by iron. The only known species with which this agrees is Laspeyres's polydymite, of which the Sudbury mineral is evidently a ferriferous variety. What relations it may bear toward beyrichite, pyrrhotite, etc., is as yet a matter of considerable uncertainty. Probably in most cases the niccoliferous constituent of pyrrhotite is millerite, but other sulphides, like the polydymite, may perhaps occur also.

The polydymite which was selected for the above analysis came from the mass in which, in average, 35·39 Ni and 5·20 Cu had previously been found. The mass weighed several kilograms, and was remarkably free from quartz. The same mass, with two smaller pieces resembling it, were also examined for platinum, by the following method: One assay ton of the finely ground ore was treated with nitric acid until all or practically all of the sulphides had been dissolved. The dried residue was then assayed in the usual manner; except that, to facilitate cupellation, a little pure silver was introduced into the lead button. From the final bead the silver was dissolved out by sulphuric acid, leaving the platinum in a finely divided gray powder. The latter dissolved easily in aqua regia, and gave all the reactions needful to identify it thoroughly. The results were as follows, "A" representing the large mass in which the polydymite was determined.

A, 2·55 oz.	Pt to the ton,	or	0·0087	per cent.
B, 1·8	"	"	·0060	"
C, 7·	"	"	·024	"

That the metal weighed was nearly all platinum is certain; but it may have contained small amounts of other metals of the same group. The material separated was not sufficient to warrant a search for the rarer associates of platinum. Probably the platinum exists in the ore as sperrylite, although this point was not proved. The amount of platinum in the mass most thoroughly examined would require, to form sperrylite only about 0·007 per cent of arsenic, which is too small a quantity for detection by ordinary analysis. That platinum should exist in appreciable quantities in an ore of such character is something quite extraordinary. Whether it could be profitably extracted is an open question.

Washington, Feb. 2, 1889.

Art. XL.—*Stratigraphic Position of the Olenellus Fauna in North America and Europe*; by Chas. D. Walcott, of the U. S. Geological Survey.*

In reviewing the history of American opinion on the succession of the Cambrian faunas, we find that the first systematic arrangement of the terranes containing them was made by Sir William Logan, on the basis of the paleontological determinations of Mr. E. Billings. In a table published on page 46 of the report of the Geological Survey of Newfoundland for 1864, the order of succession of the Lower members of the series is:

3. Upper Potsdam.
2. Lower Potsdam.
1. St. John's Group.

* Read before the Philosophical Society of Washington, March 16, 1889.

In commenting on the table the author (Logan) said: "It thus appears that the lower portion of the series is complete in Newfoundland, and the upper in New York and Central Canada. Divisions 3, 4 and 5 have not yet been recognized in the Eastern continental region. The St. John's group, 1, is represented at St. John, New Brunswick by 3,000 feet of black slates and sandstones, whose fauna, described by Mr. Hartt, was correctly referred by him to Étagé C of Barrande's Primordial zone. It there reposes on older schistose rocks, as yet unstudied, but by Messrs. Hartt and Matthew designated as Cambrian.

"The slates of St. John, New Brunswick, Newfoundland, and the Paradoxides beds of Braintree, Massachusetts, also probably belong to the same horizon.

"The Lower Potsdam, 2, is represented by several hundred feet of limestones and sandstones on the Straits of Belle Isle, and on White Bay, Newfoundland, and by the slates of St. Albans and Georgia, Vermont.

"The Upper Potsdam, 3, is that of Wisconsin and Minnesota, represented in the typical Potsdam of New York, which is overlaid by the Lower Calciferous, 4, while the Upper Calciferous, 5, is only recognized in the Northern peninsula of Newfoundland."*

This order of succession was accepted and adopted by American geologists while no stratigraphic evidence appeared that negatived it. It was not questioned until the work of the Swedish geologists showed that *Olenellus Kjerulfi* occurred beneath the Paradoxides zone in Sweden; then it became probable that the American Olenellus fauna was of a similar age and hence older than the Paradoxides fauna.

Mr. S. W. Ford adopted the classification of Billings and Logan, and argued from the embryonic phases of growth of *Olenellus asaphoides* that the species showed a genetic relation to Paradoxides and succeeded it in time—a view in which I concurred at a later date.† Mr. Ford held that *Olenellus Kjerulfi* was a true Paradoxides, allied to *P. Ölandicus*‡ and, on the report of Mr. Matthew§ that he had found the species in America, decided that it, *O. Kjerulfi*, belonged to the Menevian fauna.

Mr. G. F. Matthew has studied the Paradoxides fauna of America with more thoroughness than any other paleontologist and he has concluded from the paleontological evidence that it preceded the Olenellus fauna.‖ In the introduction of the

* Bull. U. S. Geol. Survey, No. 30, p. 64, par. 141.
† Bull. U. S. Geol. Survey, No. 30, 1886, p. 166.
‡ This Journal, III, vol. xxxii, 1886, pp. 473–476.
§ This Journal, III, vol. xxxi, 1886, p. 472.
‖ Canadian Record Sci., vol. iii, 1888, pp. 71–81.

Second Contribution to the Studies on the Cambrian faunas of North America,* there was given a description of the typical geologic sections of the Cambrian System, and the order of succession of the faunas contained in their strata as then known. A diagram† was introduced to show the correlation of the sections and the order of successions of the three sub-faunas into which the Cambrian fauna was divided. The first and oldest was the Lower Cambrian or Paradoxides fauna; the second, the Middle Cambrian or Olenellus fauna, and the third, the Upper Cambrian or Dicellocephalus fauna. Each fauna was designated by the most characteristic genus of trilobite contained in it. It was stated‡ that "the conditions that developed the Middle Cambrian (or Olenellus) fauna appeared to have been largely peculiar to the American Continent;" also that (119) "there does not appear to be an equivalent fauna in the Cambrian System of Europe, either in Bohemia, the Scandinavian area, or in Wales. The nearest approach to it is on the Island of Sardinia."

At the time the introduction was written (1885) there was no satisfactory evidence that "*Paradoxides Kjerulfi*," of the lowest Cambrian strata of Sweden, was not a true Paradoxides; nor that it was an Olenellus, similar in type to *Olenellus asaphoides* of the American "Middle Cambrian." Brögger's excellent paper on the Age of the Olenellus Zone in North America§ had not appeared; nor had the beautiful memoir of Holm's on *Olenellus Kjerulfi.*‖ The latter proved conclusively that the genus occurs in the lowest fossiliferous bed of Sweden, beneath the horizon of the genus Paradoxides. Still more recently F. Schmidt has published an account of the finding of Olenellus in Estoria, in the Cambrian blue clay, and he states that he must concur with Brögger in his view that the Olenellus fauna is beneath, and older than, the Paradoxides fauna.¶

From the evidenee given by Brögger, Holm and Schmidt, there appeared to be no doubt that the Olenellus zone in Eu rope was beneath the Paradoxides zone. In America it had been regarded by Billings, Logan, Ford, Matthew, Walcott, and Winchell** as above the Paradoxides and subjacent to the Dicellocephalus zone. Brögger analyzed the evidence upon which this view was based and concluded that, in the face of the direct stratigraphic proof of the position of the Olenellus

* Bull. U. S. Geol. Survey, No. 30, 1886. † Loc. cit., p. 44.

‡ Loc. cit., p. 57, par. 120.

§ Aftryck ur Geol. Fören Stockholm, Förhandl., vol. viii, Häft. 3, 1886.

‖ Ibid., vol. ix, Häft. 7. 1887.

¶ Mem. Acad. Imp. Sci. St. Petersburg, VII, vol. xxxvi, No. 2. Über eine Neuentdeckte Untercambrische Fauna in Estland, 1888, pp. 1–27, pl. i–ii.

** As reporter of American opinion, Cong. Geol. International 4 me. Session Londres; Res. Rep. Sous. Com. Americans, 1888, p. 9.

zone in Sweden, the American geologists and paleontologists had mistaken the order of succession.

It was stated in 1886* that the only locality known in America where the two faunas (Paradoxides and Olenellus) occur in the same geographic area is about Conception Bay, Newfoundland. The evidence given by Logan of the order of succession was unsatisfactory, but it was all that was available and I continued to use the scheme given by him in 1865. Even after reading Brögger's paper I did not feel warranted in changing the table without stronger evidence than that there given. Comparing the two faunas zoologically, it appeared to me that in time the Olenellus fauna should follow the Paradoxides fauna. In May, 1888,† I reprinted Logan's scheme, stating that the table was tentative and expressive of my present knowledge and opinion, requesting that all who use it should decide individually upon the value of its correlations.

Such was the condition of our knowledge in the spring of 1888, when I began an investigation to determine, if possible, the actual stratigraphic succession of the Cambrian faunas of North America. I first re-examined the section of Cambrian strata in Eastern New York, as some evidence was known to me there of the presence of the Paradoxides fauna. One of the results of this study was the discovery of entire specimens of *Olenellus asaphoides* that showed it to be generically identical with *Olenellus Kjerulfi* of Sweden, and *Olenellus Mickwitzi* of the East Baltic region of Russia, as described by Schmidt. Also that the genus Mesonacis, based on *Olenellus Vermontana*, included *Olenellus asphoides*, *O. Kjerulfi*, and *O. Mickwitzi*, in having a similar type of pygidium. Knowing that *O.* (*Mesonacis*) *Vermontana* was associated in the same stratum of rock with *O. Thompsoni*, and that the same type occurred beneath the Paradoxides zone in Sweden, Norway and Russia, I fully believed that the stratigraphic position of the faunas would be found to be the same in America as in Europe. I also found at the base of the great Berlin sandstone in Rensselaer County, N. Y., several species of fossils that appear to be more closely allied to the species occurring in the Paradoxides fauna than to any known elsewhere in the Olenellus fauna, notably, *Linnarssonia Taconica*, *Agnostus desideratus*, n. sp., *Agnostus* like *A. pisiformis*, *Microdiscus connexus* and *Zacanthoides Eatoni*, n. sp. These species occur in the upper portion of the shales that in their middle and lower parts contain only the Olenellus fauna

* Bull. U. S. Geol. Survey, No. 30, 1886, pp. 49–50, par. 97. Distributed in January, 1887.

† This Journal, III, vol. xxxv, 1888, p. 399.

I next proceeded to Newfoundland, where there appeared to be a prospect of settling the question for America, by discovering the two faunas in the same stratigraphic section.

The first section examined was that beneath Topsail Head, Conception Bay. It was found to be as described by Mr. Alexander Murray.* The limestone at the base is separated from the "Huronian" rocks by a fault line. Over the limestone a hundred feet or more of greenish shale completes the section.

In the limestone I found *Obolella Atlantica*, *Kutorgina Labradorica*, *Scenella reticulata* Billings, *Hyolithellus micans* Billings, *Hyolithellus micans*, var. *rugosa*, *Hyolithes princeps* Billings, *H. impar* Ford, *Microdiscus speciosus* Ford, *Microdiscus*, sp. undet., *Olenellus Bröggeri*, n. sp., *Avalonia Manuelensis*, n. gen., n. sp., *Solenopleura bombifrons* Matthew, *Agraulos* (*S.*) *strenuus* Billings, *Agraulos* (*S.*), n. sp.

In the superjacent green shales a few fragments of a trilobite were observed that indicated, by a portion of the glabella and eyelobe, a large species of Paradoxides. The evidence here obtained being somewhat inconclusive, the section at Brigus Head, on the west side of Conception Bay, was next examined and found to be essentially the same as that at Topsail Head, with the addition of a greater thickness of green and red shales above the limestone, and a sandy deposit beneath the limestone which rested unconformably against the "Huronian." The limestone series is divided into three bands. In the lowest, a specimen of *Hyolithes impar* was found similar to that in the limestone at Topsail Head, associated with fragments of a species of Olenellus (*O. Bröggeri*), *Microdiscus* ——— and *Ptychoparia* (?) ———. In the second bed of limestone fragments of trilobites were seen ; and in the upper bed *Olenellus Bröggeri* and *Agraulos strenuus*, were observed, the latter in great abundance. No fossils were discovered in the superjacent slates.

There remained but one section, known to me, where the Cambrian rocks rested on the "Huronian" gneiss and the stratigraphic succession of the beds continued unbroken up to the unquestioned Paradoxides horizon. This was on Manuel's Brook, one-and-a-half miles west of Topsail Head. A coarse conglomerate rests directly and unconformably upon a syenitic gneiss. Along the line of the brook the conglomerate is conformably subjacent to a belt of greenish shale which is succeeded by a band of red shale subjacent to a thin stratum of limestone, which is followed by greenish shales, and these in turn by black shales carrying an abundant Paradoxides fauna. This section being conformable, a careful search was made for

* Rept. Geol. Survey, Newfoundland, 1868, Reprint of 1881, p. 154.

fossils in the beds just above the conglomerate. They were first found about 1,500 feet north of the brook, in a railway cut, in some irregular masses of impure arenaceous limestone resting on the conglomerate, and subsequently in red and green shales resting on the conglomerate. In the reddish argillaceous shale a large fine species of Olenellus was found that may be referred to the sub-genus Mesonacis. It is allied to *O.* (*M*) *asaphoides*, and I propose to call it *Olenellus* (*Mesonacis*) *Bröggeri*.*

Associated with *O.* (*M.*) *Bröggeri*, in the red and green shales and in an impure siliceous limestone, are the following species: *Obolella Atlantica*, n. sp., *Hyolithellus micans* Billings, *Hyolithellus ?*, n. sp., *Hyolithes princeps* Billings, *H. impar* Ford, *H. quadricostatus* S. and Foerste, and one new species of *Hyolithes*, *Gasteropod*, n. gen., n. sp., *Scenella reticulata* Billings, *Stenotheca rugosa*, var. *acuta-costa*, n. var., *Stenotheca rugosa*, var., *erecta*, n. var., *Stenotheca rugosa*, var. *levis.*, n. var., *Stenotheca rugosa*, var. *paupera* Billings, *Platyceras primævum* Billings, *Microdiscus Helena*, n. sp., *M. speciosus* Ford, *Microdiscus* sp. ?, *Olenellus Bröggeri* Walcott, *Avalonia Manuelensis*, n. gen., n. sp., *Ptychoparia Morrisi*, n. sp., *Agraulos* (*S.*) *strenuus* Billings, *Agraulos* (*S.*) *strenuus*, var. *nasutus*, n. var., *Agraulos*, n. sp., *Solenopleura bombifrons* Matthew, *Solenopleura*, n. sp.

This fauna is essentially the same as that of the limestones of the Topsail Head and Brigus sections, and proves conclusively that the Olenellus fauna is subjacent to the Paradoxides fauna.

Mr. Murray in his report for 1868, placed on lithologic evidence the Topsail Head limestone above the conglomerate of Manuel's Brook, and the limestone of Brigus Head beneath the conglomerate, in the generalized section published in the report for 1870.†

Mr. Matthew, in studying the collections sent to him by the Geological Survey of Newfoundland, placed the fossils of the Topsail Head and Brigus limestones beneath the Paradoxides horizon on Manuel's Brook,‡ thus following the stratigraphic arrangement of Mr. Murray. Subsequently he changed his views and placed the Topsail Head and Brigus faunas in the Paradoxides zone of the Manuel's Brook section.§

The stratigraphic section on Manuel's Brook, as measured by me in August, 1888, is as follows:

* The specific name is given in recognition of the excellent work of Brögger on the Cambrian faunas of Sweden, and of the work of the Swedish geologists in first clearly proving the true order of succession of the Cambrian faunas in Europe, and suggesting that the same order of succession probably prevailed in America.

† Report Geol. Survey, Newfoundland, 1870, Reprint of 1881, p. 238.

‡ Canadian Record Sci., vol. ii, 1886, p. 256.

§ Canadian Record Sci., vol. iii, 1888, p. 74.

Manuel's Brook Section.

1. Coarse conglomerate, in massive layers. The material next to the gneiss varies in size, from bowlders of quartz and gneiss six feet in diameter, down to small pebbles, and in the upper beds from pebbles to fine sand 35
   Strike, N. 80° E. (Magnetic); Dip. 12° to 13° N.
2. Irregular beds of calcareous sandstone, siliceous limestone and greenish-colored argillaceous shale, covering the irregular upper surface of the conglomerate 0–25
   Fossils:—*Obolella Atlantica*, *Hyolithellus micans* Billings, *Hyolithellus?*, n. sp., *Hyolithes princeps* Billings, *Hyolithes impar* Ford, *Hyolithes quadricostatus*, S. and F. and two undescribed species, *Gasteropod*, n. gen., n. sp., *Scenella reticulata* Billings, *Stenotheca rugosa*, var. *acutacosta*, n. var., *Stenotheca rugosa*, var. *erecta*, n. var., *Stenotheca rugosa*, var. *lævis*, n. var., *Stenotheca rugosa*, var. *paupera* Billings, *Platyceras primævum* Billings, *Microdiscus Helena*, n. sp., *Microdiscus speciosus* Ford, *Microdiscus*, sp. ?, *Olenellus Bröggeri* Walcott, *Avalonia Manuelensis*, n. gen., n. sp., *Ptychoparia Morrisi*, n. sp., *Agraulos* (*S.*) *strenuus* Billings, *Agraulos* (*S.*) *strenuus*, var. *nasutus*, n. var., *Solenopleura bombifrons* Matthew, *Solenopleura*, n. sp.
3. Greenish argillaceous shale, conformably subjacent to 2.. 40
4. Reddish-colored argillaceous shale 4
5. Calcareous sandstone, with pinkish limestone in irregular masses 2
6. Green argillaceous shale with thin layers of hard, dark, ferruginous sandstone, interbedded at several horizons.... 270
   Strike, N. 80° E.; Dip. 12° N.
   Fossils:—Near the base the head of an Olenellus was found, also fragments of an Agraulos or Ptychoparia. At 218 feet from the base a layer of pinkish limestone contained the head of an Agraulos, like *A. strenuus*, and many fragments of trilobites. Fifty-two feet higher up quite an abundant fauna was found, and the following species were collected: *Lingulella* sp. a, *Acrothele Matthewi* Hartt (sp.), *Agnostus* sp. a, *Agnostus* sp. d, *Paradoxides Hicksi* Salter, *Conocoryphe Matthewi* Hartt (sp.), *Liostracus* sp. a.
7. Dark argillaceous shales with thin layers of limestone and sandstone, at various horizons........................... 295
   Fossils:—Zone *a*. From 10 to 20 feet feet from the base the following species were collected: *Lingulella* sp. a, *Linnarssonia misera* Billings, *Acrothele Matthewi* Hartt (sp.), *Hyolithes* sp. a, *Agnostus*, 3 sp., a, b, c, *Microdiscus punctatus* Salter, *Paradoxides Hicksi*, *Conocoryphe* (*C*) *Matthewi* Hartt (sp.), *Conocoryphe elegans* Hartt (sp.), *Agraulos socialis* Billings, *Liostracus tener* Hartt (sp.).

Zone *b.*—Forty-five feet higher up the fauna is much larger and includes: *Linnarssonia misera* Billings (sp.), *Lingulella* sp. a, *Orthis* sp. ?, *Stenotheca* sp. ?, *Agnostus punctuosus* Angelin, *Agnostus*, 5 sp., *b, e, f, g, h*, *Microdiscus punctatus* Salter, *Paradoxides Davidis* Salter, *Paradoxides Hicksi* Salter, *Paradoxides* sp. ?, *Anopolenus venustus* Billings, *Conocoryphe elegans*, *Ctenocephalus Matthewi* Hartt (sp.), *Erinnys venulosa* Salter, *Ptychoparia Robbi* Hartt, *P. variolaris* Salter, *Holocephalina inflata* Hicks, *Agraulos socialis* Billings.

From 235 to 250 feet from the base a belt occurs in which a small species of Aristozoa occurs in large numbers, associated with *Lingulella* sp. *a*, *Agnostus* sp. ? and the heads of a small *Ptychoparia ?*, sp. undet.

8. Alternating bands of dark shale and dark, compact sandstone that carry a small species of Orthis in large numbers, 400

The section is here cut off by the shore of Conception Bay.* On the islands in the bay the Upper Cambrian horizon is well developed. In the lower arenaceous shales at Lance Cove, on Great Bell Island, I found *Eophyton* sp. ?, *Cruziana semiplicata* Billings, *Arthraria antiquata* Billings, *Olenus* sp. undet. and, at a higher horizon, near the center of the island, *Lingulepis affinis* Billings, and *Lingula ? Murrayi* Billings, with fragments of Cruziana. In the sandstone at the summit of Little Belle Island, twenty feet above a band of sandstone carrying *Lingula ? Billingsiana* Whiteaves and an elongate, narrow species of Lingulella, a long slender Hyolithes ? and a broad species of Hyolithes occur. In the dark argillaceous shales beneath, *L. ? Billingsiana* occurs in great numbers.

The conglomerate (No. 1, of the section) was traced, just north of the outcrop of the gneiss, for a mile to the west of Manuel's Brook and the shales and limestone of 2 were seen in a number of sections, resting directly upon it. On the brook the stratigraphic succession is unbroken up to the summit of 8, and the strata are conformable and undisturbed with the exception of the dip of 12° to the north.

The Manuel's Brook section is the only one known to me on the North American Continent where the typical Olenellus and Paradoxides faunas occur in an unbroken stratigraphic section. The Olenellus fauna is well developed and typical, and the same is true of the Paradoxides fauna.†

*I hope to prepare a paper on the Paradoxides zone of the Cambrian, and will then give the distribution of the fauna in the Manuel's Brook section more in detail, and add descriptive notes on the genera and species.

† In Newfoundland my work was made much easier by the assistance given by Rev. M. Harvey, of St. Johns, Father Morris, of Villa Nova Orphanage, and a

The relative position of the Middle and Lower Cambrian faunas is now changed in the American scheme of classification;* the Paradoxides zone being removed to the Middle, and the Olenellus zone to the Lower division. The three divisions—Lower, Middle, and Upper—are useful in classification, as they indicate both physical and faunal changes during the deposition of the sediments forming the American, Swedish, and English sections. In the Appalachian and Rocky Mountain areas of the United States, the genus Paradoxides is unknown, and most of the typical fossils of the zone are unrepresented; but in the great Cambrian section of Eastern New York it is indicated by *Agnostus desideratus*, n. sp., *Agnostus* of the type of *A. pisiformis*, *Microdiscus connexus*, *Linnarssonia Taconica* and *Zacanthoides Eatoni*. The third and fourth species may prove to be identical with *Microdiscus punctatus* and *Linnarssonia sagittarius* from the Paradoxides zone of Newfoundland. In Nevada a peculiar fauna that is recognized by the trilobitic genera Olenoides, Zacanthoides and Asaphicus, occurs midway between the Olenellus and Dicellocephalus or Upper Cambrian faunas. Brögger has noted that the genus Agnostus is first characteristic of the Paradoxides zone, and by it he has correlated certain horizons in Nevada witn those of Sweden. This will undoubtedly hold good in many instances, and be of value when taken in connection with other genera.†

The following table exhibits the order of stratigraphic succession of the three subdivisions and sub-faunas of the Cambrian System as known in America to-day.

As previously stated the three divisions of Lower, Middle and Upper Cambrian are recognized in America and Europe. The names of the subdivisions of these three primary divisions of the period in America are the names of the typical terranes that are respectively included in each of the primary divisions. Thus under the term Prospect, of the Lower Cambrian, are included the strata of the Olenellus zone in Nevada, Utah, and the Rocky Mountain region north into British America. The typical section is that crossing Prospect Mountain in the Eureka district, Nevada. In this section the sedimentation and fauna are essentially the same as in the Rocky Mountain area.

letter telling of localities from Mr. J. P. Howley. The geological map of the Avalon Peninsula, by Mr. Howley, was of great service. In the six weeks' search for the Olenellus fauna about Conception Bay, Mrs. Walcott was my constant companion and efficient assistant, and shared with me the pleasure given by the finding of the fauna on Manuel's Brook.

* In all my previous papers with the exception of the note in "Nature," October, 1888, the term Middle Cambrian is to be changed to Lower Cambrian and Lower Cambrian to Middle Cambrian.

† Om alderen af Olenelluszonen; Nordamerika. Aftryck ur Geol. Föreningens; Stockholm Förhandl., No. 101, vol. viii, H. 3, 1886.

SILURIAN (ORDOVICIAN).

CAMBRIAN.	Upper Cambrian.	Lower Calciferous	Lower portion of the Calciferous sandrock of New York and Canada; Lower Magnesian limestone of Wisconsin, Missouri, etc.
		Potsdam	Potsdam sandstone of New York, Canada, Wisconsin, Texas, Wyoming; Gallatin limestone of Montana and portion of Pogonip limestone
		Knox	of Nevada; Knox shales of Tennessee; Coosa shales of Georgia and Alabama; the Alabama section may extend down into the Middle Cambrian.
		Tonto	Tonto calcareous shales of Arizona.
		Bell Isle	Shales and sandstones of Great and Little Bell and Kelley's Islands, Conception Bay, Newfoundland.
	Middle Cambrian.	St. John	Shales and slates of Braintree, Massachusetts; St. John, New Brunswick and the Avalon Peninsula of Newfoundland. Central portions of the New York and Nevada Cambrian sections.
		Braintree	
		Avalon	
	Lower Cambrian.	Georgia	Georgia shales and "Granular Quartz" of Vermont, Canada, New York and Massachusetts.
		Terra Nova	Limestones, etc., of L'Anse au Loup, Labrador; northwest coast and Peninsula of Avalon, Newfoundland; lower part of Cambrian section of Eureka and Highland Range, Nevada;
		Prospect	Upper arenaceous shales of Big Cottonwood Cañon, Cambrian section of Utah.

ALGONKIAN.

The topmost division, Lower Calciferous, includes the passage beds between the Cambrian and subjacent Lower Silurian (or Ordovician) systems. In northeastern New York the line between the two systems is very distinct, but in central New York and Nevada there is no stratigraphic break between them. Passage beds must necessarily exist in some localities; in the table these are recognized by the Lower Calciferous, as in Wisconsin that horizon contains a fauna more intimately related to the Cambrian than to the superjacent second fauna.

The names Potsdam, Acadian and Georgian might be used in the second column to replace Upper, Lower and Middle Cambrian. The objection, for instance, that the typical Acadian fauna is not present in the great Rocky mountain area, and that there is a Middle Cambrian zone which is recognized there, leads me to drop the denotive names in the second column and use the more universally applicable terms Upper, Middle and Lower Cambrian.

Stratigraphic Position of the Olenellus Zone.

Determined by our present information the Olenellus fauna is at the base of the Cambrian. Beneath the Olenellus zone the strata are to be referred to some of the pre-Cambrian groups.

As already mentioned the Olenellus zone of the Atlantic basin occurs in sediments resting on the Archean and close to the base of the strata referred to the Paleozoic group. In Vermont the Winooski marble series shows over seven hundred feet of limestone beneath the Olenellus zone that have not as yet yielded any characteristic fossils.* Murray and Howley state that in Newfoundland several thousand feet of sandstone occur, on the shores of Trinity Bay and vicinity, beneath the horizon of the Manuel's Brook conglomerate. They do not report fossils, which leaves in doubt the horizon to which this sandstone series should be referred.

The great series of siliceous rocks of the Wasatch section, Utah,† show 11,000 feet of strata conformably subjacent to the Olenellus zone; and all through the uplifts of Cambrian rocks in Utah and Nevada a considerable thickness of strata is known to occur in a similar position.

In western Nevada the sandstone and siliceous shales of the Wasatch and similar sections are represented by more or less calcareous strata, and it is there that we may hope to find a pre-Olenellus fauna.

At present I draw the basal line of the Cambrian in Utah and Nevada, at the bottom of the band of arenaceous shale carrying the Olenellus fauna. This refers the quartzites and siliceous shales of the Wasatch and similar sections, including that of the Eureka district and that of the Highland range of Nevada, to the Algonkian Period.

The section laid bare in the Grand Cañon of the Colorado, beneath the great unconformity at the base of the known Cambrian, shows 12,000 feet of unaltered sandstone, shales and limestone that, I think, were deposited in pre-Cambrian time and should be referred to the Keweenawan Group.‡ This presents one of the best opportunities known to me for the discovery of a pre-Olenellus fauna. The entire section is unbroken, and the sandstones, shales and limestones are much like those of the Silurian section of New York. In a bed of dark argillaceous shale, 3,550 feet from the summit of the section, I found a small Patelloid or Discinoid shell, a fragment of what appears to be the pleural lobe of a segment of a trilobite, and in a layer of bituminous limestone, an obscure, small

* Bull. U. S. Geol. Survey, No. 30, p. 15, par. 13, Nos. 1, 2 and 3 of the section.
† Loc. cit., p. 38, par. 74.
‡ This Journal, III, vol. xxxii, 1886, p. 153, foot-note.

Hyolithes. In layers of limestone, still lower in the section, an obscure Stromatoporoid form occurs in abundance.*

A similar series of rocks occur, unconformably beneath the Cambrian, in Llano County, Texas. Fossils have not been reported from them.†

The Geographic Distribution of the Olenellus Fauna.

I have endeavored to show that on the American continent the Olenellus fauna occurs in sediments deposited on the margins of a continental area that, in later Cambrian time, was depressed beneath the sea and largely covered by sediments of Upper Cambrian age.‡ My studies in Newfoundland, during the past summer, lead me to think that there the Olenellus zone was also a shore deposit about an Archean land area that was probably not depressed deeply, if at all, at any one time, beneath the sea in any part of Cambrian time.

The Olenellus zone of Norway, Sweden, Russia (Lapland and Esthonia) occurs on the margins of an old Archean continent, and the Olenellus zone of England and probably of Scotland and the Island of Sardinia is on the western side of the European area. In other words, the Olenellus fauna, as far as known to-day, lived on the western side of a pre-Cambrian continental area, outlined by the present continent of Europe; also on the eastern and western sides of a continental area that extended, on the east, from Labrador southwest along the Atlantic coast line, and also on a line now occupied by the valleys of the St. Lawrence, Lake Champlain and the Hudson River, and probably the central line of the Appalachians to Alabama; and on the west by the eastern ranges of the Rocky Mountains, from Arizona far into British America.

The correlations in the following table follow the Newfoundland section. In New York the Paradoxides zone has not been recognized, unless we consider the representative species, *Linnarssonia Taconica*, *Agnostus desideratus*, *Agnostus*, of the type of *A. pisiformis*, *Microdiscus connexus*, and *Zaconthoides Eatoni*, as indicating it. This I am at present inclined to do.

In Newfoundland the genus Olenus is represented, but in New York, Nevada, Wisconsin, etc., the genus Dicellocephalus is taken as the representative genus of the Upper Cambrian.

In the southern Appalachian area, Tennessee, Alabama, etc., the Upper Cambrian fauna is well developed, and the Middle is indicated by *Olenoides Curticei*, n. sp., *Ptychoparia antiquata* Salter, *Agnostus*, 2 sp.

* This Journal, III, vol. xxvi, 1883, pp. 437–442.
† This Journal, III, vol. xxviii, 1884, pp. 431–433.
‡ This Journal, III, vol. xxxii, 1886, pp 154–157.

Table showing the order of succession of the Cambrian faunas in typical areas in America.

		Newfoundland.	Massachusetts.	New York.	Tennessee.	Nevada and Utah.	Upper Mississippi Valley.
CAMBRIAN SYSTEM.	UPPER CAMBRIAN.	Olenus zones.	Unknown.	Dicellocephalus zones.	*Present.*	Dicellocephalus zones.	Dicellocephalus zones.
	MIDDLE CAMBRIAN.	Paradoxides zones.	Paradoxides zones.	Indicated by other genera than Paradoxides.	Same as in Nevada and Utah.	Represented by other genera than Paradoxides.	Unknown.
	LOWER CAMBRIAN.	Olenellus zones.	Olenellus zones.	Olenellus zones.	Unknown.	Olenellus zones.	Unknown.

The details of this table will be described in a future paper.

The succession of the Cambrian faunas in Europe is the same as on the Atlantic basin side of North America, as shown in the following table:

*Table showing the order of succession of the Cambrian faunas in Europe, where the Olenellus zone has been recognized. The local sections are given in Dr. Lapworth's paper.**

		Scandinavia.	Russia.	Britain.	Sardinia.
CAMBRIAN SYSTEM.	Upper Cambrian or Olenus zones.	Dictyonema and Olenus zones.	Dictyonema.	Dictyonema and Olenus zones.	?
	Middle Cambrian or Paradoxides zones	Paradoxides zones.	Unknown.	Paradoxides zones.	?
	Lower Cambrian or Olenellus zones.	Olenellus zones.	Olenellus zones.	Olenellus zones.	Types of the Olenellus fauna, but not Olenellus.

* Nature, vol. xxxix, 1888, p. 213.

The Olenellus Fauna.

A summary of the Cambrian fauna is given in the Introduction to Bull. 30, U. S. Geol. Survey, in which the Olenellus fauna is credited with 43 genera, 107 species and 2 varieties. In this summary 3 genera and 19 species are included that are not found in association with the genus Olenellus or typical species of the fauna. They were found beneath the Potsdam horizon and above the Georgia or Olenellus horizon, and are now referred to the Middle Cambrian. They are: *Protospongia fenestrata* Salter, *Eocystites?? longidactylus* Walcott, *Leperditia Argenta* Walcott, *Agnostus interstrictus* White, *Olenoides Nevadensis* Meek (sp.), *O. quadriceps* Hall and Whitfield (sp.), *O. Wasatchensis* Hall and Whitfield (sp.), *O. spinosus* Walcott, *O. typicalis* Walcott, *Ptychoparia Housensis* Walcott, *P. Kingi* Meek (sp.), *P. Piochensis* Walcott, *P.? Prospectensis* Walcott, *P. quadrans* Hall and Whitfield (sp.), *P. subcoronata* Hall and Whitfield (sp.), *Bathyuriscus Howelli* Walcott, *B. productus* Hall and Whitfield (sp.), and *Asaphiscus Wheeleri* Meek. *Ptychoparia Piochensis* occurs 100 feet above the Olenellus zone proper, in the Highland Range section,* but as it also occurs 1137 feet higher up in the same section, it is now referred to the Middle Cambrian fauna and not to the Olenellus fauna.

From the Olenellus zone of eastern New York, I subsequently described:† *Lingulella Granvillensis*, *Linnarssonia Taconica*, *Orthis Salemensis*, *Hyolithellus micans*, var. *rugosa*, *Modiolopsis?? prisca*, *Leperditia dermatoides*, *Aristozoa rotundata*, *Microdiscus convexus*, *Olenoides Fordi*, *Solenopleura?? tumida*, *Ptychoparia Fitchi* and *P.? clavata*, and recent collections have added *Agnostus desideratus*, n. sp., *Agnostus* of the type of *A. pisiformis*, and *Zacanthoides Eatoni* n. sp.

All of these occur in association with Olenellus, although *Linnarssonia Taconica*, *Agnostus desideratus*, *Agnostus* type of *A. pisiformis*. *Microdiscus connexus*, *Zacanthoides Eatoni*, n. sp., are types of the Paradoxides fauna.

Professor N. S. Shaler discovered an area of fossiliferous Lower Cambrian rocks in Bristol County, Massachusetts, from which he has described, in association with Mr. A. F. Foerste, the following species:‡ *Obolella crassa* Hall (var.), *Obolella?*, *Fordilla Troyensis* Barrande?, Lamellibranch?, *Scenella reticulata* Billings, *Stenotheca rugosa*, var. *paupera*, *S. rugosa*, var. *abrupta*, *S. recurvirostra* (n. sp.), *Platyceras primævum*

* Bull. U. S. Geol. Survey, No. 30, 1886, pp. 33, 34.
† This Journal, III, vol. xxxiv, pp. 188–198, 1887.
‡ Bull. Mus. Comp. Zoölogy, vol. xvi, No. 2, 1888.

Billings, *Pleurotomaria* (*Raphistoma*) *Attleborensis* (n. sp.), *Hyolithes quadricostatus* (n. sp.), *H. communis*, var. *Emmonsi* Ford, *H. Americanus* Billings, *H. princeps* Billings, *H. Billingsi* Walcott?, *Hyolithellus micans* Billings, *Salterella curvatus* (n. sp.), *Paradoxides ? Walcotti*, n. sp., *Ptychoparia mucronatus* (n. sp.), *P. Attleborensis* (n. sp.). Of these, two genera—Pleurotomaria and Paradoxides—have not before been found in a strongly marked Olenellus zone fauna; and eight of the species and two varieties were unknown in 1886.

It is doubtful if the genus Paradoxides occurs in this lower Olenellus zone fauna. *P. Walcotti* is founded on a small head that appears to be generically identical with similarly sized heads of *Olenellus asaphoides* that are associated with a similar fauna at Troy, N. Y.

In Newfoundland I have found 14 genera and 23 species and 5 varieties in the Olenellus zone, as follows: *Obolella Atlantica*, n. sp., *Kutorgina Labradorica*, *Hyolithellus micans* Billings, *H. micans*, var. *rugosa* Walcott, *Hyolithellus ?*, n. sp., *Hyolithes princeps* Billings, *H. impar* Ford, *H. quadricostatus* S. and F., *H.*, 2 n. sp., *Pteropod ?*, n. gen., n. sp., *Scenella reticulata* Billings, *Stenotheca rugosa*, var. *acuta-costa* Walcott, *Stenotheca rugosa*, var. *erecta* Walcott, *Stenotheca rugosa*, var. *levis* Walcott, *Stenotheca rugosa*, var. *paupera* Billings, *Platyceras primævum* Billings, *Microdiscus Helena*, n. sp., *M. speciosus* Ford, *Microdiscus* sp. ?, *Olenellus Bröggeri* Walcott, *Avalonia Manuelensis*, n. sp., *Ptychoparia Morrisi*, n. sp., *Agraulos* (*S.*) *strenuus* Billings, *A.* (*S.*) *strenuus* var. *nasutus*, n. var., *Agraulos* n. sp., *Solenopleura bombifrons* Matthew, *Solenopleura*, n. sp. Of these, 2 genera, 14 species and 4 varieties were not previously known in the fauna.

A list of all the genera and species now known to me from America, gives a total of 55 genera, 127 species and 9 varieties, as follows:

Spongiæ.
- Leptomitus Zitteli, Walcott.
- Girvanella ? sp. ?
- Protospongia sp ?

Hydrozoa sp. ?
- Phyllograptus ? simplex, Emmons.
- Climacograptus ?? Emmonsi, Walcott.

Corals.
- Protopharetra, sp. ?
- Spirocyathus Atlanticus, Billings.
- Coscinocyathus Billingsi, Walcott.
- Archæocyathus profundus, Billings.
- – – —(A) rarum, Ford.
- – – — (A) Rensselaericum, Ford.
- Dwighti, n. sp.
- Ethmophyllum Whitneyi, Meek.
- Meeki, n. sp.

Crinoidea.
- Eocystites ? sp. ?

Trails, burrows and tracks.
- Planolites incipiens, Billings.
- congregatus, Billings.
- annularius, n. sp.
- Helminthoidichnites marinus, Emmons.
- Scolithus linearis, Haldeman.
- Cruziana sp. ?

Brachiopoda.
- Lingulella cælata, Hall (sp.)
- Ella, H. and W.
- Granvillensis, Walcott.
- Linnarssonia Taconica, Walcott.
- Kutorgina cingulata, Billings.
- Labradorica, Billings.

Brachiopoda.
Kutorgina pannula, White (sp.)
Prospectensis, Walcott.
Iphidea bella, Billings.
Acrotreta gemma, Billings.
Acrothele subsidua, White.
Obolella Atlantica, n. sp.
chromatica, Billings.
Circe, Billings.
crassa, Hall (sp.)
gemma, Billings.
nitida, Ford.
Orthis Highlandensis, Walcott.
Salemensis, Walcott.
Orthisina festinata, Billings.
orientalis, Whitfield.
? transversa, Walcott.
? (sp. undetermined.)
2 sp. ?
Camerella ? antiquata, Billings.
? sp. ?
Lamellibranchiata.
Fordilla Troyensis, Barrande.
Modiolopsis (??) prisca, Walcott.
Gasteropoda.
Helenia bella, n. gen., n. sp.
Stenotheca ? elongata, Walcott.
curvirostra, S. and F.
? rugosa, Hall. (sp.)
var. abrupta, S. and F.
var. acuta-costa, n. var.
var. erecta, n. var.
var. levis, n. var.
var. paupera, Billings.
Scenella conula, Walcott.
reticulata, Billings.
retusa, Ford.
? varians, Walcott.
Platyceras primævum, Billings.
Pleurotomaria (Raphistoma) Attleborensis, Shaler and F.
Pteropoda.
Hyolithes Americanus, Billings.
Billingsi, Walcott.
communis, Billings.
var. Emmonsi, Ford.
impar, Ford.
princeps, Billings.
quadricostatus, S. and F.
sp. (undetermined.)
similis, n. sp.
terranovicus, n. sp.
Hyolithellus micans, Billings.
var. rugosa, Walcott.
Coleoloides typicalis, n. gen., n. sp.
Salterella pulchella, Billings.
rugosa, Billings.
curvatus, Shaler and F.

Crustacea.
Leperditia (I) dermatoides, Walcott.
sp. ?
Aristozoa rotundata, Walcott.
Troyensis, Ford.
sp. ?
Protocaris Marshi, Walcott.
Trilobita.
Agnostus nobilis, Ford.
desideratus, n. sp.
sp.
Microdiscus bella-marginatus, S. and F.
connexus, Walcott.
lobatus, Hall.
Meeki, Ford.
Parkeri, Walcott.
speciosus, Ford.
sp. ?
Olenellus (Mesonacis) Vermontana, Hall (sp.)
(M.) asaphoides, Em. (sp.)
Gilberti, Meek.
Iddingsi, Walcott.
Thompsoni, Hall.
(M.) Bröggeri, n. sp.
Paradoxides ? Walcotti, Shaler and F.
Olenoides Fordi, Walcott.
? Marcoui, Whitfield. (sp.)
Zacanthoides Eatoni, n. sp.
levis, Walcott.
Bathynotus holopyga, Hall.
Avalonia Manuelensis, n. gen., n. sp.
Conocoryphe trilineata, Emmons. (sp.)
Ptychoparia Adamsi, Billings.
Attleborensis, S and F.
(?) Fitchi, Walcott.
misera, Billings.
sub-coronata, H. and W.
Teucer, Billings. (sp.)
Vulcanus, Billings. (sp.)
2 sp. ?
Agraulos strenuus, Billings.
var. nasutus, n. var.
Crepicephalus Augusta, Walcott.
Liliana, Walcott.
Oryctocephalus primus, Walcott.
Anomocare parvum, Walcott.
Protypus Hitchcocki, Whitfield. (sp.)
(?) clavata, Walcott.
senectus, Billings. (sp.)
var. parvulus, Billings.
Selenopleura bombifrons, Matthew.
nana, Ford.
(?) tumida, Walcott.
Harveyi, n. sp.
Howleyi, n. sp.

Resumé of Fauna.

	Genera.	Species.	Varieties.
Spongiæ	3	3	0
Hydrozoa	2	2	0
Corals	5	9	0
Crinoidea	1	1	0
Trails, burrows and tracks	4	6	0
Brachiopoda	10	27	0
Lamellibranchiata	2	2	0
Gasteropoda	5	10	5
Pteropoda	4	15	2
Crustacea	3	5	0
Trilobita	16	46	2
Total	55	127	9

The Olenellus Fauna in Europe.

Until the memoir of Holm's on *Olenellus Kjerulfi** appeared, American paleontologists were unwilling to admit that the genus Olenellus was represented in Europe. The figures and descriptions given by Linnarsson and Brögger were unsatisfactory, and they did not care to change the scheme of classification proposed by Logan without very positive evidence. Personally I avoided referring to the debated question while engaged in its study in America and while waiting for fuller data from Europe. I felt the force of Brögger's argument, but preferred to wait for stronger proof before accepting or rejecting the European view.

To the American fauna I will add the European forms that are at present known to me:

Scandanavia.—Holm states† that according to Linnarsson and Brögger, the fauna of the Olenellus zone in Scandanavia consists of: *Olenellus Kjerulfi* Linnars., *Ellipsocephalus Nordenskioldi*, *Arionellus primævus* Brögger, *Hyolithes* sp. undet., *Metoptoma* sp., *Lingulella ? Nathorsti* Linnars., *Obolus* sp., *Discina ?* sp.

From the Eophyton sandstone beneath the *Olenellus Kjerulfi* zone Linnarsson described‡ *Bythrotrephis* sp., *Medusites radiata* Linnars., *Medusites Lindstromi* Linnars., *Mickwitzia Monolifera* Linnars., *Hyolithes levigatus* Linnars., *Arenicolities spiralis* Torell, *Fræna tenella* Linnars., *Cruziana dispar* Linnars., *Scotolithus mirabilis* Linnars., *Eophy-*

* Aftryck vr. Geol. Fören. Stockholm, Förhandl., vol. ix, häft 7, 1887.
† Aftryck vr. Geol. Fören. Stockholm, Förhandl., vol. ix, häft 7, p. 22, 1887.
‡ Geog. och Pal. Iakttag. Eophytonsandstenen i vestergotland Kongl. Svenska Vet. Akad. Handl., vol. ix, No. 7, 1871.

ton Linnœanum Torell, *E. Torelli* Linnars. These last three species are probably based on inorganic markings.

Russia.—The Olenellus zone in Estland, Russia, has, according to Schmidt, the following genera and species:

Olenellus Mickwitzi Schmidt, *Scenella discinoides* Schmidt, *Scenella? tuberculata* Schmidt, *Mickwitzia monilifera* Linnarsson (sp.), *Obolella?* sp., *Discina?* sp., *Volborthella tenuis* Schmidt, *Platysolenites antiquissimus* Eichwald (sp.), *Medusites Lindstromi* Linnarsson, *Frœna tenella* Linnarsson, *Cruziana*, *Primitia?* (sp.).*

Britain.—The Olenellus fauna was first described in Britain by Professor Charles Lapworth.† At the Cumley quarries, Little Caradoc, Shropshire, he obtained *Olenellus* ——, Hyolithellus, Kutorgina, Scenella, Ptychoparia and Obolella, from calcareous sandstone, in the Cumley sandstone. The stratigraphic position of the sandstone in relation to the Paradoxides zone was not known until the fauna proved that it belonged to the Lower Cambrian. In the more complete section of the Cambrian, at St. David's, S. Wales, the purple, green and red sandstones and slates of the Caerfai group of Hicks occupy the stratigraphic position of the Olenellus zone in Newfoundland, as do the somewhat similar beds near Llanberis and Bangor, in North Wales. As yet the few fossils found—*Lingulella primæva*, *Discina? Caerfaiensis*, *Leperditia? Cambrensis*,—from St. David's, and *Hyolites* sp., and *Conocoryphe viola*, from North Wales, do not prove the presence of the Olenellus zone, although I shall include them in the Lower Cambrian fauna.

Spain.—The only species recorded from the Spanish peninsula that can be classed with the Olenellus fauna is *Ethmophyllum Marianus* Roemer.

On the Island of Sardinia a large Cambrian fauna has been discovered that includes the genera Archæocyathus, Coscinocyathus, Obolella, Kutorgina, Olenopsis, Metadoxides, etc., etc. Until more complete data are published on the geological section and the range of the species. it is not safe to assign any of the species to the Olenellus zone.

Excluding the Sardinia fauna and admitting the genera and species except where evident duplication exists, the pre-Paradoxides-Olenellus-zone faunas of Europe may now be credited with twenty-five genera and thirty-eight species. Of these twelve genera and all the species have not been recognized in America. Adding the European fauna to the American we have

Genera 67; Species 165; Varieties 9.

* Loc. cit., p. 13.

† Nature, vol. xxxix, pp. 212, 213, 1888. Advanced sheets dated Oct. 25, 1888.

To this number there will yet be added many of the genera and species from Sardinia, and probably a considerable number from Britain and Scandanavia.

In the second part of this paper the stratigraphical and zoological relations of the Lower and Middle Cambrian faunas will be discussed.

[To be continued.]

ART. XLI.—*Earthquakes in California*, (1888); by EDWARD S. HOLDEN.

IN 1887 I compiled a list of earthquakes which had been recorded in California, etc., from 1769 to the end of 1887. This was printed by the Regents of the University of California in a pamphlet of 78 pages and widely distributed. The data there given have been discussed in two papers subsequently written. The first is a note on Earthquake Intensity in San Francisco (1808–1888) printed in this Journal for June, 1888; and the second has the title Earthquakes in California, Washington, and Oregon (1769–1888) and has been communicated to the California Academy of Sciences. These three publications contain all the data which I have been able to collect, and I believe that no deductions of especial value can be drawn from the data except those which are there given. These statistics could, of course, be tabulated in several different ways, but it is my opinion, from trials, that no important results not already given would follow.

The examination of past records has naturally led to the consideration of the best manner of making future ones. The object of such records is to bring to light all the general facts as to distribution of earthquake shocks, as to topographic areas, as to time, as to average intensity, etc., and also to enable a study to be made of particular shocks,—as to velocity of transit, area of the disturbed region, intensity, etc. In order to study any of these questions with profit it is necessary to have some kind of a measure of the intensity of each earthquake shock. The most satisfactory instruments which I have seen for this purpose are those invented by Professor Ewing, F.R.S. These are devised on sound mechanical principles and are well constructed by the Cambridge Scientific Company.

It is necessary at the Lick Observatory to keep a register of all earthquake shocks in order to be able to control the positions of the astronomical instruments. Accordingly I ordered a set of Professor Ewing's instruments for the Observatory, which were delivered in 1887. They are described with woodcuts in Volume I of the *Publications* of the Observatory, (page 81), and in the *Hand Book of the Observatory*, (page 54). The complete set of instruments will give for each shock the time of its beginning, and that of every tremor; the amplitude of the vibration in the east and west, the north and south, the up and down directions at every instant. Such a complete set of instruments requires continual attention and is far too delicate and troublesome in adjustment for general use. The *Duplex Seismometer* of Professor Ewing seems, however, to be well suited for general purposes. It gives with considerable accuracy, the magnitude of the earthquake force in any two directions as east and west and north and south. The vertical component is not registered, and the time of occurrence must be taken from a watch. Copies of this instrument can be had from the California Electrical Works (35 Market street, San Francisco), for $15. It therefore seems to be a suitable pattern for use in California, and elsewhere, since it combines comparative accuracy, with cheapness. A complete set of Professor Ewing's instruments, is provided as I have said, at the Lick Observatory. The duplex seismometers multiply four times; while the vertical component is multiplied $1\frac{6}{10}$ times, the horizontal component $3\frac{3}{10}$ times in the complete instrument.

Another complete set, exactly similar, belongs to the University of California, at Berkeley, and is installed at the Student's Observatory there, under charge of Professor Soulé. This Observatory also has a Gray-Milne seismometer, complete. Copies of the duplex seismometer are set up also at the following stations:

(1.) San Francisco, near Cliff House, residence of Hon. A. Sutro.

(2.) San Francisco, 917 Pine street, residence of Hon. J. R. Jarboe.

(3.) Chabot Observatory, Oakland, in charge of Mr. Burckhalter.

(4.) Private Observatory of Mr. Blinn in East Oakland.

(5.) Kono Tayee, Clear Lake, residence of Capt. R. S. Floyd.

(6.) Observatory of University of the Pacific, San José, in charge of Professor Higbie.

(7.) Students' Observatory, Berkeley, in charge of Professor Soulé.

(8.) One will be shortly installed at Smith Creek Hotel, at the foot of Mt. Hamilton.

(9.) Office of State Weather Bureau, Carson, Nevada, in charge of Charles Freund, Esq.

Copies of this instrument are also in possession of Warner and Swasey of Cleveland, and of Capt. C. E. Dutton, of the U. S. Geological Survey for experiments. I believe that one will be shortly mounted at the Blue Hill Observatory, near

Boston, Massachusetts. The Lick Observatory also possesses a seismometer invented by Professor Milne and kindly presented by him, which is designed to serve for general purposes. We have not thoroughly tested this as yet. It is simple in construction, and inexpensive. A description of it may be found in *Trans. Seis. Soc. of Japan*, vol. xii.

The instruments above named which are in California have been visited and adjusted by Mr. Keeler of the Observatory (who is in charge of our earthquake instruments), and the owners of these instruments have kindly reported the occurrence of shocks, and have often sent blue prints or tracings of the records made. The reports of Mr Jarboe, Mr. Blinn, and Mr. Burckhalter have been especially full, as will be seen from what follows. Wm. Irelan, Esq., Dr. J. B. Trembley of Oakland, and U. S. Surveyor General Irish of Nevada, have kindly taken the pains to send accounts of all shocks.

I have also copied from such newspapers as fell under my eye all data respecting California earthquakes. These are given in what follows, together with the results obtained from the various instruments. To make this record complete the reports of the U. S. Light House Board, of the U. S. Geological Survey, and the annual records of earthquakes given by Professor Rockwood in this Journal should be consulted. As these are available to all, I have not reprinted any data from them. It is intended in future years to continue such records as the present one. The extremely local character of some of these shocks is noteworthy.

Earthquakes in California, 1888.

1888, *January* 7, 10:25 P. M.—S. F. (II): Berkeley (IV),—at Berkeley a loud explosion.—Professor Kellogg.

January 13, at night.—Berkeley, a slight shock (N.E.-S.W.) recorded on duplex seismometer (I? II? III?).—Professor Soulé.

January 16, 11:39 P. M.—S. F.: single, short, sharp shock (IV).—E. S. H. (I have no other report of this, and it must therefore be regarded as doubtful.)

January 17, 10:10 P. M.—S. F.—E. E. Barnard. Oakland, from N.E. to S.W. (III? IV?).—Professor Edwards.

January 26, ?—Healdsburg, 10 sec. duration, S. F. *Chronicle*, Jan. 28. (Total eclipse of the moon on January 28.)

January 29, 10:35 P. M.—Carson, Nevada, a slight shock (IV to V) Grass Valley, Cal.: the same shock (II).—*Grass Valley Tidings*, Feb 3.

January 30, 4:15 A. M.—S. F. [not reported in newspapers].—J. R. J.

February 18, 2:50 A. M.—Fort Bragg: three severe shocks, (V?); the first at 2:50, the other at intervals of one or two minutes. Mendocino: three shocks; the first at 2:55, the others at intervals of three or four minutes.—(S. F. *Bulletin*, February 18.)

February ? about 4 A. M.—Menlo Park: sleepers waked (V or VI).—J. T. Doyle, Esq.

February 29, 2:51 P. M.—S. F.: on Montgomery street, people alarmed (V); Pine and Mason streets, more severe, (VI); Washington and Mason streets, (VI). Two waves on duplex seismometer (917 Pine street.). The motion of the earth was

a—N. 68° W. to S. 68° E. *b*—S. 56° E. to N. 56° W.

The shock *b* was most severe.

Berkeley: not felt, not registered.—Oakland: (II.)—Belmont: not felt.—San Rafael: (IV or V) 2:48 P. M., E. to W.—Santa Rosa: 2:55 P. M., violent; people ran out of houses, (VI).—Petaluma: 2:55 P. M., walls cracked (VII) sound of an explosion heard. The severest for many years.—Healdsburg: 2:44 P. M., light N. to S.—Martinez: 2:45 P. M., two shocks one minute apart (VI).—S. F. *Alta*, *Chronicle*, *Bulletin*, Feb. 29th and Mar. 1.

March 7, 7:54 A. M.—Pasadena: 7:58 A. M., (VI); from N.W. to S.E., duration three seconds.—Los Angeles: a little after 8 A. M. (VI)? "severest for 18 years; no damage to buildings," no very heavy articles overturned (VI). [Note: on 1883, Sept. 5th, a shock (VI) was felt at Los Angeles, E. S. H.]—San Diego: scarcely felt (II). (Pasadena *Daily Star*; also S. F. *Alta*, *Chronicle*, Mar. 7, 8).

March 28, 1:41 A. M.—S. F.: slight shock, but sufficient to awaken a sleeper (V). Direction of shock nearly N. and S., on duplex seismometer, 917 Pine street. Professor Davidson says duration $\frac{3}{4}$ second, and shock from W. to E.—S. F. *Bulletin*, Mar. 29.

April 9, 7:50 A. M.—Riverside: slight shock (IV) N.E. and S.W. (S. F. *Bulletin*, April 9, *Chronicle*, April 10.)

April 12, about 5:15 A. M.—Riverside: the shock sufficient to waken sleepers (VI) with loud noises accompanying. Colton, 5:30 A. M. (S. F. *Chronicle*, April 13.)

April 28, [8:45 P. M.]—On the Lick Observatory seismograph an earthquake record was found April 29. From the trace of this shock the following data are taken. The dimensions given below are to be divided by 3·3 for the Horizontal and by 1·6 for the Vertical components, to get the actual earth movements. The times are given in seconds after a zero epoch arbitrarily assumed. The pen which marks the W. and E. components registered a line $\frac{4}{10}$ of a millimeter wide throughout. There appear to be widenings of this line as early as fifteen seconds before the zero second adopted, but the amplitude of E. and W. tremors is never more than $\frac{6}{10}$ of a millimeter during the whole shock and the time of their beginning cannot be fixed. I presume we have here a case where the normal vibrations were strictly in an E. and W. plane. The transverse vibrations which arrived later are therefore N. and S. and of their full size in the diagram. We may then dismiss all further consideration of the E. and W. wave. It had scarcely a measurable amplitude. At 0 seconds the N. and S. tremors begin to show; the whole record of the vertical component is lost till 17 seconds.

At 3 sec.	the earth moved	S.	of the neutral line	1^{mm}
5	"	N.	"	1
6	"	S.	"	1
9	"	S.	"	1
10	"	N.	"	1
11½	"	S.	"	1
13	"	N.	"	1
15	"	S.	"	¾
16	"	N.	"	½
18	"	S.	"	½
19	"	N.	"	½

and small tremors with a double amplitude of about $\frac{1}{2}^{mm}$ (on the trace) continue till 66 seconds.

The vertical component as recorded by the machine is given below:

At 18 sec.	the earth moved	above	the neutral line	1^{mm}
19	"	below	"	½
21½	"	above	"	½
23	"	below	"	1

and tremors of not more than $\frac{1}{2}^{mm}$ continue on the trace till about 56 seconds.

We may assume for a basis of computation:

Number of waves in 10 seconds $=4$,
Period, about 2·5 seconds $=T$,
Amplitude magnified, 1^{mm}, $a=0{\cdot}3^{mm}$,

$$\text{Velocity of projection} = V = \frac{2\pi a}{T} = 0{\cdot}75,$$

$$\text{Intensity} = \frac{V^2}{a} = 1{\cdot}90,$$

which corresponds to about I on the Rossi-Forel scale. The period of these waves is very slow.

April 28, 8:48 P. M.—Reno (Nevada), a smart shock: three waves in 3 sec., followed by a general trembling for 10 sec.

The time of the third and severest shock was 8 h. 48 m. 38 s. P. M. Direction S. to N. (letter from U. S. Surveyor General Irish). Two other observers say W. to E.—Grass Valley: felt in the Idaho mine below the 1600 ft. level, *Alta*, May 2d. Very heavy, lasting 5 sec., from E. to W. (*Chronicle*, April 30). —Grass Valley: the Orleans mine was flooded. The shock was at 8:45 P. M. and very heavy (VII). It was preceded by a loud noise. The duration was about 5 sec., and the wave was E. to W. Clocks stopped, plastering fell, and also tops of chimneys.—Nevada City: walls of courthouse cracked (VIII). —At Marysville, Downieville, Truckee, Colfax and Sacramento the shock was very strong (G. V. *Tidings*, April 30, May 2).—Nevada City: two severe shocks at 8:48 P. M. preceded by a deep rumbling sound. Direction N.—Dutch Flat; 8:46 P. M., severe from S. to N. People were badly frightened.—Stockton: four shocks at 8:40, from N. to S.—Dixon, 8:45 P. M.—Biggs: heavy shock "lasting 75 (?) seconds" [seven to five? E. S. H.], at 8:45 (VII) plastering cracked, etc.—Santa Rosa: slight shock at 8:45, N. and S. (III).—Truckee: 8:47, duration two seconds, (S. F. *Examiner*, April 29).—Oroville: 8:45 P. M. Short, quick shock.—S. F.: barely perceptible in third story of 917 Pine street. No record on duplex seismometer in basement (I).

April 30, *about* 4 A. M.—Grass Valley: *Tidings*, April 30. —Downieville: 3:40 A. M. two light shocks (IV), (S. F. *Bulletin*, April 30).

May 4, 1:55 P. M.—S. F., 917 Pine street, decided shock, not registered on duplex seismometer, J. R. J.—S. F., slight shock (II) of a few seconds duration, (*Bulletin*, May 4).

May 6, 9 h. 42 m. 22 s. P. M. (E. S. H.).—Lick Observatory: sudden shock (III) E. S. H., preceded by a rumbling noise (PORCHER.) (Registered on duplex seismometer).

July 11, *at night.*—Susanville: slight shock (IV ??), S. F. *Bulletin*, July 13.

August 14, 9:57 A. M.—S. F., 917 Pine st. Intensity (II) on R. F. scale. The duplex seismometer gives a looped trace on the plate (magnified four times) 7^{mm} N.N.E. to S.S.W. (direction of first shock), 4^{mm} at right angles to this. The motion of the earth was therefore S.S.W. to N.N.E.—Lick Observatory: direction on the plate N.N.E., of the earth S.S.W. The trace is a wavy line (magnified four times) 8^{mm} long. N.N.E. and S.S.W. with six waves 1^{mm} high at right angles to this. Probably the shock was nearly vertical here.

September 10, 1:53 A. M.—S. F., 917 Pine street: slight shock (II) not registered on duplex seismometer, J. R. J.—Oakland: slight shock, C. Burckhalter. Three shocks at 1:50 A. M. in quick succession, attended by noise; windows did not rattle

(III ?), Dr. Trembley. It waked sleepers in Oakland (V ?), E. Booth.—Berkeley; slight.

September 15 ?—Lick Observatory: the seismograph started at 6:15 A. M., but as the record was not like that of a shock, Mr. Keeler (in charge of the instrument) supposes the tremor which started the instrument to have been due to a high wind.

September 17, 3:51 A. M.—Lick Observatory: The seismograph gives the following records (magnified 1·6 times for the vertical, 3·3 times for the horizontal components). At 3 seconds after an assumed zero second, the vertical component began its trace with a wave of period about 1½ seconds. The amplitude (on the trace) is hard to estimate but is probably not less than 5^{mm} for the first semi-wave, then about 1^{mm} for a full wave, and after this mere tremors until about 40 seconds. The N. and S. component (magnified) was as follows:

At 4·3	seconds the earth moved	S.	of the neutral line	5^{mm}
5·7	"	N.	"	2
5·9	"	on to	"	—
6·1	"	N.	"	2¼
6·4	"	S.	"	1½
6·9	"	N.	"	1
7·5	"	S.	"	1½
8·9	"	N.	"	1¾

and tremors occasionally as large as $\frac{3}{4}^{mm}$ continued until about 40 seconds.

The E. and W. component (magnified) was as follows:

At 4·3 seconds there was strong movement of the earth west of about 3^{mm}; this was followed by a wave of period about 1 second double amplitude 2^{mm}; and this again by another of period ¾ second double amplitude 1^{mm}. After this tremors continue for about 30 seconds.

The strata of which Mt. Hamilton is composed lie at a high angle to the horizon and the direction of the stratification is nearer N. and S. than E. and W. The earthquake instruments are at the very summit of the mountain. This may account for the fact that (at least for the shocks so far observed) the vertical component is relatively large, and that the N. and S. component (in the general direction of the stratification) is usually far larger than the E. and W. component. The record of this shock on the duplex seismometer is very interesting, but it gives no information additional to the above.

We may then assume as a basis of computation for this shock:

Number of waves in 10 seconds = 6 or 7, say 6½.
Period, T, of the representative wave = 0·5 sec.
Amplitude of the representative wave (magnified) = $2{\cdot}5^{mm}$.
$a = 0{\cdot}8^{mm}$.

$$\text{Velocity of projection} = \frac{2\pi a}{T} = 10{\cdot}0.$$

$$\text{Intensity} = \frac{V^2}{a} = 126.$$

This corresponds approximately to V–VI on the Rossi-Forel scale, according to the table in this Journal, June, 1888, p. 429, which was derived from Japanese shocks.

Chabot Observatory: the time of the shock is 3 h. 50 m. plus or minus one-quarter of a minute (W. Irelan, Esq.). It is registered on the duplex seismometer plate as follows. The first motion (of the pen, magnified four times) is 2^{mm} to the W., then follow several small tremors towards the S.E. The motion of the earth is of course in the reverse directions.—Lick Observatory, 3:51 A. M.: severe shock, lasting several seconds. Strong vertical component (VI to VII) observed by E. S. H. Also on L. O. seismometer.—Gilroy, sharp shock: Santa Cruz, heavy, (S. F. *Call*, Sept. 18).—S. F., 917 Pine street: very slight, no record on seismometer, J. R. J.

September 23, *about* 11:30 A. M.—S. F., 917 Pine street: very slight shock, J. R. J.

October 3, 12:52 P. M.—San Miguel, S. L. O. Co.: light shock, 2 sec. duration, N. to S. (III). Another at same place at 1:02 P. M., quite severe, N. to S., 4 sec. duration, no damage done (VI ?), S. F. *Chronicle*, Oct. 4.

October 4, P. M.—Paso Robles: slight shock.—S. F. *Report*, October 5.

October 4, 11 P. M.—San Diego.—S. F. *Bulletin*, October 5.

October 5, 4h. 41m. 30s. ±10s. A. M—Chabot Observatory: the shock was sufficient to waken a sound sleeper (VI). On the duplex seismometer plate the trace begins with a tremulous motion toward the W., followed by two sharp jerks to the S. The motion of the earth is contrary to the motion of the plate.

October 23 ?—Lick Observatory: During Mr. Keeler's absence the earthquake instruments were in charge of Mr. Hill. On October 23, at 6 P. M., I noticed that the earthquake instruments were in their usual state. I also noted at 9 P. M., October 24, that a shock had occurred previously. The clock dial of the earthquake clock is divided to 12 hours (instead of to 24 hours as it should have been), and there is an ambiguity of 12 hours in the time of the shock, which is either

October 23, 11h. 42m. P. M., or October 24, 11h. 42m. A. M.—The shock was sufficient to start the clock of the Ewing seismograph, but the plate did not move. The duplex seismometer plate shows a tremulous wave in the direction N.E. and S.W.

October 24, 2:50 A. M.—East Oakland: (V) Mr. Blinn's Observatory. The duplex seismometer plate shows a trace from S. to N. in general direction. The first trace on the plate is that of a single wave about 2m. in amplitude (magnified four times) followed by small tremors.—Chabot Observatory: the plate of the duplex seismometer shows the first wave strongly towards the N.E. The trace of this wave (magnified four times) is a straight line 6^{mm} long. This is followed by two waves of the earth as it regained its original position. The motion of the earth is contrary to that of the pen on the plate.

October 25, in the night.—Mr. Blinn's Observatory. The duplex seismometer gives a tremor, and the general direction of the trace on the plate is S.E. to N.W.

November 4, 3:36 A. M.—Lick Observatory (VI).—E. S. H. Mr. Barnard gives the time as 3h. 37¼m., plus or minus ½ m. The duplex seismometer gives a very complex knot of curves ending by a trace on the plate towards the S.W. The trace on the Milne seismometer (in cellar of the Meridian Circle House) cannot be interpreted, as the instrument had just been set up and probably was not adjusted properly.

November 18, 2:28 P. M.—S. F., 917 Pine street: two shocks north and south (VII) registered on seismometer. Another light shock at 5:38 P. M.—J. R. J.—San Rafael: 2:30 P. M., N. and S.—Oakland: 2:29 P. M.; one chimney fell (VII?).—Berkeley: 2:28 P. M.; duration 7 sec.; a third shock at 5:35 P. M. (S. F. *Examiner*, Nov. 19.)

Lick Observatory: not felt, not registered.—Chabot Observatory: 2h. 27m. 53s., very sharp shock; 3:30, slight; 5h. 37m. 20s., sharper than the second shock. The duration was 3 sec. The trace on the duplex seismometer is a very complicated circular knot of 5 to 6^{mm} diameter (magnified four times) with a looped excursion of the pen toward the east 6^{mm} from the center of the knot, and another straight one from the center to the W.S.W, also of 6^{mm}. All three shocks are on this single plate.—In Oakland no real damage was done. Two or three chimneys were overthrown and panes of glass were broken (VI, or VII?).—East Oakland: 2:29 P. M., N. to S., duration 2 sec.; 3:45 P. M., very light; 5:36 P. M., E. to W., duration 2 sec.—(S. F. *Bulletin*, Nov. 19).—Napa: 2:36 P. M., duration 10 sec.—S. F. *Chronicle*, Nov. 19.—Haywards, San Leandro, Niles: not felt.—Mr. Burckhalter.—Clear Lake: not felt.—Capt. R. S. Floyd.

It is also reported by Capt. Edmundson of the ship "Drumlanrig," that he found soundings of 35 fathoms, 35 miles S.W. of the Farallones where no shoal is now known to exist. This point will be determined by the proper authorities. It is supposed by some that the shock of Nov. 18 may have produced this shoal which is not down on the charts.

East Oakland: Mr. Blinn's Observatory. The first shock was severe (VI) lasting about two seconds. The time was very approximately 2h. 27m. 57s. (Blinn). Mr. Irelan gives 2h. 27m. 54s. Trees and hedges were seen to move. A few light articles were overthrown, pictures were displaced, a clock was stopped, (its pendulum was in the plane N.E. and S.W.); 5 chimneys were thrown down on 23d avenue; a noise was heard *after* the first shock. The second shock was (II) at 3:48 P. M. The duplex seismometer trace is a loop about 1^{mm} in diameter. The third shock was (III) at 5h. 38m. 45s. P. M. The trace on the duplex seismometer begins in an ellipse 2^{mm} E. and W., 1^{mm} N. and S., and then there is a confused record of trembling 3^{mm} N.W. and S.E. by $1\frac{1}{2}^{mm}$ at right angles to this.

December 11, 3:29 P. M.—Lick Observatory: the shock was sudden and (IV) in intensity. Time by watch 3h. 28m. 59s.; by earthquake clock 3h. $29\frac{1}{4}$m.—J. E. K. A humming noise was heard *after* the shocks. There were two such at an interval of 2 sec. The time of the last was 3h. 28m. 58s. plus or minus 3 sec.—E. E. B. Intensity (V), time 3:28.8.—E. S. H.

The duplex seismometer gives a record (magnified) beginning with a sharp straight trace to the N.W. 3^{mm} long, then a straight trace to the N.E. $1\frac{3}{4}^{mm}$ long, then a straight trace to the N.W. nearly 2^{mm} long, and at the end of this the pen has recorded a confused tremor in a space about 1^{mm} square. The record of the Ewing seismograph is as follows: (The adjustment of the marking pen for seconds has been changed so that there are 95 beats of the pen to 1 min. of time.)

There are very slight *vertical* tremors for the first three beats; they then vanish completely. Their period is from $\frac{1}{8}$ to $\frac{1}{9}$ of a second of time; their double amplitude is not above $\frac{3}{10}$ of a millimeter.

The *east and west* vibrations last only for two beats though the faintest perceptible tremor lasts until the twentieth beat after the beginning. Their greatest double amplitude is not above $\frac{1}{2}$ a millimeter, and their period appears to be about $\frac{1}{2}$ a second.

The *north and south* vibrations are well marked. From the zero beat (beginning) until $1\frac{1}{4}$ beats there are marked tremors. From $1\frac{1}{4}$ beats to $4\frac{3}{4}$ beats vibrations having a double amplitude of about one-half a millimeter, and a period of about $\frac{1}{3}$ to $\frac{1}{4}$ of a second time. At the end of the 6th beat the marked tremors cease and a very faint tremor continues to the end of the 20th beat, and possibly to the end of the 33d beat. As a basis of computation we may assume from the record of the north and south component:

Double amplitude magnified 3·3 times $=0·5^{mm}$.
$a=0·08^{mm}$.
T $=0·3$ seconds.

$$v=\frac{2\pi a}{T}=1·7. \qquad I=\frac{V^2}{a}=36.$$

This corresponds to about II on the R.–F. scale according to the paper frequently cited above. The intensity was, however, IV or higher.

Art. XLII.—*Chemical Action between Solids*;* by William Hallock.

In a note on a new method of forming alloys published some time ago,† I suggested some additional experiments which I intended to make, and I now give the results thus far obtained. Unfortunately other work prevents my continuing the investigation at present.

Inasmuch as the method and principle‡ seemed well established where metals were used to produce alloys, an attempt was made to include some chemical reactions in the list. The most natural cases were the freezing mixtures where solid reagents are used. In order to surely have both constituents in a decidedly solid state the experiments were performed in a vessel cooled to a temperature of minus 10° or 12° C., care being always taken to leave the reagents in the vessel long enough for them to assume a temperature decidedly below zero Centigrade. Under these conditions a crystal of rock salt ($NaCl$) and a piece of clean dry ice were gently brought in contact, lying side by side on a watch glass. Of course the result was a solution of salt, but old as this experiment may be, it appears here in a new connection, as an example of the union of two solids below the melting point of either, but above that of the product. The piece of ice was frozen to the glass and during the operation the crystal was drawn several millimeters across the glass, doubtless by capillarity, as the solution ran out at the bottom of the surface of contact as fast as it formed, the attraction being sufficient to move a crystal several grams in weight.

Similar experiments were performed with sodium and potas-

* This paper was read in part before the Phil. Soc. of Washington, D. C., October 13th, 1888.

† W. Hallock, Zeitschr. f. Phys. Chem., ii, 6, 1888. Science, xi, 265, 1888.

‡ O. Lehmann Wiedemann Ann., xxiv, p. 5, 1885, suggested the theoretical possibility of producing an alloy in this way. I had overlooked his paper until recently. Mr. Lehmann, however, evidently did not consider it possible to fulfill the necessary conditions and did not try the experiment.

sium nitrate, potassium, calcium and ammonium chloride and sodium and potassium hydrate, with a similar result in all cases. These are all well known results, but wherein do they differ from the new method of forming alloys? This question suggests another. Are the metals combining to form an alloy in the new way a freezing mixture? A thorough investigation of this question would require more complicated experiments than I had time to perform. One test, however, is very simple, that with potassium and sodium.

Into a small porcelain crucible weighing 15 grams and containing about an equal weight of petroleum were placed pieces of the two metals, about 3 grams of each. One junction of a thermo-element was forced into the piece of potassium and gave its temperature accurately. After the whole had assumed the room temperature, clean faces of the two metals were brought in contact, the liquefaction began and *the temperature immediately fell.* It required about two hours to complete the liquefaction and about one and a half hours to attain the minimum of temperature. No precautions were taken to prevent the calorimeter taking up heat from its surroundings, and no doubt it absorbed considerable in the long time, and yet the maximum fall in temperature amounted to 2·4° C., very large considering the small weight of the reagents compared with the calorimeter. Thus it appears that sodium and potassium are, under such circumstances, a "freezing mixture," and analogy at least would lead one to believe that other alloys also absorb heat in their formation; but future experiment must decide the point.

In the cool vessel above described a piece of sodium or potassium was placed upon a piece of dry ice, almost instantly the reaction commenced and proceeded vigorously. It is, however, scarcely safe to consider this a case of chemical action between solids, because the reaction is probably as follows: the vapor from the ice attacks the metal forming the hydrate which unites with other ice forming a solution, which is then further acted upon by the metal, and in the whole process heat is generated sufficient to raise the temperature of the reagents very considerably. Perhaps in the other freezing mixtures, ice and salt, etc., it is the vapor of the water or ice which initiates the reaction.

In view of these and other considerations, the idea is evident that perhaps many substances have a slight vapor tension at temperatures considerably below their melting points, and are surrounded by a thin atmosphere of their own vapor over their clean surfaces, and it is only necessary to bring two such atmospheres to interpenetration in order to initiate the reaction which will then continue, provided the product (liquid or gas) escapes easily and does not clog the operation. In very many cases substances are found to give off a vapor below their melting point, and it is natural to suppose that there is a film of that vapor over the surface of the body, as there is a layer of saturated air over water. The mechanical theory of the composition of matter lends plausibility to the above suggestion. If these considerations are correct they foretell the regelation of substances like camphor and ice, without any pressure whatever. That loose pieces of camphor will become welded together by simple contact is well known. The operation appears to me thus: In an irregular mass of camphor in an atmosphere of camphor vapor, there is a constant interchange of state for the molecules at the surfaces of the solid, molecules previously solid are getting too far off and becoming gas, and molecules previously gas are beating upon the solid and staying there, thus the state of equilibrium is when, as a whole, there are as many molecules which fly off and become gas as fly on and become solid. On a projecting point of the solid the chances are in favor of more flying off than on, in a reëntrant angle the reverse is true. Theoretically, then, the piece ought ultimately to become a sphere, not only by the rounding down of the corners, but by the building up of the flat or reëntrant sides. That the corners do round off all know. If this is all true we only need to bring the two pieces together and consider them as one and the crack between them as a reëntrant angle, and the union is brought about as above indicated. If in the above the word liquid be substituted for vapor or gas, the explanation will apply to the regelation of ice in water at 0° C.

We may go even further and predict a uniting without actual contact and this prediction has been experimentally demonstrated in the case of ice and water. A large rough block of ice (about 15 lbs.) was sawed nearly in two, the slit washed out and all the fine pieces removed. In this way it was possible to hold two plane surfaces of ice parallel and near each other (1 to 2^{mm}) without danger of actual contact. Into the outer edge of the saw-cut a cotton wick was pressed, thus isolating the space between the faces from the outside and preventing any currents from circulating through the crack. The whole block was then placed in water at zero and enclosed in non-conducting cases and left for 25 to 30 hours. This experiment was tried three times and each time a freezing across the space had taken place. The whole space was not filled, but in numerous places notably along just inside the wicking and up from the bottom of the cut. No doubt the regelation would have gone further if the experiment could have been continued longer. The melting of the whole block puts an end to each experiment. As these experiments were performed in summer there is scarcely a possibility that the ice was colder than 0° C.

Inasmuch as there seems to be an increasing inclination to regard solutions and alloys as chemical compounds it seems justified to speak of the action according to the alloy law as chemical. On the other hand there are some cases which at first appear as chemical action between solids which upon closer investigation can be explained on a simpler assumption.

For example, Mr. W. Spring* in a recent paper on this subject cites three particular cases as being chemical action between solids, the union of copper and sulphur, the reaction between copper and mercuric chloride, and between potassium nitrate and sodium acetate.

The formation of the sulphide of copper, and other sulphides, was accomplished by Mr. Spring by compression of the elements. But it is not even necessary that the sulphur and copper be in contact. I have made the sulphide at ordinary temperatures with the two an inch apart and a wad of cotton in the tube between them. It is simply the *vapor* of sulphur which attacks the copper. That sulphur gives off a perceptible vapor at ordinary temperatures, especially in vacuo, is a fact any one can easily demonstrate. The case of the copper and mercuric chloride is precisely the same. The *vapor* of the chloride will go through a whole tube past cotton wads and attack the copper (or color potassic iodide). Hence we can scarcely assert that these reactions are between *solid* bodies. The reaction between potassium nitrate and sodium acetate is equally unconvincing. Mr. Spring expected an interchange of bases and acids and left the mixture of the dry fine powders four months in a desiccator to give time for the exchange. On removing them from the desiccator a deliquescence was noticeable and he therefore concludes that the interchange had taken place, since the original salts do not easily deliquesce; but the product of the reaction (potassium acetate) does. It appears to me thus: the moment the powders were brought to the air, the water vapor enters the operation and we have, potassium nitrate, water vapor, and sodium acetate, and the result of their mutual interaction is a solution of potassium acetate and sodium nitrate. In fact if the dry powdered salts are stirred together, in a very few moments deliquescence begins, showing that whatever the reaction it goes on at once, and is a matter of moments and not of months. Thus even this experiment in its present form does not convince us that a chemical exchange took place *before* the water vapor entered the reaction.†

* W. Spring, Zeitschr. für phys. Chemie, ii, p. 536, 1888.
† See note on p. 406.

The question of chemical action between solids is by no means new but is being constantly extended. I may say I believe chemical action may take place wherever the product or products are liquid or gaseous even though the reagents are solid, with perhaps the added condition that one or both the reagents be soluble in the liquid produced. If this be true my new method of forming alloys is but a special case of the above general principle.*

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SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Spectrum of Magnesium.*—Liveing and Dewar have studied the spectrum of magnesium produced by the arc discharge. Most of the lines produced by the spark discharge are observed in an electric arc formed between electrodes of magnesium. The greater number of lines seen in the arc discharge, however, may be due not to lowness of temperature but to the greater mass of incandescent matter and to a wider range of temperature at different portions of the discharge, recombinations occurring at its edge. The electric discharge itself may also give rise to vibrations distinct from those due to heat. The seven bands in the green are due to the oxide, as they are produced only in the presence of oxygen or of its compounds. If a piece of burned magnesium wire be heated in the oxyhydrogen flame, the spectrum of magnesium is produced, the metallic lines appearing if the hydrogen is in excess. The triple line near M, which is produced when magnesium is burned, is found to be produced in the arc between magnesium electrodes and in many other cases when oxygen is present, but not in an atmosphere of nitrogen or hydrogen; hence it is due to the oxide. Vacuum tubes are found to be very untrustworthy for the ultra-violet spectra as the water-spectrum and lines of nitrogen are nearly always present and the spectra sometimes vary unaccountably. The authors describe in their paper a pump in which rubber connections and free contact of mercury with air, are both avoided.—*Proc. Roy. Soc.*, xliv, 241; *J. Chem. Soc.*, lvi, 89, February, 1889. G. F. B.

2. *On a Lecture Experiment for showing Raoult's Molecular depression of the Freezing Point.*—Cimician has described an apparatus for showing, as a lecture experiment, Raoult's law of the lowering of the freezing point. A large test tube, 2·5 cm. in diameter and 16 cm. high, is used to contain the solution, which

* Experiments endeavoring to produce carbon disulphide from the elements at ordinary temperatures are in hand and give promise of positive results. Also experiments on the interaction of potassium nitrate and sodium acetate have been started; it will however be sometime before further results can be given.

is placed in a large beaker and surrounded with a freezing mixture of ice and salt. Within this test tube is the bulb of an air thermometer cylindrical in form, 12 cm. long and 1·5 cm. in diameter, the tube of which, about 10 cm. long and 1·5 mm. in bore, is bent twice at right angles, its end dipping in a vessel of colored water. Upon the larger upright portion of this tube two bulbs are blown to act as safety bulbs ; one near the top to prevent the liquid from passing over into the thermometer-cylinder on contraction and the other near the bottom to prevent the escape of any air from the thermometer when it is heated. The freezing point of water is first obtained with the apparatus. For this purpose the test tube is filled with distilled water, the thermometer bulb inserted into it, the whole placed in the freezing mixture and the water constantly agitated by means of a stirrer. The column of colored water rises in the tube as the cooling goes on, reaching at first a higher than the normal point, owing to surfusion, but suddenly falling to this as soon as the formation of ice begins, remaining then stationary. The motion of the column can be readily seen throughout an ordinary lecture room, the position of rise being indicated on an attached scale or marked with a slip of paper. If now the experiment be repeated with various solutions each containing in the same quantity of water (say 100 c. c.) molecular quantities of different organic substances, it will be observed that the height of the colored column, while approximately the same in each case, is always greater than when pure water is used. With solutions of 34·2 grams cane sugar, 18·2 grams mannite, 5·8 grams acetone, 6·0 grams glacial acetic acid, in 100 c. c. water for example, the difference in height is several centimeters and is therefore visible from a considerable distance. The solutions may be prepared during the lectures and in this way it can be clearly demonstrated that isotonic solutions cause the same depression of the freezing point. The difference is greater if an electrolyte be used. In a solution of 5·85 grams sodium chloride in 100 c. c. water, this difference is nearly twice that obtained with the organic solutions.—*Ber. Berl. Chem. Ges.*, xxii, 31, January, 1889. G. F. B.

3. *On Chydrazaïne or Protoxide of Ammonia.*—Maumené has described a gas obtained by the action of permanganic acid upon ammonium oxalate, to which he has given the formula N_2H_6O and the name chydrazaïne. To prepare it, 158 grams of potassium permanganate, 141·2 grams crystallized ammonium oxalate and sulphuric acid equivalent to 40 grams SO_3, are mixed in a flask holding 6 liters and heated to 100° on a water bath. A second inverted flask placed above the first acts as a condenser; and a tube from this conducts the evolved gas into an acid where it is condensed, nitrogen only escaping. In the inverted flask beautiful crystals of chydrazaïne bicarbonate are deposited. If hydrogen chloride be used to absorb the gas, the liquid yields on evaporation the hydrochlorate in minute crystals, very soluble in water, scarcely soluble in alcohol. The sublimed hydrochlorate

afforded on analysis the formula $N_2H_6O(HCl)_2$, but the crystals dried by means of the anhydrous salt, contained one-fifteenth of their weight of water. When mixed with platinic chloride, various double salts are obtained, according to the proportions. When the chydrazaïne hydrochlorate is in excess a yellow salt is obtained, differing in appearance from the double salt of ammonium, and having the formula $N_2H_6O \cdot H_2PtCl_6$. With an excess of the platinum chloride, the platinum in the salt is increased. The sulphate is obtained in minute crystals, soluble in water and in alcohol. Mixed with aluminum sulphate, it forms an alum crystallizing in octahedrons. The nitrate crystallizes readily; but during evaporation, nitric acid, nitrous oxide, nitrogen and the substance H_2N_2 are evolved.—*Bull. Soc. Ch.*, II, xlix, 850; *J. Chem. Soc.*, lvi, 14, January, 1889. G. F. B.

4. *On a new Stannic acid.*—Spring has described a new stannic acid obtained by the action of barium peroxide upon stannous chloride. For this purpose a saturated solution of stannous chloride in water, containing hydrogen chloride, is treated with an excess of barium peroxide at the ordinary temperature, the peroxide being produced by precipitating hydrogen peroxide with barium hydrate. A turbid liquid is obtained which cannot be obtained clear either by subsidence or filtration. By dialyzing out the barium chloride formed, which in the author's experiments required three months, and by evaporating on the water bath, the white colloidal jelly becomes a white mass, corresponding on analysis to the formula $H_2Sn_2O_7$. In the analysis both the water and the oxygen were directly determined. The author calls it hyperstannic acid and regards it as proof of the existence of hyperstannic oxide, SnO_3.—*Bull. Soc. Chem.*, II, li, 180, February, 1889. G. F. B.

5. *On Ethyl Fluoride.*—Moissan has produced ethyl fluoride by allowing ethyl iodide to drop slowly upon silver fluoride contained in a brass vessel, care being taken to moderate the temperature. By means of a lead worm above the vessel cooled to $-20°$, the volatilized ethyl iodide is condensed and returned to the silver salt; the last traces of the iodide being removed by passing the product over silver fluoride, and then collecting it over mercury. As thus obtained ethyl fluoride is a colorless gas of specific gravity 1·70, having an agreeable ethereal odor. Under normal pressure it liquefies at $-48°$, and under eight atmospheres at 19°. By suddenly diminishing the pressure it may be solidified. Water dissolves 1·98 volumes of it at 14°. Ethyl iodide dissolves 14·8 volumes. Ethyl bromide, ether and alcohol also dissolve it freely, the gas being expelled unaltered on heating. The gas is dissolved also by concentrated sulphuric acid. It burns with a blue flame which becomes green when small quantities of methyl or ethyl chloride are present. When mixed with a small quantity of oxygen it burns with a bright flame; with an excess of oxygen it explodes violently when ignited. Heated to 108° in sealed tubes with potash solution it yields potassium

fluoride, alcohol and ether. Chlorine has no action on ethyl fluoride in the dark.—*C. R.*, cvii, 260; *J. Chem. Soc.*, liv, 1262, December, 1888. G. F. B.

6. *Chemical Lecture Notes*; by PETER T. AUSTEN, Ph.D., F.C.S., etc. 12mo, pp. 98. New York, 1888 (John Wiley & Sons).—This little book, as the author tells us in his preface, is "simply a collection of notes and observations on certain topics which experience as a teacher has shown me often give the student more or less trouble." Although, as he says, "no particular order has been observed in the arrangement of the topics," yet the information given seems accurate, and the book is likely to be of use for those for whom it is intended. G. F. B.

7. *An Elementary Text-book of Chemistry*; by WM. G. MIXTER, Professor Chem. Sheffield Scientific School of Yale University. 459 pp. 12mo. New York (John Wiley & Sons).—This elementary work on Chemistry, prepared by Professor Mixter for use in schools and colleges, presents the general facts and principles of the science under a succinct form and a sensible arrangement well adapted for its purpose. After brief explanations of the subjects connected with the physics of chemistry, including crystallography, it introduces the student gradually to the principles of chemistry through descriptions of some of the more common elements and their compounds, along with directions for simple chemical experiments. By this means the way is prepared for understanding the explanations of principles as they are successively brought out, and the definitions of atomic weight, valence, bases, acids, salts. Finally, in the closing chapters of the volume, after the elements and their more prominent compounds have been described, the Atomic Theory and the Periodic law in atomic weights are explained. The volume is handsomely printed and the illustrations are excellent.

8. *Rays of Electric Force.*—The experiments of HERTZ continue to excite great attention in Europe. He has lately repeated his experiments with oscillations ten times as rapid as those he formerly employed and with waves more than ten times as short as those first discovered. He has succeeded in producing distinct rays of electric force and has repeated the elementary experiments of light and radiant heat, such as reflection, refraction, and polarization.—*Annalen der Physik*, No. 3, 1889. J. T.

9. *Rotation of plane of polarization of light by the discharge of a Leyden jar.*—Dr. OLIVER LODGE takes a piece of heavy glass (or a tube of CS_2 a yard long) and surrounds it by four large helices containing about 80 yards of gutta percha covered wire, No. 16. On passing the discharge from a battery of several jars and having arranged suitable polarizing arrangements, the field flashes out in a brilliant manner. The effect increases in direct proportion to the capacity of the Leyden jars employed. It was found that CS_2 was able to show the effect when the alternations of the spark were 70,000 per second. The effect is practically instantaneous. The analyser of the polarizing

apparatus is set to as near darkness as possible. The trace of residual light is received upon a rotating mirror, by which it is spread out into a faint band; on then sending sparks through the coil round the tube of CS_2 the band brightens and presents a distinctly beaded appearance at every spark. Rotating the analyzer a little, every alternate bead grows fainter, while the other alternate ones brighten, thus proving most directly the oscillatory character of the light and of the Leyden jar discharge. —*Phil. Mag.*, April, 1889, pp. 339–349. J. T.

10. *On Limit to Interference when Light is radiated from moving Molecules.*—In the Annalen der Physik und Chemie, No. 2, 1889, EBERT discusses the application of Döppler's principle to the radiation from the moving molecules of an incandescent gas and arrives at the conclusion that the widths of the spectral lines, calculated upon the basis of the principle, are much greater than is consistent with experiments upon interference with a large relative retardation. Lord RAYLEIGH remarks "that unless this discrepancy can be explained the dynamical theory of gases has received a heavy blow from which it could with difficulty recover. If it be true that a gas consists of molecules in irregular motion, and that for the most part each molecule radiates independently, there seems no escape from the conclusion that the character of the aggregate radiation must be governed by Döppler's principle." Lord Rayleigh therefore examines the subject from a mathematical point of view, and does not find the discrepancy pointed out by Ebert. In the analysis Lord Rayleigh, however, acknowledges that certain assumptions have been made, and regards the question of very great interest and trusts that Ebert will continue his research.—*Phil. Mag.*, April, 1889, pp. 298–304. J. T.

11. *Selective Reflection by Metals.*—At a meeting of the Physical Society in Berlin, March 8, Dr. REUBENS described some experiments upon this subject. The light emitted from an incandescent plate of zirconium was concentrated by a lens on a mirror surface of the metal under investigation, and the reflected rays were then allowed to fall into a spectroscope with flint glass prism, whose eye-piece had been replaced by a bolometer. The mirror was then replaced by the glowing zirconium, in such a way that the rays of light coming from the point previously occupied by the mirror pursued the same course as in the first experiment. The intensity of light was measured from near F, in the blue, to 2μ in the red. It was found that silver possesses for blue rays a very considerable reflective power, which reaches its maximum in the red and remains constant for rays of the greatest wave-length. Gold possesses a much smaller reflective power for blue and green rays; this rises to a maximum in the yellow and falls toward the red. Copper reflects the blue and green rays even less than gold does; its reflective power increases rapidly into the red, and then somewhat more slowly. In the ultra red it reaches the point of silver. Iron and nickel gave very

similar curves without reaching the maximum points attained by gold and silver. It is possible to deduce the dispersive power of the metals and to compare their indices of refraction with those experimentally determined by Kundt. The agreement has been found in most cases to be close.—*Nature*, April 4, 1889, p. 552.

J. T.

II. Geology and Mineralogy.

1. *Recent discoveries in the Carboniferous Flora and Fauna of Rhode Island.*—During the past spring (1888) the museum of Brown University was enriched by the donation of a valuable collection of fossil plants presented by the Rev. Edgar F. Clarke of Providence, R. I., who found them in a thin layer of carbonaceous shale at Pawtucket. These were sent to Prof. Leo Lesquereux for identification.* Besides the plants, several fossil cockroaches of two genera, and the remains of an Arthrogastrous Arachnidan of the genus Architarbus, have been found by Mr. Henry Skolfield and others in the Pawtucket bed. These are in Mr. Scudder's hands for description. In addition Mr. Skolfield has been fortunate enough to discover in the same beds the impression of an Annelid worm, several shells of Spirorbis, and what appears to be the track of a gastropod mollusc; he has kindly placed these in the hands of the writer for examination.

It will be remembered that until very recently no animal remains had been known to exist in the beds of the Rhode Island coal basin, but now, chiefly through the zeal and industry of Mr. Clarke, there have been discovered representatives of the class of worms, molluscs, arachnids and insects; while the age of the beds has been established with a greater degree of certainty than ever before. Mr. Lesquereux, in a letter to the undersigned, remarks: "These specimens taken altogether are interesting as indicating, more than any other lot of fossil plants of Rhode Island I have seen, the stratigraphical relation of your coal strata to those of the part of the Anthracite measures of Pennsylvania, where, even, I have not observed such a predominance of species of Odontopteris, typically allied to those described by Fontaine and White from the Upper Carboniferous of Pennsylvania."

Providence, Aug. 18, 1888. A. S. PACKARD.

2. *Annual Report of the Geological Survey of Arkansas for* 1888; by John C. Branner, Ph.D., State Geologist. 320 pp. 8vo. Little Rock, Arkansas, 1888.—The first volume of this Geological Report, contains, besides the administrative report of Professor Branner, a report on the geology, and especially the economic geology, of the central western part of Arkansas by Dr. T. B. Comstock. The geological results are mostly deferred to another volume, while the various mining regions and their products are described with fullness. Two maps accompany

* The list of plants received from Prof. Packard will be found on page 229 of this volume. This note should have accompanied it.

the report, showing the positions of mines, hot springs, and general features of the country, and also give the courses of a number of anticlines in the stratified rocks. The course on the map for the principal system of anticlines is about N 75° E, and for another, in Garland Co., less prominent about N 20° E. The interesting fact is brought out that black shales and earth in Garland, Montgomery, Hot Spring and Polk counties, in which thermal springs formerly existed, contain much graphite, and that the graphitic earth is used in paint manufacture. The valuable report closes with a list of the minerals in central western Arkansas. This first volume is to be followed by three others : the *second*, by Prof. R. T. Hill, on the Mesozoic geology; the *third*, by Mr. A. Winslow, on the geology of a part of the Coal regions; and a fourth, to consist of reports on Little Rock, Magnet Cove and other localities, besides a chemical and a topographical report.

3. *The Cretaceous and Tertiary Geology of the Sergipe-Alagôas basin of Brazil ;* by JOHN C. BRANNER, Ph.D. pp. 369 to 434 of vol. xvi of Trans. Amer. Phil. Soc., 1889, with Plates I to V.—This valuable memoir by Dr. Branner is based on observations made by him in the years 1875, 1876, while assistant geologist in the Geological Survey of Brazil. The author favors the view that the Mesozoic rocks of the region are Cretaceous, and identical with the coastal Cretaceous, opposing the view of Mr. Derby. The Tertiary sand-beds are described as in part changed to quartzyte; not by ordinary metamorphic methods, but as a result of weathering or through the action of the rains and heat of the climate. The solid "glassy quartzyte" in some places projected out in blocks, when but a few feet within the material was only sand partially consolidated, and in the interval the firmness increased toward the surface.

4. *Tertiary Volcanoes of the Western Isles of Scotland.*—Prof. J. W. Judd has a notice of Dr. Geikie's memoir on this subject in the Geological Magazine for February, on p. 91. He refers to the views in his paper of 1874, on the Ancient Volcanoes of the Highlands, and states that while Dr. Geikie agrees with him in several of his conclusions, he does not in two, he holding (1) that the ejection of the "felstone" lavas and the intrusion of the granites preceded the appearance of the basalts and gabbros;" and (2) "that the five centers of eruption mark the sites of as many great volcanic cones now ruined and dissected by denudation." In opposition to the latter view, Dr. Judd pointed out in his paper, as he states, "that the numbers and dimensions of the Tertiary dykes are not such as would warrant us in inferring that they formed the conduits through which the enormous masses of lava forming the plateaus were erupted ; and the absence of all proofs of contact-metamorphism at their sides, and of evidence that the majority of them ever reached the surface at all was commented on." He adds that in "1874 he further pointed out that some of these dykes appear to mark the

radial fissures on which sporadic cones ("puys") were thrown up, after the great central volcanoes became extinct; and this is supported by the circumstance of the close analogies between the materials erupted at this later period and the rocks which constitute some of the undoubtedly post-Mesozoic dykes." Prof. Judd, in this notice, also alludes to the fact that the volcanoes of the Hawaiian Islands favor his views on this point.

5. *Nummulites up the Indus valley at a height of* 19,000 *feet.*—According to observations by T. D. La Fouche, of the Geological survey of India, a Nummulitic limestone occurs in Zánskár at a height of 19,000 feet. He found the rock on crossing the Singhe lá (Singala of the Survey Map), in the region where they had been reported to exist by Dr. T. Thomson in 1852. He first came upon them in loose blocks of a dark gray limestone at Linshot, at a height of 12,850 feet, on the southern slopes of the range, and followed them up the cliffs on the west of the pass. He found the nummulites *in situ* "at an altitude of 18,500 feet, at the base of two precipitously-scarped masses, rising 500 or 600 feet higher and forming the summit of the peak." The rock, to the top, "consisted of layers from a few inches to over a foot in thickness of the same black fetid limestone that was found in the talus below." The beds rest on quartzite, with shales below and are much flexed. "It is thus proved that in middle Eocene times the southern shore-line of the Tertiary sea (occupying what is now the Indus valley) extended far south and included the Singhe lá."—*Rec. G. Surv. India*, xxi, 160, 1888.

6. *Sand-drift rock-sculpture.*—R. D. Oldham states that many examples of sand-drift sculpturing occur in India, in the desert region between the Aravalis and the Indus. He remarks that the sculpturing differs from that of glaciers in consisting of numerous broad and shallow grooves, deepest at the end from which the wind blows. The grooves on a conglomerate quartzyte are an eighth of an inch wide and less, and cross pebbles and the finer parts alike without interruption. On limestone, near Jessalmer, they are two to three yards long and four to six inches broad.—*Rec. G. Survey of India*, xxi, 159, 1888.

7. *Catalogue of Fossil Cephalopoda in the British Museum.* Part I, containing part of the suborder Nautiloidea; by ARTHUR H. FOORD, F.G.S. 344 pp. 8vo. London.—The author, besides presenting lists of species with synonymy and full references, gives descriptions with over 50 woodcuts, and has a valuable introduction on classification and other general topics in which the views of Hyatt and others are mentioned. This museum catalogue is consequently a convenient manual on the fossil Nautiloids.

8. *The Nature and Origin of Deposits of Phosphate of Lime;* by R. A. F. PENROSE, JR., with introduction by Prof. N. S. Shaler. Bulletin No. 46, United States Geological Survey, Washington, D. C., 1889. The introduction to this memoir, by Professor Shaler, gives a general sketch of the value of phos-

phate of lime, of its occurrence in different geological horizons and of its increasing importance in agriculture. Dr. Penrose's paper is intended to show in a condensed form the mode of occurrence and the theories as to the origin of phosphate deposits with the object, not only of advancing the scientific study of this interesting subject, but also to facilitate the search for deposits of the different kinds of phosphatic minerals. The various deposits are first classified as Mineral Phosphates and Rock Phosphates. These headings are again divided into other sub-classes to include the various forms of apatite, phosphorite, nodular phosphates, phosphatic limestones, guano and bone beds. Under mineral phosphates he begins with an extended account of Canadian apatite and gives numerous diagrams, illustrating the mode of occurrence of the mineral; then follow descriptions of the apatites of Norway and Spain, and the phosphorites of Nassau, Southwestern France and Spain, with several illustrations. Under rock phosphates are described the celebrated South Carolina phosphate deposits, those of North Carolina, Alabama, Wales, England, France, Belgium, Russia and other places. Then comes a description of the guanos of the coasts of South America, Africa, Arabia, Australia and other places, as well as of the islands of the Pacific Ocean, the West Indies and the Gulf of California, with a notice of the bat guanos of America and Europe and the local deposits of bone beds.

The article ends with an extended bibliography on phosphates. The work contains many illustrations, maps and analyses.

R. T. HILL.

9. *On the Fulgurites of Mt. Viso;* F. RUTLEY, F.G.S.—Mt. Viso is 12,680 feet in height. The fulgurites described by Mr. Rutley have a surface ploughed out by the lightning, with curved and branching semi-cylindrical furrows from $\frac{1}{2}$ to $\frac{1}{32}$ of an inch in diameter. The tubes are lined with fulgurite glass, and this glass proved, on careful microscope study, to contain microlites of different forms instead of being perfectly clear as in other fulgurites studied by the author. The rock is a glaucophane schist.

10. *Scheelite from Idaho.*—Tungstate of lime occurs, massive, in an auriferous quartz vein near the town of Murray, Idaho Territory, on the western slope of the Coeur d'Alene Mountains.

WM. P. BLAKE.

11. *Hülfstabellen zur mikroskopischen Mineralbestimmung in Gesteinen zusammengestellt* von H. ROSENBUSCH.—These admirably arranged tables giving all the needed characters of rock-making minerals will be of great service to workers in petrography, supplementing in a very useful way the author's large treatise.

12. *Les Minéraux des Roches* par A. MICHEL LÉVY and A. LACROIX, 334 pp. 8 vo. Paris, 1888.—Students of microscopical mineralogy need not now be at a loss to find text-books, with the many excellent works that have been recently placed at their disposal. This new volume is one of the most original, and con-

tains much new matter both in the theoretical portion prepared by M. Lévy, and in the second half, prepared by both authors, which gives the physical and optical data for all important species. It should be in hands of all workers in this subject.

III. Botany.

1. *Contributions to American Botany*, XVI; by Sereno Watson, Proceedings of Am. Acad. of Arts and Sciences, vol. xxiv, pp. 52. 1. Upon a collection of plants made by Dr. E. Palmer, in 1887, about Guaymas, Mexico, at Muleje and Los Angeles Bay in Lower California and on the Island of San Pedro Martin in the Gulf of California. 2. Descriptions of some new species of plants, chiefly Californian, with miscellaneous notes.—Dr. Watson states that of the 415 native species collected by Dr. Palmer, 89, or more than one-fifth, are wholly new and many others are of great interest in various respects. "The larger part of the collection was made about Guaymas itself, which town lies on the eastern side of the Gulf of California, in the State of Sonora, in lat. 28° N. and 250 miles south of the United States boundary. It is hemmed in closely by very rocky hills and low mountains (of 1200 to 1500 feet altitude) intersected by narrow valleys. The artificially watered gardens, with their irrigating ditches and brush fences, protecting and favoring the growth of numerous native plants, the rocky islands in the harbor, and the valleys and mountains around, were all alike searched. Dr. Palmer remained here from the middle of June to the middle of November, during which time there were only occasional slight showers, which commenced in August. The species obtained here numbered 283, of which 40 were also found in other localities . . . . The characteristics of the flora of the region bordering on the Gulf of California, so far as shown by this collection, are for the most part those common to the flora of the whole arid region of the interior, from southeastern California, Arizona, and New Mexico southward into Mexico, distinct in a great measure from that of California proper on the one side, and that of the Gulf States on the other. . . . The proportion in which the several orders are represented in the collection is somewhat remarkable. Of the 415 species, one-fourth are equally divided between the Gramineæ (50) and the Compositæ (50). Another fourth includes only the four orders Leguminosæ (44), Euphorbiaceæ (32), Malvaceæ (17), and Solanaceæ (15). These are followed by the Nyctaginaceæ (15), Convolvulaceæ (13), Asclepiadaceæ (10), and 53 other orders with still fewer species. The important orders Ranunculaceæ, Rosaceæ, Saxifragaceæ, Umbelliferæ, Ericaceæ, Cupuliferæ, Coniferæ, and Orchidaceæ are wholly unrepresented."

The second paper mentioned above gives descriptions of ten new species. The extent of Dr. Watson's contributions to North American Botany can be understood when attention is called to the fact that these two communications, which contain descriptions of about one hundred species new to science, comprise only one-tenth of all the well-characterized species which he has added. G. L. G.

2. *Key to the System of Victorian Plants*, I; by BARON FERD. VON MUELLER, [Melbourne, 1887–88. pp. 559, 12mo. With map]. Part 2 of this useful work was published in 1885, and comprised an enumeration of the native species arranged under genera and orders, with annotations of their regional distribution, and with 152 illustrations on wood.

The part which has just come to hand gives a dichotomous arrangement of the orders, genera and species of the native plants, with annotations of their primary distinctions and supporting characteristics. The whole work is marked by two important features, (1) there are extremely few abbreviations in the treatise, even where abbreviations could have been used to economise space without endangering clearness, (2) some of the technical terms differ from those generally in vogue. Among these terms may be mentioned the following,—*ovulary* for ovary, *albument* for albumen, *hairlet* for hair, *placentary* for placenta, etc. These organographic alterations introduced "into these pages for the first time, in contrast to zoologic terms have been ventured on only tentatively, but from a desire of the author to simplify the wordings for organs of plants in a book written especially for almost a new country and particularly for the juvenile portion of its population." It is difficult to see why such zoological terms as ovary, hair, and albumen should have been changed for the sake of contrast, while the following should have been retained,—valve, lobe, membrane, and filament.

The arrangement of the key is exceedingly convenient, and enables a student to trace out the name of a plant with great rapidity. At the end of the volume there is a list of plants "hitherto immigrated and naturalized in Victoria, with indications of their nativity and English popular names." A few of these 200 plants are noted as coming from Asia, or from Africa, or from Europe, but almost all have placed against their names the three countries with no specific assignment: 23 of the list are given as coming from America. A second table gives the vernacular names of indigenous plants. Here we get the names, "Wattle," "Mallee," "Currajong," etc., and also some given off-hand by the settlers, "Wooly Butt," "Stringy-bark," "Pig-face," "Double-tail," and "Sand-stay," while by far the greater number merely echo the familiar names which the settlers have brought from home, such as "Avens," Rib-herb," and the like.

It is with an ever fresh surprise that one reads in these lists of plants supposed to be indigenous, such names as *Myosurus minimus*, *Cakile maritima*, *Potentilla anserina*, *Verbena officinalis*, etc. It is certain that the geographical botanist of the future will revise many of these decisions and assign to such plants some date of an earlier introduction, and withdraw them from the catalogue of indigenous plants. The strenuous efforts which Baron von

Mueller has continually made to popularize the study of Botany in Victoria must certainly be followed by happy results. It is to be hoped that this his latest work in this direction will be productive of an increased interest in the life history of the plants of the southern continent. G. L. G.

3. *Revision of North American Umbelliferæ;* by J. M. COULTER and J. N. ROSE, 1888. pp. 144 and pl. ix.—In this work the authors have given us a sufficient account of the structural peculiarities of the family, together with a systematic analysis of the genera, accompanied by illustrations of cross sections of the fruit. An artificial analysis supplements the treatise. This contribution, part of which has already come before the public in installments in the Botanical Gazette, will be very welcome to all botanists in its completed form. G. L. G.

4. *Flora Italiana*, vol. viii. Florence, March 1889.—We have here Professor Caruel's examination of part of the Order Umbelliferæ. There are descriptions of 221 species, in many cases with pretty full accounts of the geographical distribution. He divides the 63 genera represented, into seven groups. The present volume closes with the genus Caucalis, leaving two more genera to complete the treatment of the family. G. L. G.

5. *Diagnoses plantarum novarum asiaticarum*, VII. C. J. MAXIMOWICZ. (Bulletin de l'Acad. imperiale des sciences de St. Petersbourg, t. xii.)—Attention is called to the critical study given by the author to the 250 species of Pedicularis and the illustrations of 115 of them. The communication possesses great interest not only to the systematic botanist but to those who are engaged in the investigation of adaptive characters of the flower.

G. L. G.

6. *The Orchids of the Cape Peninsula;* by HARRY BOLUS, F.L.S. [Cape Town, 1888, (Trans. South African Philosophical Society, vol. v, part I, pp. 125, 36 plates, some of them colored in part.)]—The area of the Cape Peninsula, as here restricted, is about 200 square miles, and contains 1750 species of plants, of which 102 are orchids. In the relative richness of its vegetation in orchids it is said to be surpassed only by some portions of Australia. Only one of the 102 species has yet been detected beyond the limits of South Africa, namely, *Liparis Capensis*, in the Cameroons Mountains, where it is said that some other typical Cape plants have been detected. Thirty-three of these species are confined to the Cape Peninsula, although many of them will perhaps be found outside of its narrow limits as exploration proceeds. The amazing abundance of these highly specialized plants in an area less than one-sixth of that of the State of Rhode Island, renders this a field of exceptional character for a biologist. Mr. Bolus has given us a useful systematic handbook of the Cape Orchids, with no attempt at present to deal with the biological questions involved. While he has placed botanists under great obligations by this systematic work he leads them to ask whether he cannot, better than any one else, give the life-histories of the more interesting species. G. L. G.

7. *Handbook of the Amaryllideæ, including the Alstrœmerieæ and Agaveæ;* by J. G. Baker, F.R.S., [London, 1888, 8vo, pp. 216.]—In his long service at Kew, the first assistant in the Herbarium has had exceptional opportunities for studying the plants of this order in their living state. The handbook which he now publishes comprises the notes which have been long accumulating, together with many which he has published from time to time in current journals. The number of species included is not far from 700, and of genera 61. Two orders assigned to Amaryllideæ are omitted, namely, Hypoxideæ, containing 66, and Vellosieæ, 68 species. Of the species here described, about 250 are Old-world species in 31 genera, and 450 are New-world species in 30 genera. The author has not taken up to any great extent the garden hybrids which are so abundant in this order, nor has he alluded to the cultivation of the species, but the work is of great use to cultivators as well as to working botanists. G. L. G.

8. *Synoptical List of North American Species of Ceanothus;* by Wm. Trelease. (Contrib. from Shaw School of Botany. No. 4. June 15, 1888, pp. 13).—*Ceanothus L.;* by C. C. Parry, (Davenport Acad. of Nat. Sci., read Dec. 28, 1888, pp. 13).—Dr. Parry's revision of this genus differs in many particulars from that by Professor Trelease. Both the communications are important contributions to systematic botany and serve, besides, to show how differently two conscientious students may regard the same problem. A comparison of the two papers brings up again the question of how far adaptive characters are to be considered in the determination of affinities: the adaptive characters being, of course, those which press themselves most prominently upon the attention in the field.

In Dr. Parry's paper there is given an interesting addition to the list of projectile fruits which we copy entire. "The fruit, which so strongly simulates in external appearance some of the Euphorbiaceous genera as to have suggested a near relationship, though not carried out in other points, varies considerably in size, its smooth or resinously coated exocarp and its accessory appendages, but has otherwise very uniform characters of seed and pericarp. A fact not often noticed, but which is probably more or less true of all species, is that the rigid cocci, when released from their attachment to the indurated disc, expel their smooth-coated seeds through the ventral slit with considerable force. I have had occasion lately to notice this, even in herbarium specimens of nearly mature fruit, which, when brought into a warm apartment, revealed their explosive nature by a continuous fusilade, till the ammunition was all expended and the fragments of the ruptured pericarp alone left to determine their carpological features. The manifest utility of this provision for disseminating seeds will largely account for the gregarious habit of most of the species, and no doubt, also serves as a protection against the aggression of omnivorous rodents." G. L. G.

9. *On the multiplication of Bryophyllum calycinum.*—Dr. B. W. Barton, of Baltimore, in an interesting preliminary communication respecting this subject, calls attention to the fact that the leaves of a plant under cultivation which grew well during the summer, fell during the month of September. But, instead of withering before their fall, these leaves remained plump and green up to the very last, whereas the leaves of our ordinary plants are emptied of their protoplasm before they are detached. These fresh leaves in about ten days after they were separated gave rise to buds and a fine crop of healthy plants. Dr. Barton asks whether the time of defoliation may be related to the time of occurrence of hurricanes in the tropics.

10. *Enumeratio Plantarum Guatemalensium imprimis a H. DeTuerckheim* collectarum quas edidit John Donnell Smith. Pars I. (Oquawka, Ill., 1889).—Mr. J. Donnell Smith, of Baltimore, has been engaged for some years in the elucidation of the flora of Central America. The present list is one of the results of that study. Mr. Smith is at this time making a botanical journey in Guatemala. G. L. G.

11. *Journal of André Michaux*, 1787–1796. (Proceedings of American Philosophical Society, vol. xxvi, No. 129.)—This is the carefully edited publication of the diary (in French) of our most assiduous botanical explorer. Professor C. S. Sargent has furnished critical notes and an abstract of the biography of Michaux, thus enabling the reader to follow intelligently the daily life of a botanist of the last century. The diary demanded in its printing very great care, and this it appears to have received throughout. G. L. G.

12. *Annals of Botany.* London, 1889.—This valuable journal is now in its third volume and has gained for itself an assured position among first-class scientific periodicals. It is pleasant to note that some of the important contributions have come from this country, mainly from the laboratory conducted by one of the editors, Professor Farlow. The price of the journal has been advanced to thirty shillings. G. L. G.

13. *Herbarium of the late Rev. Dr. Joseph Blake.*—This large collection, representing the fruits of a life-long interest in botany, and containing specimens from nearly all the American botanists who have been in active exchange during the last fifty years, is now offered for sale. The herbarium is in good condition, and comprises, besides the plants referred to above, a considerable number of species beyond our own limits. Information regarding the collection may be obtained from Mrs. Joseph Blake, Andover, Mass. G. L. G.

14. *Outlines of Lessons in Botany. Part I. From seed to leaf;* by Jane H. Newell. Boston, 1889. Small 8vo, pp. 140. —Miss Newell's large experience in the teaching of young children has enabled her to prepare an exceedingly useful book. The questions are well chosen and sharply put. G. L. G.

Miscellaneous Scientific Intelligence.

1. *A deep-sea depression in the Pacific near Tongatabu.*—In a "List of Oceanic Depths" published by the British Hydrographic Department, bearing the date of February, 1889, for a copy of which we are indebted to the Department, soundings of 4295 and 4428 fathoms are reported to the southeast of Tongatabu, the southern and the largest of the Tonga or Friendly Islands. The soundings were made by H. M. Ship Egeria, under Captain Pelham Aldrich, in the course of a line of soundings from New Zealand to the islands, and they were repeated around the depression so as to make a complete investigation of the area. The depths obtained about the area are the following:

Lat.	Long.	Depth in fms.	Lat.	Long.	Depth in fms.
24°27′	176°15′	530	24°49′	174°07′	2889
24 18	175 50	2030	24 49	173 56	3036
24 26	175 38	2449	24 37	175 08	*4428*
24 49	175 07	*4295*	24 26	175 10	900+
24 59	174 46	3110	24 00	175 16	3692
24 55	174 29	2990	23 18	175 38	941
24 44	174 18	3006	23 12	175 40	596

The depths appear to indicate a crater-like depression. Its position with reference to Tongatabu is very much like that south of the Ladrones with reference to Guam, the largest and most southern island of that group. J. D. D.

2. *Lists of Dredging Stations in North American waters*, from 1867 to 1887, by Sanderson Smith. 144 pp. 8vo. From the Report of the Fish Commission.—Mr. Smith has prepared these tabulated lists of deep-sea soundings on the North American side of the Atlantic with great labor and care. The soundings of the U. S. Fish Commission, the Fish Hawk, Albatross, Challenger Expedition, Travailleur, Talisman, Washington, and of other vessels or expeditions, Norwegian and British, are all here registered, with the necessary precision as to time of observation and geographical position; and, besides, the routes and locations are exhibited on a number of accompanying folded charts.

3. *National Academy of Sciences.*—At the meeting of the Academy held in Washington, April 16–19, Professor O. C. Marsh was re-elected President, and the following new members were elected: Professor Boss, of Dudley Observatory, Albany, Professor Sereno Watson, of Cambridge, Professor C. S. Hastings, Yale University, Professor C. A. White, U. S. Geological Survey, and Professor Michel, of Tufts College. The following papers were accepted for reading:

D. P. Todd: Composite coronography.

W. A. Rogers: Additional experimental proof that the relative coefficient of expansion between Baily's metal and steel is constant between 0° and 95° F.

Wolcott Gibbs and Hobart Hare: Method and results of a systematic study of the action of definitely related chemical compounds upon animals.

C. S. Peirce: Sensations of color.—Determinations of gravity.

E. D. Cope: Pliocene Vertebrate Fauna of Western North America.—North American Proboscidia.
A. Hall, Jr., The mass of Saturn.
Ira Remsen: Nature and composition of double halides.—Rate of reduction of nitro-compounds.—Connection between taste and chemical composition.
T. C. Mendenhall: Recent researches in atmospheric electricity.
A. A. Michelson: Measurement by light waves.
A. A. Michelson and E. W. Morley: Feasibility of the establishment of a light-wave as the ultimate standard of length.
S. C. Chandler: The general laws pertaining to stellar variation.
C. H. F. Peters: Review of the trivial names in Piazzi's star catalogue.
J. S. Newberry: Cretaceous flora of North America.
Cleveland Abbe: Terrestrial magnetism.
Romyn Hitchcock: Spectrum photography in the ultra-violet.
W. K. Brooks: North American Pelagidæ.—Development of Crustacea.
C. D. Walcott: The plane of demarcation between the Cambrian and pre-Cambrian rocks.
D. P. Todd: Report of the American Eclipse Expedition to Japan, 1887.

4. *Proceedings of the U. S. National Museum.* Vol. X, 1887. Published under the direction of the Smithsonian Institution. 772 pp. 8vo, with 39 plates.—This volume is made up of original contributions to Zoölogy and Botany, partly paleontological, and mostly describing new species. The chief contributors are R. Ridgway, L. Stejneger, J. B. Smith, R. Rathbun, J. McNeill, T. H. Bean, C. H. Bollmann, C. H. Gilbert, E. D. Cope, D. S. Jordan, G. N. Lawrence, L. Lesquereux, T. Gill, C. H. Eigenmann, F. W. True, R. E. Call, E. Linton, C. H. Townsend, O. P. Hay, and E. G. Hughes. It contains also an account of an Arkansas meteorite, by S. F. Kunz, with a plate.

5. *Examination of Water for sanitary and technical purposes*, by Dr. H. Leffman and Wm. Beam. 106 pp. 12mo. 1889. Philadelphia (Blakiston, Son & Co.).—This little volume gives the chemical methods for testing mineral and other waters especially with reference to those ingredients that have a sanitary bearing, and also other facts and information on the subject.

The Geological Record for 1880–1884 inclusive. A list of publications on Geology, Mineralogy and Palæontology published during those years, together with certain references omitted from previous volumes; edited by Wm. Topley, F.R.S., F.G.S., and Charles Davies Sherborn, F.G.S. Vol. 1. Stratigraphical and Descriptive Geology. 544 pp. 8vo. London, 1888 (Taylor & Francis).—A work of great value to students in Geology, although only a catalogue. The six preceding volumes covered the years 1874 to 1879 inclusive, and were by Mr. W. Whitaker, excepting that for 1878, which was by Whitaker and W. H. Dalton. Price of each, 16s., excepting for that for 1874, 15s.

Bulletin from the Laboratories of Natural History of the State University of Iowa, Iowa City, Iowa, vol. i, No. 1, contains valuable geological papers by Prof. S. Calvin; on the Saprophytic Fungi of Eastern Iowa by T. H. McBride; and on the Mollusks of eastern Iowa by B. Shimek, besides other papers.

University Studies, published by the University of Nebraska, at Lincoln. This quarterly publication, No. 2 of which was published in October, 1888, contains, besides literary and linguistic papers, a memoir on the conversion of some of the homologues of benzol-phenol into primary and secondary amines, by Rachel Lloyd.

Preliminary Report of the Dakota School of Mines upon the Geology of the Black Hills. 171 pp. 8vo. Rapid City, 1888.

A Bibliography of Indian Geology: compiled by R. D. Oldham, Deputy Superintendent Geol. Survey of India. 145 pp. roy. 8vo. Calcutta, 1888.

OBITUARY.

Miss ANNIE E. LAW was born in Carlisle, England. She was the eldest of three children of John Law, whose brother was governor of the Island of Malta. Her father with his family emigrated to Tennessee about the year 1851, settling near Marysville, where her parents and brother are buried. She remained at various points in eastern Tennessee until about 1874, when she moved to Hollister, California, and thence to Watsonville, where she remained with her sister, Mrs. Andrews, in impaired health, until Jan. 12th, 1889, when she passed away, endeared to all with whom she came in contact. Her rare intellect, combined with her wonderful musical talent, made her the center of a large and cultivated society, while as a writer she occupied a high position, her poems being remarkable for their pathos and sweetness. While Miss Law will be long and widely missed by those acquainted with her socially, there is a much larger circle who will ever honor her name as that of one of the most devoted conchologists we have ever known. She described no species and wrote no articles on the subject, but she contributed none the less to the advancement of science by collecting material for the publications of others. She was a most generous correspondent, distributing lavishly the many novelties she collected in the mountains of Tennessee and North Carolina. She first drew attention to the richness of those localities which have since proved almost a new fauna in land mollusks, collecting eleven species and one genus new to science. As an instance of her enthusiasm, the writer may mention that when he urgently begged her to obtain for him the living animal which had formed the shell of the so-called *Vitrina latissima* in order to verify its generic position, she undertook a perilous wagon journey of several weeks over mountain roads, camping out at nights; she reached Black Bald Mountain, and found numerous specimens, which enabled the writer from its external and anatomical characters to describe the remarkable genus. W. G. B.

Dr. HEINRICH VON DECHEN, the eminent geologist of Germany, died at Bonn on February 15, having nearly reached his 90th birthday.

Professor GIUSEPPE MENEGHINI, of the University of Pisa, and Senator of the kingdom, the author of works and memoirs on zoology and geology, died on the 29th of January, 1889, at the age of 78.

THEODOR KJERULF, one of the best and most active of Norwegian geologists, died on the 26th of October, 1888.

JOHN ERICSSON, physicist and mechanician, and one of the most remarkable men of the century, died in New York, on the 8th of March. He was born in Wermland, Sweden, on the 31st of July, 1803.

CONTENTS.

VOL. XXXVII. JUNE, 1889.

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THE AMERICAN JOURNAL OF SCIENCE.

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THIRD SERIES.

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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XLIII.—*Topographic Development of the Triassic Formation of the Connecticut Valley*; by WILLIAM MORRIS DAVIS.

[Published, as far as relates to work done for the U. S. Geological Survey, with the permission of the Director.]

CONTENTS :—Itinerary of Harvard Summer School of Geology—Faults in the Meriden region—Cross-section of the District—Means of detecting the unfaulted sequence of Triassic beds—Mechanism of monoclinal faulting—Topographic development of the Triassic belt—Initial constructional stages represented by the faulted blocks of Southern Idaho—Mountain ranges of the Great Basin equivalent to a later Jurassic Stage—The whole region base-leveled in late Cretaceous time—The present valleys worn in the Cretaceous base-level plain after its elevation—Polygenetic topography—The origin of the Connecticut river outlet via Middletown—The Connecticut river was originally consequent on the monoclinal faulting, and still persists near the course then taken, but has entered a second cycle of life as a result of the elevation of the lowland that was produced in its first cycle.

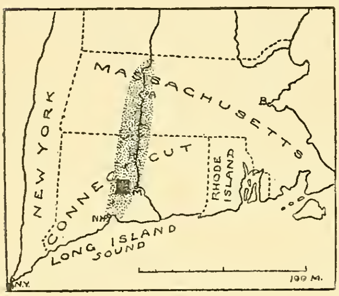
SINCE presenting two years ago a suggestion to account for the mechanical origin of the faulted Triassic monocline* I have visited the region about Meriden with the Harvard Summer School of Geology during its sessions of 1887 and 1888. An itinerary of the excursions made by the school in

* This Journal, xxxii, 1886, 342–352; Proc. Amer. Assoc., xxxv, 1886, 224–227; Seventh Ann. Report U. S. Geol. Survey, 1886, just issued.

deciphering the structure of the district together with maps and sections to illustrate the facts of observation and a detailed consideration of the arguments leading to certain conclusions is now in press in the Bulletin of the Museum of Comparative Zoölogy at Cambridge. The structural problems of the region afford excellent opportunity for practical instruction in geology. A brief summary of the results reached is presented here.

The small black square in figure 1 indicates the position of the Meriden district in central Connecticut and in the southern part of the New England Triassic area. Figure 2 is the same

1.



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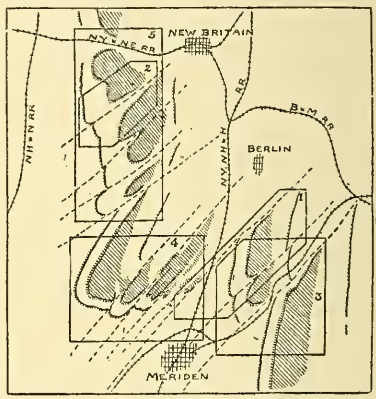
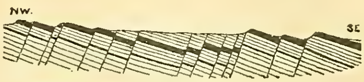


district on a larger scale. The main trap sheet, whose monoclinal ridges dominate the relief of the region, is shaded with oblique lines; the subordinate ridges formed on the anterior and posterior trap sheets are indicated by lines on either side of the main ridges. The chief faults of the region are drawn in broken lines, and their general southwest trend is clearly seen. The several enclosed spaces numbered 1 to 5 mark the areas represented on maps of still larger scale in the Bulletin above referred to. The "mountains" formed by the main trap sheet are, beginning on the southeast: Higby (or Besick) Mountain, Chauncy Peak and Lamentation Mountain, the Hanging Hills group northwest of Meriden (consisting of Cat-hole Peaks, Notch Mountain and West Peak), Short Mountain, High Rock and Shuttle Meadow Mountain, and Bradley's Mountain, before coming to Cook's Gap, a pass followed by the New York and New England railroad westward from New Britain. The evidence seems to me very strong that the faults separating all these blocks were produced after the trap sheets had taken their place in the stratified series, all the sheets here shown being extrusive surface flows, poured out during the accumulation of the aqueous strata.

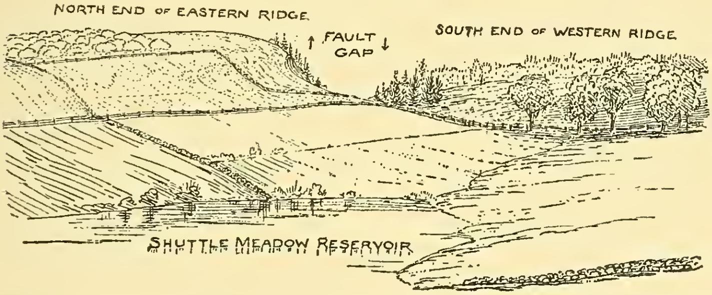
A cross-section of the district from northwest to southeast, on the scale of figure 2, is given in figure 3; but its construction is not very accurate as to the values of dip and dislocation. The heave of the faults is on the southeast in every case, with the single exception of the fault between High Rock and Short Mountain, where the heave is on the other side; this departure from the prevailing rule of dislocation being indicated by a corresponding departure from the prevailing rule of topography. In passing northward across a fault of the ordinary kind, the repeated portion of a ridge is found in what Percival called "advancing order," that is, farther west than before; but here the repeated ridge is found in "receding order," and hence the fault is known to have a reverse throw. The distinct topographic effect of the faults is illustrated in two figures. The first (fig. 4.) is a view southwestward through a gap in the anterior trap ridge, on the line of the fault that

3.



GENERAL CROSS SECTION.

4.



runs from New Britain through Shuttle meadow reservoir. The heaved side of the fault is on the left (southeast), where the back of the ridge is shaded by an apple orchard and its outcrop bluff is clothed with hemlocks: the thrown side is on the right, where the trap sheet lies lower, but rises westward to another ridge like the first; an old pasture field on its back, and a bold cliff facing the broad Southington valley beyond. This cliff runs two or three miles north, but shortly turns around the southern end of the ridge where it is terminated by the oblique fault; the other ridge falls away to the left of the view as it approaches the fault, but continues southward till it is again broken by another fault, and the topographic dislocation is repeated.

The second view (fig. 5.) is of larger range: it is taken from a hill about a mile east of Berlin, looking south to two masses of the main trap sheet. Lamentation Mountain is on the right with the slightly detached Chauncy Peak rising a little over its farther end ; and Higby (Besick) Mountain rises on the left. The strong fault that passes a little east of Meriden separates

5.

HIGBY AND LAMENTATION MOUNTAINS.

these two mountains, while the greater fault which runs west of Meriden cuts off the north end of Lamentation. The view of these mountains is highly suggestive.

The extension of the faults to the northeast and southwest of the trap ridges is seldom traceable very far. Southwest of the anterior trap ridge, the country is generally soon covered with drift ; but occasionally certain beds of conglomerate serve to indicate the course of a fault, as is the case with the great fault between the Hanging Hills and Lamentation Mountain, which may be followed two miles southwest of Meriden. To the northeast, the occurrence of a second posterior ridge in certain localities may in time serve to unravel the fault lines, as it has already for the fault between Chauncy Peak and Higby Mountain, which is thus traced about three miles to the northeast of the gap that it produces in the main sheet. All these localities are given in detail in the itinerary of the summer school, as above.

The systematic arrangement of the faults in this district, already mentioned in earlier papers, is thus confirmed. When this is once perceived, it is evident that the normal sequence of the Triassic beds can be found only by crossing the monocline obliquely to the northeast, always keeping within the limits of a single fault-block. This seems to me to be the key to the structure of the region. The remainder of this paper is occupied with considerations not discussed in the Bulletin.

The mechanism suggested to account for the production of a monocline with its system of faults thus arranged has been in the mind of other writers. Some fourteen years ago, Mr. G. K. Gilbert conceived its essential features, and gave a brief account of it in his description of the Great Basin Ranges.* He made the theoretical suggestion "that in the case of the Appalachians, the primary phenomena are superficial ; and in that of the Basin Ranges they are deep-seated, the superficial being secondary ; that such a force as has crowded together the strata of the Appalachians—whatever may have been its

* Wheeler's Surveys west of the 100th Meridian, iii, 1875, 62.

source—has acted in the Ranges on some portion of the earth's crust beneath the immediate surface; and the upper strata, by continually adapting themselves, under gravity, to the inequalities of the lower, have assumed the forms we see. Such a hypothesis, assigning to subterranean determination the position and direction of lines of uplift in the Range system, and leaving the character of the superficial phenomena to depend on the character and condition of the superficial materials, accords well with many of the observed facts, and especially with the persistence of ridges where structures are changed." The essential peculiarities of the method for the production of a faulted monocline is here clearly stated, although no opportunity is noted for independent verification of the suggestion, such as appears in Connecticut in the correspondence between the course of the faults and the trend of the underlying schists.

In my previous paper concerning the origin of the faulted monocline, no special consideration was given to the cause of the discordance between the course of the faults and the strike of the beds in the Meriden region, which now appears as so strong a structural characteristic. It may be suggested that this is the result of a force of compression acting on the whole mass of crystalline and overlying rocks in a direction oblique to the strike of the schists, whose structure determines the course of the faults. The schists trending northeast and the compression being exerted from west to east so that movement of any point in the schists must take place in an east and west vertical plane, a result such as that which here obtains might be produced. A consequence of this would appear in the much greater uplift given to the southwestern than to the northeastern part of any block thus obliquely tilted; but the unworn surface of any block would slope eastward, in the direction of the dip of its beds. When deeply eroded, the older members of the series of tilted beds would be revealed in the southwestern part of the block; while the newer still remain in the northeastern part, as we find them.

The topographic development of the Meriden region and indeed of the valley as a whole, may be briefly sketched. Its early structural topography, such as would have resulted from its dislocation without erosion, finds modern illustration in the tilted lava blocks of Southern Idaho, as described by Russell. This writer, from whose vivid descriptions we derive so clear a picture of our western country, says that the whole of the Great Basin—the "immense region lying between the Sierra Nevada and the Rocky Mountain systems has been broken by a multitude of fractures, having an approximately north and south trend, that divide the region into long, narrow, orographic blocks. These have been tilted so as to form small but extremely rugged mountain ranges, often from fifty to a hundred miles in length, with a width of but a few miles."— The fractures by which the blocks are separated "are of a comparatively recent date, and present bold scarps, that are frequently but slightly scarred by erosion, while the most recent examples of all were unquestionably formed within the past few years, and are yet unclothed by vegetation." . . . "The exhibition of fault-scarps, tilted blocks, and sunken areas, to be seen at the southern end of the Warner Lakes, is the most interesting of its kind that it has ever been our privilege to examine. In this narrow zone, the orographic blocks of dark volcanic rock are literally tossed about like the cakes of ice in an ice-floe; their upturned edges forming bold palisades that render the region all but impassable." . . . "These fault-scarps rise in sheer precipices that overshadow the Warner Lakes throughout their entire extent. Toward the northern end of the valley the great fault-scarp forming its eastern wall sends off a number of branches, at quite regular intervals, with a general northwest trend. The blocks thus separated pass under the lake beds that floor the valley, and appear again on its western border, where they form cliffs of considerable height." . . . "It is between the high walls enclosing the southern portion of the valley that the greatest confusion of the minor blocks is to be seen. Many of these fragments measure a mile or so on their edges and are tilted in various directions, leaving narrow rugged valleys between their upturned margins. The diverse tilting and the numerous fault-scarps that rise without system into naked precipices combine to make this a region of the roughest and wildest description." (Fourth Ann. Report U. S. G. S., 443, 445, 446.)

It is apparent from these extracts and from others that could be quoted that while southern Oregon has a more complicated structure than that of the Connecticut Trias, it nevertheless serves admirably as a picture of the early stages of the latter, when its faults were still growing: except in the matter of diverse displacement and in the amount of erosion suffered, the description of these long narrow blocks might apply to those of the Connecticut valley.

The blocks in Idaho have been dislocated so rapidly and so recently that they preserve their constructional topography with insignificant alteration, and in this they are the best examples of any region yet described. Nowhere else can we find so good an illustration of a mountain system in its infancy —almost in its birth. A similar constructional topography probably once existed in Connecticut; but it has long since disappeared. The upper surface of the Triassic region being of shales or sandstones, instead of hard sheets of lava, presumably allowed erosion to follow displacement rapidly, but it seems highly probable that the topography of the region was for a considerable time closely consequent on the deformations that closed the period of deposition and ushered in the long cycle of erosion that has since then endured with little interruption.

As time went on and the forces of deformation slackened, the forces of erosion made better headway in reducing the region to a water-sculptured topography; we find existing illustration of this stage of the history of central Connecticut, in the present form of the central ranges of the Great Basin. The following description is also condensed from accounts by Russell.

The central ranges of the Great Basin are structurally composed of long narrow blocks of bedded, aqueous and igneous rocks separated by faults and tilted into monoclinal attitudes; but the simple original structural form that they may once have had is now no longer immediately apparent; the orographic blocks here have been long enough exposed to denudation to reduce them to a water-sculptured form, in which the slopes are trenched by numerous ravines, and the ridges are notched by passes which break the crest-line into peaks, and everywhere develop topographic detail dependent on the unequal hardness of the bedded components of the mass. Much of the detritus taken from the upper portions is now lodged in the depressions between the adjacent ranges. Variety of form has thus been gained, and a marked feature of this variety is that it all tends to the better collection and discharge of the rain that falls upon the ranges. The topographic variety is now near its fullest development, and with further denudation it must lose strength; the ravines will consume more of the mass, the passes will be lowered and the peaks will be attacked and reduced from all sides. The original structural form will be then even less distinct than now, and a continually closer approach will be made to the ultimate featureless base-level lowland, to which all land forms are in time reduced, if no disturbance, such as elevation, interrupt the normal simple progress of their geographic evolution.

Some mountainous variety of form must in a similar manner have obtained for a time in central Connecticut and Massachusetts, when the strongly faulted monoclinal blocks were laterally furrowed by ravines and notched by passes. This may be provisionally called the Jurassic stage of the evolution of our district. But even mountainous ridges are not permanent. Given time enough, and the faulted ridges of Connecticut must be reduced to a low base-level plain. I believe that time enough has already been allowed, and that the strong Jurassic topography was really worn out somewhere in Cretaceous time, when all this part of the country was reduced to a nearly featureless plain, a "*peneplain*," as I would call it, at a low level; a plain that was broadly uplifted in early Tertiary time—or thereabouts—and thus thrown into another cycle of destructive development, and whose elevated remnants are now to be recognized in the crystalline uplands on either side of the present Triassic valley of Connecticut and Massachusetts (Emerson), and in the crest-line summits of the main trap ridges. The general equality of upland altitude on very diverse structures is the essential argument for the base-leveling of the region; but it is not intended to discuss this in detail at present. The post-cretaceous elevation that lifted the ancient lowlands was greater in the interior than near the coast, and our present valleys are deeply sunk and broadly opened in it. An extension of the same ancient lowland, now similarly elevated and dissected, is to be found in northern New Jersey. Standing on a commanding point of view, such as the fine drumlin a mile or more southeast of Meriden, whence the main trap ridges may be seen for many miles north and south, one must in imagination refill the low ground with the shales, sandstones and conglomerates that have been worn away, and thus raise the surface up to the level of the main trap ridges, or even a little higher, in order to perceive the form attained by the land in the late stage of the degradation of the dislocated Triassic blocks, when all this region stood lower. It was only after the close of this first cycle of degradation and after the elevation of the country to something like its actual altitude at a later date that the beginning of the present or second cycle of valley-making was reached. Some unmeasured part of the Tertiary and later time has been allowed for this part of the work. In the crystalline rocks, the valleys are narrow and steep sided, as is so finely shown in the expressive topographic map-sheets of western Massachusetts; but in the Triassic area, where the sandstones are relatively soft, the valleys have been widened out into broad lowlands, only the thicker trap-sheets retaining still some indication of their former altitude. The latest touches have been given to their form by glacial action, both destructive and constructive, as well as by river deposits in the valley bottoms and by estuary deposits in the coastal districts. Except in terrace and gorge cutting, post-glacial erosion is insignificant. If this sketch be correct, we may conclude that the present topography is not an immediate product of erosion on the Jurassic deformations of the Triassic beds; it is an uncompleted advance in a second cycle of development, with recent complications by glacial action and slight changes of level. Like mountains of repeated growth, this topography may be called "polygenetic." The present form of the region is modeled with reference to at least two base-levels.

Just as southern Idaho and central Nevada furnish illustration of the initial and somewhat advanced topographic forms assumed in the development of our Connecticut district, so there will doubtless be found somewhere on the earth, regions of similar structure, presenting actual illustrations of its later stages, when its stronger forms were subdued and finally worn down to the featureless surface or peneplain of its old age. Thus the evolution of the region will be better understood. By this process of comparison,* we may not only restore in some measure the past history of our region, but may as well look into its possible future. When later elevation raises our eastern continental slope to still greater altitude and exposes the mass of the land to still deeper attack by erosive forces, it may happen that the base-level will take such a position as to allow the discovery of the ridges of fundamental crystallines between the fault lines at the base of the Triassic trough; and this stage has its forerunner in a district of northern China (Shantung), described by Richthofen.† The structure of the district is summarized as consisting of crystalline schists of steep dip, unconformably overlain by Cambrian sediments; this compound mass is broken by a system of sub-parallel faults running east or southeast, with upthrow on the southern side, and with a tilting of the faulted blocks by which the uncomformable cover of Cambrian sediments dips southward toward the faults. The deformation is ancient, and subsequent denudation has exposed the fundamental crystallines in long narrow ridges, which by their superior hardness have become water sheds (whether they have always been so or not does not appear, as the successive cycles of river history from the first to the present are not deciphered), while the Cambrian sediments remain in narrow monoclinal strips between every ridge and the next fault to the south. The bottom of our Connecticut trough may some day be worn into similar ridges and valleys.

* During the preparation of this paper, I have had pleasure in meeting evidence of the value of the method here outlined in an essay by Dr. V. Hilber of Graz, Austria In discussing the origin of cross-valleys, he suggests an inductive illustration of their development, as follows: "Auch eine Methode welche in der vergleichende Erdkunde noch kaum Anwendung gefunden hat, welche aber auch für andre Fragen derselben berücksichtigenswert erscheint . . . . ist das Aufsuchen derjenigen Oberflächenformen, welche als Entwickelungsstadien der vollendeten Erscheinung betrachtet werden können." Die Bildung der Durchgangsthäler, Pet. Mitth, xxxv, 1889, 15.

† China, II, 239, Fig. 56. See also Philippson, Studien über Wasserscheiden, 119.

There is a peculiarity of the drainage of the Triassic belt that perhaps finds explanation through considerations such as the above. The Connecticut river from where it receives the Passumpsic between northern New Hampshire and Vermont, follows a line of ancient slates that lead it southward with direct course to the Triassic formation in northern Massachusetts; it crosses this State with tolerably direct southern course and continues in much the same line across Connecticut as far as Hartford; but there it turns to the southeast, and at Middletown it leaves the soft Triassic rocks and enters the hard crystallines, which it follows through a deep and rather steep-sided valley to the Sound at Saybrook. This departure from the low escape now open to the river along the line of easy grades that is followed by the Consolidated railroad from Hartford to New Haven, calls for some special explanation. It is evidently an example of the same kind as those described by Jukes in his famous paper, "On the mode of formation of some of the river valleys in the south of Ireland." But it remains to be seen why the Connecticut should turn from the Triassic belt of soft sandstones which here might lead it to the sea, and why if so turning it should take a course to the southeast rather than to the southwest.

Let it be admitted for the moment that the present course of the river is in the main inherited from the course that it had at the end of the development of the Cretaceous lowland; and that the course that it had during this early cycle of development was consequent upon the original dislocations of the Triassic surface. It is natural enough that the initial drainage of a faulted area should be consequent; we have excellent illustrations of immediately consequent drainage in the lava block country of southern Idaho, already referred to. Now if we can independently determine the probable direction of consequent drainage immediately after the time of dislocation in the lower Connecticut valley, and if this correspond to the present course of the Connecticut where it turns from the Triassic to the Crystalline rocks, the explanation offered may be at least deemed worthy of further examination.

The simplest method of determining the direction of the initial consequent drainage of the dislocated Triassic surface involves a reconstruction of the primitive form that the surface would have had if its dislocation had not been accompanied by erosion; the "structural surface" of la Noë and Margerie. This may be done most easily by developing the surface of the great lava flow that we now call the main trap sheet; restoring its lost portions by extending it upwards into the air along the plane of its dip, and stripping it bare where still covered; but limiting every part of the reconstructed surface by the fault planes that bound the several blocks. The original surface of the uppermost bed of sandstone would have been essentially parallel to this surface of the trap sheet, but a few thousand feet higher.

Percival long ago called attention to the great curve of the main trap sheet from the Hanging Hills to Mount Holyoke in Massachusetts. The restored surface of the sheet, although somewhat interrupted by faults, forms a great half-boat, with the keel along the line joining the ends of the curve and the western side of the boat following the main trap ridge. The boat may be enlarged by extending the sheet southeast from the Hanging Hills through Lamentation, Higby (Besick), Paug and Toket Mountains to the eastern margin of the Triassic formation north of Branford. In this portion of the curve, the faults are much stronger than farther north; but viewed in a large way, the whole sheet from Toket to Holyoke may be regarded as a somewhat broken half-boat, in the attitude already described, with the bow at Belchertown, Massachusetts, and the stern above Branford, Connecticut. Before the Cretaceous base-leveling was completed, the western side of the half-boat reached much higher into the air than the crests of the main ridges reach now.

The upper surface of the Triassic formation would have had a form similar to this, if not eroded. A drainage-system established upon it must have found outlet not to the west or south, where the side and the stern of the boat prevented discharge, but to the east, where the boat was open, and the location of the discharge would be somewhere about the lowest point of the keel. In other words, the chief stream of the region, during the early development of the dislocated country, would have run out to the east, some distance north of the point where the main sheet now reaches the crystalline rocks on the eastern margin of the formation. This corresponds with the general course of the Connecticut closely enough to give some degree of acceptance to the explanation; and the lower Connecticut may therefore be tentatively classified as an originally consequent stream, which has lived far through one cycle of life, and has now in obedience to the general elevation of its drainage area, entered a second cycle in which it is well advanced, still persisting more or less closely in the course chosen in its first cycle.

Thus explained, it may be called in this portion of its valley a revived river of originally consequent course. It is not intended to imply that the dislocated Triassic region ever had a purely "structural surface;" but only to indicate that the summation of all the movements of deformation, which would produce such a surface, sufficed to throw the drainage of the region into the area of least elevation.

The objection to the explanation does not seem to me to be in its inherent improbability, for I believe that every step in the process may find its homologue in the present stage of other regions of similar structure but less age. The objection lies rather in a difficulty not yet named; namely in the occurrence of a strong fault or series of faults, by which the eastern margin of the formation is determined, and whose upthrow is on the east. The drainage from the centripetal slopes of the Triassic half-boat must have surmounted this barrier in order to flow to Saybrook, and in doing so may have formed a large lake in the bottom of the boat, to be drained later on when the outlet was deepened. Whether suppositions so transcendental as these shall be approved remains to be seen.

Cambridge, Mass., February, 1889.

Art. XLIV.—*Analyses of three Descloizites from new Localities*; by W. F. Hillebrand.

[Read before the Colorado Scientific Society, Mar. 4th, 1889.]

1. *Mayflower Mine, Bald Mountain Mining District, Beaverhead County, Montana.*

Through Messrs. W. H. Beck and George E. Lemon of Washington, D. C., was received about a year ago for examination a large lump of friable, uncrystallized material, having a dull yellow to pale orange color, and consisting chiefly of a vanadate, but carrying a large percentage of gangue. Two samples as pure as could be selected from different parts of the lump were analyzed with the following results:

	I.	II.	Mean.	Molecular ratios.		
PbO	56·02	55·84	55·93	·2508		
CuO	1·16	1·13	1·15	·0145	·4718	4·02
FeO	0·70	0·70	0·70	·0097		
ZnO	15·96	15·91	15·94	·1968		
V_2O_5	----	20·80	20·80	·1140		
As_2O_5	0·32	----	0·32	·0014	·1173	1·00
P_2O_5	0·27	----	0·27	·0019		
H_2O	4·37	4·36	4·37	·2428	----	2·07
SiO_2	0·20	0·16	0·18			
CaO	0·10	----	0·10			
MgO	0·06	----	0·06			
			99·82			

From I 27·62 per cent of gangue insoluble in cold dilute nitric acid has been deducted, and from II 22·20 per cent; manganese was present in the gangue in small quantity, apparently as pyrolusite, but it was not dissolved by the acid. The insoluble portion was found also to retain very small quantities of lead and zinc, which were estimated and included in the analysis as probably belonging to the vanadate. The water had to be estimated indirectly by deducting from the total amount of water afforded by the dried mixture of vanadate and gangue that belonging to the latter alone, which was found as follows. The mixture, dried at 100° C., was dissolved in cold dilute nitric acid, and the insoluble matter collected in a Gooch crucible was dried at the same temperature and then ignited. The loss on ignition gave the water in the gangue, there being no ferrous iron in the latter to influence the result. The traces of SiO_2, CaO and MgO may be neglected as probably derived from the gangue. The water, it will be noticed, is double that required by descloizite, $R_2(OH)VO_4$, but in view of the liability to error inherent in the method of water estimation employed this is not deemed sufficient cause for separating the mineral from descloizite, although the close agreement of the two water determinations, made as they were on samples containing different proportions of gangue, would indicate the correctness of the formula $2[R_2(OH)VO_4]+H_2O$.

Other specimens have since been received from the above named persons in which the earthy vanadate was associated sometimes with compact cerussite and galena in process of alteration. A dull reddish substance which constituted a part or even the whole of some lumps contained, besides silica, iron and some antimony in an oxidized condition, but carried little or no vanadium.

Professor F. A. Genth has already called attention* to the occurrence of vanadinite and probably of descloizite in the Bald Mountain mine, Beaverhead County, Montana. His specimens, however, showed the supposed descloizite as a pale brownish crystalline coating on yellow ferruginous quartz, whereas the present mineral shows no evidence of crystalline structure.

2. *Commercial Mine, Georgetown, Grant County, New Mexico.*

This is one of the most interesting occurrences of descloizite known, because of the extreme brilliancy of coloring of the mineral. The ore bodies in the Commercial mine, as well as in the adjoining MacGregor and Naiad Queen mines, occur in limestone immediately under an overlying slate, and appear to narrow in depth where certain eruptive dikes cut through the lime, as Mr. MacIntosh, foreman of the Commercial mine, informed me. The absence of the superintendents of the several mines and the very brief visit I was forced to make prevented obtaining more certain and detailed information.

* Proc. Am. Phil. Soc., xxiv, 38, 1887.

In places where the rock is most fractured and crushed the descloizite appears in greatest quantity and finest condition as an incrustation on quartz, often covering large surfaces, and in color varying from yellow through all shades of orange-red to deep reddish brown, the last named colors predominating. The black color so frequent in descloizite from Lake Valley, New Mexico, caused by a superficial coating or admixture of pyrolusite, is so far as my observation extended, wanting, hence specimens from Georgetown are likely to be much sought after for their showy appearance. A specimen in one of the banks at Silver City, New Mexico, taken from one of the Georgetown mines, resembled a stalactite in form. It was probably fully three feet in height by six to eight inches or more in diameter, and was deep reddish brown in color.

The incrustations are for the greater part distinctly crystalline and are generally made up of aggregates of more or less globular forms of a size ranging from microscopic to a diameter of one or two millimeters. Each of these is composed of a great number of apparently flat crystals, intergrown, and projecting sufficiently from the surface to give brilliant reflections when observed under the lens, and to the naked eye a frosted appearance where the globular growths are largest. The richest reddish brown color is always coincident with this development in size. The globular character changes frequently to acicular. In such cases the incrustation seems to have originally formed on bunches of radiating acicular, almost colorless, vanadinite, which frequently appears thus coating the quartz and running under the descloizite incrustations. Sometimes the vanadinite has entirely disappeared, and then there may be a hollow through the center of the descloizite needle.

The occurrence of vanadate of lead in the MacGregor mine at Georgetown has been noticed by Professor Genth (l. c., p. 38). The specific gravity of the mineral was not determined; the hardness is about 3·5; the color of the powder is orange-yellow. An analysis gave the following results after deducting 11·91 per cent of insoluble matter, almost entirely quartz.

			Molecular ratios.		
PbO	56·01	·2512			
CuO	1·05	·0132			
FeO	0·07	·0010	·4843	·4788	4·12
ZnO	17·73	·2189			
V_2O_5	20·44	·1119			
As_2O_5	0·94	·0041	·1178	·1162	1·00
P_2O_5	0·26	·0018			
H_2O	2.45	·1361	----	·1361	1·17
Cl	0·04	·0011			
SiO_2	1·01				
CaO	0·04				
MgO	0·03				
	100·07				

The third column of molecular ratios gives those values after allowing for admixed vanadinite calculated on the basis of the chlorine found. A further correction has probably to be made for an admixed soluble hydrous (zinc ?) silicate, which might make the ratio approximate more closely to 4 : 1 : 1.

3. *Lucky Cuss Mine, Tombstone, Cochise County, Arizona.*

Mr. W. F. Staunton, Superintendent of the Tombstone Mining and Milling Co., and Mr. Frank C. Earle, assayer at Tombstone, kindly placed at my disposal for examination specimens of a vanadium mineral the identity of which had not been established. It was found in the Lucky Cuss mine as an incrustation, sometimes half an inch thick, on quartz, showing more or less botryoidal surfaces of an indefinable dull greenish color. On a fractured surface the color is brown; the luster is resinous; the structure granular, only occasionally diverging fibrous; the hardness 3·5; the specific gravity of sample analyzed, containing a little impurity, 5·88 at 19° C.; color of powder lemon-yellow. Analysis gave the following results after deducting 0·67 per cent of insoluble matter.

		Molecular ratios.			
PbO	57·00	·2556	·4485	·4385	3·93
CuO	11·21	·1412			
FeO	trace.	----			
ZnO	4·19	·0517			
V_2O_5	19·79	·1084	·1145	·1115	1·00
As_2O_5	1·10	·0048			
P_2O_5	0·19	·0013			
H_2O	2·50	·1389	----	·1389	1·25
Cl	0·07	·0020			
SiO_2	0·80				
CaO	1·01				
MgO	0·04				
K_2O	0·10				
Na_2O	0·17				
CO_2	0·82				
	98·99				

The low total is probably owing to a loss of zinc during analysis. Calcite was present as an impurity, and as the CO_2 just suffices for the CaO and MgO these are rejected in considering the composition of the vanadate. The figures in the third column of molecular ratios are found by allowing for probably admixed vanadinite calculated from the chlorine found. In another specimen a qualitative test for chlorine indicated a greater admixture of vanadinite. As in the case of the descloizite from Georgetown, New Mexico, previously described, a further allowance has perhaps to be made for a soluble hydrous silicate. There can be no doubt that the general formula for the vanadate is that of descloizite.

In almost every respect this mineral resembles, so far as the published descriptions allow of judging, the descloizite of Penfield,* the cupro-descloizite of Rammelsberg,† and the ramirite of de Leon,‡ perhaps also the tritochorite of Frenzel,§ to the similarity of which with his variety of descloizite Penfield draws attention in his paper. Professor Genth's surmise (l. c., p. 39) of the specific identity of all these substances seems highly probable. Characteristic for the present variety is the greater replacement of the lead-zinc vanadate—true descloizite—by the isomorphous lead-copper vanadate, and the lessened tendency toward a fibrous structure, which in the other varieties described seems to be a decidedly pronounced feature. Possibly this last characteristic of the Tombstone mineral, if it be not accidental in view of the few specimens (three) examined, is a condition of the first.

According to Rammelsberg,‖ the lead-copper vanadate corresponding to the lead-zinc vanadate (descloizite) is mottramite or psittacinite, though it seems not improbable that it may be the chileite of Dana's Mineralogy. Domeyko's analyses,¶ which led Kenngott to ascribe the above name to the Chilian mineral, show a deficiency of 2·5 and 2·8 per cent, which may very well be V_2O_5. At all events, a recalculation of his analyses based on this assumption leads to a proportion for $PbO+CuO : V_2O_5 : H_2O$ of nearly 4 : 1 : 1.

In view of the well defined character of all these highly cupriferous varieties of descloizite it would be well to designate them once for all by some distinctive name. Tritochorite would have precedence if the substance to which that name has been given is really identical with the others, but Rammelsberg's cupro-descloizite is more appropriate as indicating at once the relationship to descloizite, and I would suggest that it be henceforth used for all cupriferous descloizites showing the physical characteristics of the mineral above described.

Note.—Since the foregoing was written there has appeared in the Bull. Soc. Franc. Min., Feb., 1889, p. 38, a paper by F. Pisani, in which he gives another analysis of the Mexican cupro-descloizite and discusses briefly the relations of various vanadates. The essential identity of all the above enumerated cupriferous lead-zinc vanadates, with the addition of another—schaffnerite—concerning which I have been unable to find any further reference in mineralogical literature, is therein upheld, and the suggestion of Penfield's regarding the possible identity of tritochorite and

* This Journal, III, xxvi, 361, 1883.

† Monatsb. Berl. Acad., 1883, 1215.

‡ La Ramirita, nueva espèce mineral, Mexico, 1885.

§ Tschermak's Min. and Petr. Mitth., iii. 506, 1880; iv, 97, 1881.

‖ Chemische Natur der Mineralien, p. 32.

¶ Ann. d. Mines, IV, xiv, 150, 1848; Phil. Mag., III, xxxiv, 395, 1849.

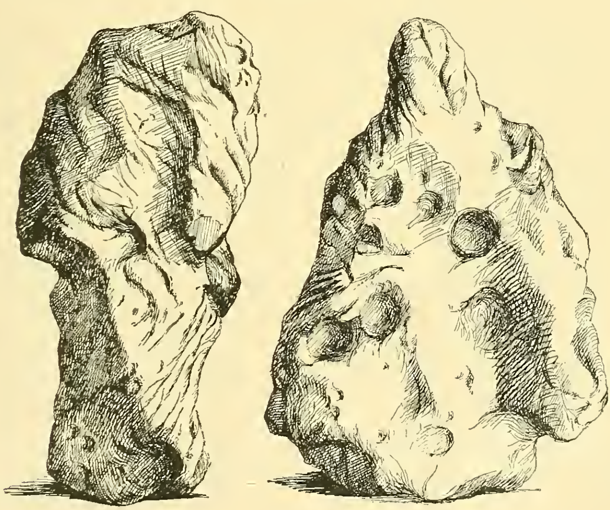
cupro-descloizite is confirmed by Frenzel himself, who is quoted as writing to Professor DesCloizeaux that he had not thought it necessary to consider as an essential constituent the two per cent of water which he had found in tritochorite.

Laboratory of the U. S. Geological Survey,
Washington, D. C., Feb. 9, 1889.

Art. XLV.—*A new Meteorite from Mexico;* by J. Edward Whitfield.

While in Mexico during the summer of 1888, Prof. H. A. Ward, of Ward and Howell, Rochester, N. Y., obtained an undescribed mass of metoric iron weighing 33·0 kilos.

The meteorite was found on a peak of the Sierra de San Francisco, called La Bella Roca, in front of Santiago Papasquiaro in the state of Durango. The date of its discovery and the name of the finder are unknown.



The two greatest dimensions of the mass are $24{\cdot}13^{cm} \times 34{\cdot}92^{cm}$; an idea of the shape and general appearance may be had from the accompanying cut which shows what is supposed to be the front and back of the meteorite, at least during the latter part of its flight.

The composition of the metallic portion does not differ materially from that of other meteorite irons as the following analysis will show.

Fe	91·48
Ni	7·92
Co	0·22
P	0·21
S	0·21
C	0·06
	100·10

A feature of the meteorite is the presence of large, deep pittings on one side; these are a little greater in diameter just below than immediately at the surface and each one has a little substance left at the bottom, which evidently is the remains of what originally filled the cavities. I succeeded in breaking from the bottom of one pitting material sufficient to determine its nature. It proved to be troilite as the analysis will show.

NiS 2·13, FeS 85·27, Fe 9·37.

The exposed surface of the troilite was greatly decomposed; this portion gave by analysis the following figures.

NiS 2·07, FeS 37·51, Fe_2O_3 37·80, Moisture =19·85.

This decomposition gives grounds for the idea that the deep pittings were formed by the removal of troilite nodules, partly while the mass was hot and partly by the subsequent weathering.

There are nodules of troilite throughout the entire mass of the meteorite but none are removed, so as to form pittings, on any other part of the surface but the side which is supposed to have been the front.

The mass is deeply furrowed, as may be seen to some extent in the figure, and all the furrows tend away from the side containing the pittings.

Slices of the meteorite, when etched, show rather coarse Widmanstättian figures and also dark diagonal bands of troilite.

From the locality in which this meteorite was found it is but proper that it should be called "La Bella Roca."

I am indebted to Messrs. Ward and Howell for the material for examination and the privilege of description.

Chemical Laboratory, U. S. Geol. Survey,
Washington, D. C., March 3d, 1889.

ART. XLVI.—*Contributions to the Petrography of the Sandwich Islands;* by EDWARD S. DANA. With Plate XIV.

THE rock specimens, the results of whose study are detailed in the following pages, were in part collected by Professor James D. Dana on his trip to the Sandwich Islands in August, 1887, and the remainder by the Rev. E. P. Baker of Hilo in 1888. The first series includes about thirty specimens from Kilauea, a third of them from the projectile deposits on its borders; several from other points in Hawaii; about a dozen specimens from the island of Maui, chiefly from the extinct crater of Haleakala; and finally an equal number from different points on the island of Oahu. The special localities are mentioned beyond. The second series of specimens are all from Hawaii, and chiefly from Mokuaweoweo, the summit crater of Mauna Loa. There are also a few specimens from Makaopuhi and Nanawale on Hawaii, points which belong to the Kilauea region.

For our present knowledge of Hawaiian lavas we are indebted in the first place to the general descriptions of J. D. Dana in the Geology of the Exploring Expedition (1849), and W. T. Brigham in his Notes* on the Volcanoes of the Hawaiian Islands (1868); also C. E. Dutton (1884) and others. On the other hand, on the petrographical side, there have been published the microscopic study of basaltic glass of Hawaii, especially Pele's Hair, by Krukenberg† in 1877; a paper by Cohen‡ devoted chiefly to the glassy basaltic lavas of Hawaii; brief descriptions of isolated specimens of nepheline basalts believed to have come from Oahu by Wichmann§ and by Rosenbusch;‖ finally a recent memoir by Silvestri¶ describing a series of ancient and modern lavas from Kilauea collected by Prof. Tacchini in 1883.

1. *Lavas of Mauna Loa and its summit crater, Mokuaweoweo.*

For the collection of lava specimens from the summit crater of Mauna Loa, the writer is indebted, as is stated above, to the Rev. E. P. Baker.** The collection is a large one and evidently

* Mem. Boston Soc. Nat. Hist., vol. i, pt. 3.

† Mikrographie der Glasbasalte von Hawaii, petrographische Untersuchung von C. F. W. Krukenberg, Tübingen, 1877.

‡ Jahrb. Min., vol. ii, 23, 1880.

§ Jahrb. Min., 172, 1875.

‖ Mass. Gesteine, 510, 1877.

¶ Bull. Com. Geol. d'Italia, xix, 128–143, 168–196, 1888.

** Mr. Baker's extended trip over Hawaii, which included, besides an exploration of the summit crater, a visit to the sources of several of the great lava streams, was undertaken in order to make the collections of rocks and gather facts with regard to the eruptions, and some extracts from his notes are published in this volume at p. 52. The results have proved to be of very great interest.

represents well the characteristic types of rocks. It numbers, exclusive of the "pumice" and scoria upwards of seventy specimens; of these about fifty have been subjected to microscopic study. In regard to the geographical distribution of the rocks with reference to their relative age but little can be said. A considerable part (Nos. 90–109) are from the talus within the southern crater of Mokuaweoweo against the neck between it and the central pit. (See the map in vol. xxxvi, plate II). A number of others (78–89) are from the eastern side of the central pit; and in the case of scattering specimens, the special source is mentioned more minutely beyond, when interest seems to attach to it.

In general it may be said that all the specimens in hand from Mauna Loa belong to the same class of basaltic lavas, although they vary widely: in color from dark gray to light gray or dull brick-red; in structure from compact to highly cellular or vesicular; from those of uniform grain to those which are prominently porphyritic with chrysolite or feldspar; and in composition from the very highly chrysolitic kinds to the feldspathic or augitic forms with little or no chrysolite. Specimens of pumice-like scoria are largely represented in the collection.

The specimens may be divided pretty sharply into two groups, besides which there are several other types more or less distinct from these.

Clinkstone-like basalt.—The first of these doubtless includes the rock which former observers have spoken of as resembling phonolite. Macroscopically it has a uniform fine-grained texture, for the most part free from vesicles and apparently compact, though often found on closer examination to be minutely porous. The color varies from a dark bluish gray to light gray, and to dull brick-red or brown, the grayish kinds being the most common. The specific gravity varies from 2·82 to 3·00.* Many of these specimens, as taken from the talus between the central and southern craters, are in the form of thin slabs and their resemblance to clinkstone in the hand specimen, though not going beyond external aspect, is sufficiently close to explain their having been so named. As regards composition the rocks of this type are most strongly marked by the fact that the chrysolite, which is so common in large grains in the other specimens to be described, is absent or only sparingly present.

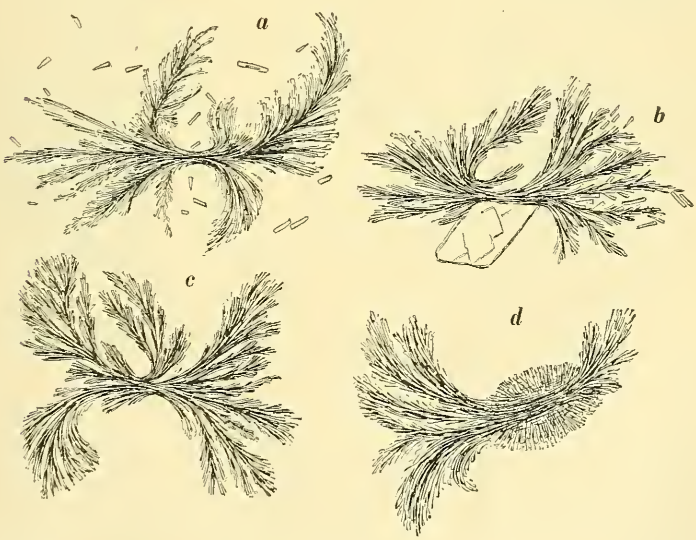
The microscopic characters of this group of fine-grained compact rocks are also such as readily to distinguish them from the other forms. In general they consist of augite and plagio-

* Some of the separate determinations on fragments freed from air by boiling are: 3·00, 2·94, 3·00, 2·87, 2·82, 3·00, 2·82.

clase, and titanic, or magnetic iron or both, prominent, but with little or no chrysolite. Their most interesting feature is the form taken by the augite, which is only exceptionally developed as an idiomorphic constituent, but on the other hand is not simply a formless substance filling the spaces between the feldspar. It is uniformly, though with varying degrees of distinctness, grouped in radiating forms, fan-shaped or feather-like, of great variety and beauty.

This structure is eminently characteristic of this group of rocks. It is shown best in a fine-grained purplish colored specimen (No. 97, G.=2·82). This is seen under the hand glass to be minutely porous though not properly vesicular, with minute slender red crystals (augite) projecting into the cavities. An occasional grain of chrysolite can be detected in the mass and cleavage sections of feldspar are also seen. Under the microscope it is made up of lath-shaped feldspar individuals and the beautiful groupings of augites, these set out in relief by the fine grains

1.



Feather-forms of augite; *a* (× 35), *b* (× 35), *c* (× 50) from Mokuaweoweo, *d* (× 70) from Kilauea.

of iron ore surrounding them. In the simplest cases the augite is bunched together in long parallel groups slightly diverging at the extremities; generally these branch off at various points into feather-like or dendritic forms, of such variety as to be beyond description. Groups of these forms radiating from a center are common.*

The accompanying figure, 1, shows several of the more complex of these forms (*a*, *b* from this specimen) and gives a fair representation of this remarkable structure. Figure 2 gives the appearance of the entire field of the microscope, showing forms like the frost crystals occasionally seen on a stone pavement; this figure is simplified by the omission of some of the less defined parts.

Some of the simpler rosettes are made up of both feldspar and augite alike radiating from a common center; and frequently the extremities of the feather ends are feldspar individuals. Figure 3 gives a detailed drawing of part of one of

2.

Feather-augite in basalt from Mokuaweoweo. Magnified 60 times.

3.

Detailed drawing showing the feather-like grouping of augite and feldspar. Magnified 100 times.

the groups. It would seem that the feldspar was as usual first separated, and the augite as it crystallized out into these dendritic forms drew the feldspar needles into position with it. The two minerals are sometimes so intricately involved with each other that it requires close examination to separate them. In polarized light the distinction comes out more sharply.

* Mr. H. Hensoldt of New York has called the writer's attention to an augitic lava from Tahiti in which the pinkish, pleochroic augite is present in radiating groups of acicular crystals, often having a nucleus of chrysolite. The section is one of very exceptional beauty and interest, although the arrangement of the augite is hardly to be compared with that here described, since the individual crystals are sharp and geometrically grouped—after the manner of the tourmaline in luxullianite—which is in marked contrast to the feather forms of the Mauna Loa augite.

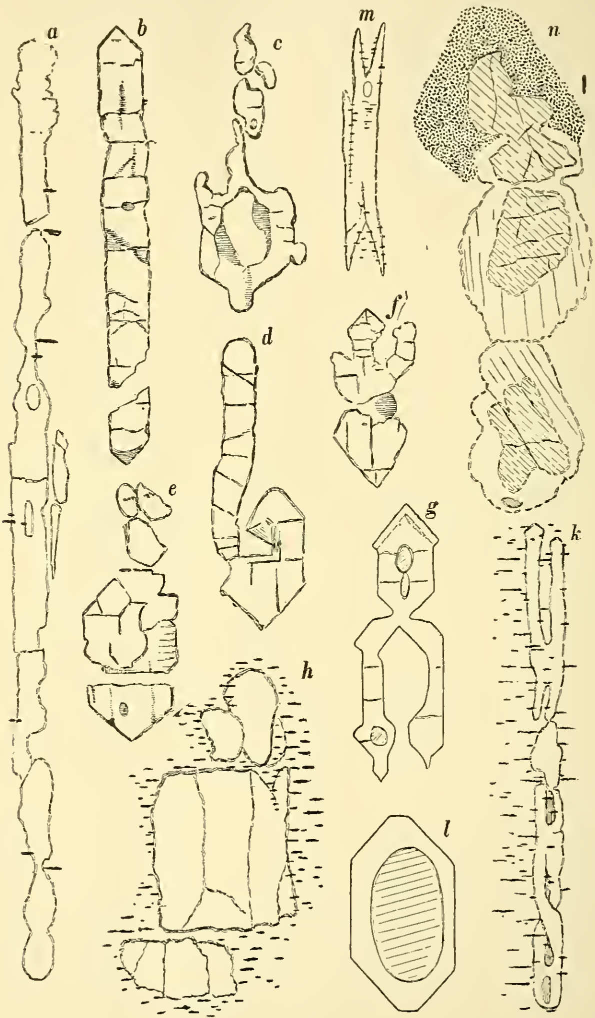
Occasionally the feldspar is present in larger forms; and more interesting to note is an occasional augite crystal (fig. 1, *b*) that evidently belongs to an earlier generation, and shows the distinct cleavage, and more or less also the crystalline outline of the species. The alteration to which this specimen, with others like it, has been subjected, and to which the red or purple color of the rock in the mass is due, has stained the iron red and reddened also the augite, although only exceptionally to such an extent as to make it opaque. The alteration spoken of may be simple weathering, although the occasional brick-red color rather suggests the action of hot water or steam; the feldspar remains perfectly clear and unchanged.

From the specimen described, which may be taken as the type, we pass to the coarser grained kinds on the one hand and to the very fine-grained on the other; both of these still retaining, however, the same general characters. A highly cellular specimen (74) with large vesicles, from the northwest brink of the crater, departs in general aspect most widely from the type; but, while relatively coarse-grained, it exhibits the same grouping though somewhat more rigid and geometrical, and shows even more clearly the mutual relations of the feldspar and augite. In the finer grained varieties (as 78) the augite sometimes predominates so largely that the whole becomes like a confused carpet pattern of interlacing arabesque forms, though here, when an individual form can be traced out, it has great beauty and perfection, branching and re-branching like some delicate forms of vegetation. Figure 1, *c* is an attempt to illustrate one of these forms, but it lacks the delicacy of the original. These forms consist almost exclusively of augite with very little feldspar. In another specimen of similar character a partial fluidal structure was noticed in the arrangement of the feldspar.

When the iron grains are only sparingly present and there has been no conspicuous alteration, the rock is of a light uniform gray, but the presence of iron in large amount makes it nearly black and obscures this structure; and when it and the augite are highly altered, the rock is a bright brick-red and in a section appears as a collection of nearly opaque red rosettes, the feldspar, however, still remaining clear. Glass is present occasionally, but usually in insignificant amounts, and for the most part it is nearly or quite absent. This feather-form of augite, which has been described, is not entirely confined to the clinkstone-like varieties of lava although eminently characteristic of them. It was occasionally noted more or less distinctly, in some other forms, especially the vesicular kinds to be mentioned later (p. 450) where it is seen in the minute second-generation augite which formed in the last process of consolidation. All the facts observed serve to connect its formation with rapid cooling.

Chrysolitic basalt.—The second group of rocks makes a very marked contrast with those just described. These are of coarse grain, often open-cellular, and very highly chryso-

4.



Chrysolite in part with orientated titanic iron; *a–f* (× 55–60), from crystalline basalts of Mokuaweoweo. *g* (× 75) from basaltic glass, Mokuaweoweo; *h* (× 60) from Nanawale; *k* (× 60) Kilauea; *l* (× 100) crystal enclosing glass, Kilauea; *m* (× 60), forked form, Maui: *n* (× 60) portions of crystal enveloped by augite and clusters of magnetite grains, Maui.

litic; on this account the specific gravity is much higher, it varying from 3·00 to 3·20.* In many cases they have suffered some alteration which has given them a dull waxy surface, while the large grains of chrysolite are frequently iridescent and sometimes have an almost metallic luster. The color varies with the amount of iron oxidation from light gray to dull reddish gray or brown. The mineral constituents present are those of normal basalt; and most prominent among these is the chrysolite; in some specimens it must make up nearly half the mass of the rock; and in one case (102) probably more, this particular specimen having the unusual specific gravity of 3·20. The chrysolite was evidently early separated from the magma, and the changes of condition through which the lavas have passed is well shown in the irregularly corroded or occasional broken form of many of the crystals and grains. Even when there is a distinct crystalline outline, it is not a rare thing to find the crystal broken and the parts slightly separated. This is shown in the accompanying figures 4, *a* to *f*. Some of the corroded forms take very fantastic shapes. A novel and common feature of this chrysolite is the occurrence of very slender acicular forms. The length is often considerable, even when viewed macroscopically, in one case 2 to 3^{mm}, but in breadth they are often hardly more than a line, (note fig. 4, *a*.) This chrysolite shows the partial alteration alluded to in a broad rim of brown iron oxide; we can pass in the same slide from a crystal still preserving its transparency throughout, to those where only a string of chrysolite grains mark the position of the original individual, and from these to the cases where a narrow brown line of iron oxide alone is left; in a few cases (as 94) the chrysolite is stained bright red, showing that there has been oxidation of the iron without hydration.

The orientation of these peculiar rod-like forms, which are distinctly visible on a polished surface of the rock, is a matter of some interest. The fact that, in such a form as that of fig. 4, *b*, and others like it, the plane of the optic axes is transverse to the longitudinal direction and the bisectrix normal to the surface presented, shows that they are elongated in the direction of the vertical axis, the narrow dimension being that of the macrodiagonal. This chrysolite has often an unusually deep green color possibly connected with the partial alteration, and then shows distinct pleochroism with the absorption least in the direction of the vertical axis. It often shows spherical inclusions of a pale brown glass, sometimes arranged in parallel lines.

* Some of the separate determinations gave: 3·09, 3·18, 3·09, 3·04, 3·00, 3·20, 3·00.

The plagioclase feldspar is present in the ordinary forms, and shows no unusual features. The augite forms irregular grains crowded among the feldspars. Occasionally augite in larger more distinctly crystallized forms appears, evidently belonging to an earlier generation. This earlier augite shows the tendency, often observed, to cluster about the chrysolite grains. The titanic iron is not as a rule abundant, and for the most part appears in long slender rods often parallel among themselves over a limited area, and sometimes orientated by the chrysolite. In two or three of the specimens of this class the augite shows a tendency to assume the radiating form but this is the exception. Apatite is probably present in some sections, but only in small amount, and in most cases it was not detected. Glass is almost entirely absent from these rocks.

The occasional fractured character of the chrysolite has been spoken of; one specimen (90) shows this in an extreme degree, the chrysolite being separated here into many angular fragments for the most part showing no crystalline outline. The feldspar and augite individuals have also suffered in the same way and the ground mass has a curiously mottled microcrystalline structure suggestive of some porphyry. This specimen stands comparatively alone, although two or three others are of somewhat similar character.

Lavas with minute crystals of feldspar and augite in their cavities.—Allied to this second class of rocks just described, are a number of specimens which are interesting because of their remarkable crystalline structure. One of these (82) is a light gray rock with only occasional vesicles. It is, however, throughout open and porous with minute cavities into which project thin tabular crystals of feldspar seen distinctly with a strong hand-glass. A light yellowish augite is also observed, but the crystals are less distinct. Iridescent grains of chrysolite are scattered through the mass, and the fractured surface shows the same long lines of this mineral that are seen in the sections.

An interesting feature of this specimen and of others like it (including one very similar collected two or three hundred feet below the summit of the wall making the E.N.E. side of Kilauea, called Waldron's Ledge, also others from Makaopuhi) is the presence in cavities, of a mineral in very minute nearly spherical forms of a milk-white color. These are rather abundant through the mass of the rock, each little cavity containing one or two of them. They are so small (rarely more than ·2 or ·3^{mm} in diameter) that it is very difficult to determine their form, especially as the crystalline faces are dull and give almost no reflections. A hexagonal outline can usually be made out, and occasionally a triangular face through which the angle of another crystal sometimes projects, as if they were complex penetration twins, which the nearly spherical form also suggests. Only one of these forms was detected in the thin sections, and the free side of this had a hexagonal outline, the whole being divided into sectors which alternately had like extinction, the surface of the sector being mottled in polarized light after the manner of some crystals showing anomalous optical double refraction. The fact that these little white spheres occur also on the inner glazed surface of the vesicles would seem to mark them of subsequent origin and hence probably zeolitic. Their form suggests a rhombohedral zeolite grouped like phacolite or the Australian herschelite. Two or three other zeolitic minerals were observed in isolated cases, but too sparingly and in too minute form to be satisfactorily identified.

In other specimens of this class (as 105, 107) the color is darkened because of slight alteration, the texture is coarser and the cavities larger. Here the clear glassy feldspar tablets are very distinct, and augite crystals, red or brown on the surface and opaque, also project into the cavities. Octahedrons of magnetite are often seen implanted upon the augite needles, and broad plates of titanic iron, with rhombohedral planes on the edges, sometimes attain a relatively large size. The feldspar tablets were here large enough to allow of their being separated and examined optically. In form they are either rhombic or acute triangular in outline, being bounded by the planes *c* (001) and *y* ($\bar{2}$01) or *c* and *x* ($\bar{1}$01), with the prisms very small when present at all. They can often be seen to be twins in accordance with the usual albite law. The extinction on the clinopinacoid made an angle of -14 to $-15°$ with the basal edge, which conforms to typical labradorite, as might have been anticipated. These highly crystalline specimens are also much like some of those collected from ejected masses about Kilauea, and they may here have had a similar origin.

All the specimens that have been thus far described were obtained with a single exception (No. 74 already located) either from the talus in the southern crater against the wall of the neck that joins it with the central pit, or else from the east side of the interior of central Mokuaweoweo. Nothing can be said in regard to the relations in place of the two types of basalt which have been described and which occur together at the points mentioned.

Other varieties of the lavas.—A number of the specimens cannot be classed in either of these two groups. They are light gray in color, not vesicular, and sparingly provided with chrysolite, if it is present at all, and characterized by a very uniform granular mixture of augite and plagioclase. A specimen taken from a vein in the western wall belongs here, also another stated to have come from the highest point on the edge of the crater. Still another specimen from the north brink is similar, but is porphyritic with patches of a glassy plagioclase.

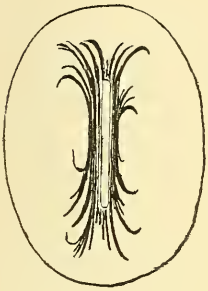
Another group of specimens, differing in aspect widely from those described, although not essentially so in composition, are the highly vesicular kinds, sometimes coarsely vesicular and again with very minute cavities. They have for the most part a common character. Large grains of chrysolite are usually present, often very large in comparison with the size of the vesicles themselves, and with these also are sometimes large crystals of augite and feldspar, often grouped together. The ground-mass filling up the space between these first separated constituents is a dark fine-grained mass of plagioclase and augite with minute grains of iron sometimes so abundant as to render the whole nearly black and opaque. The augite sometimes shows a tendency to group itself in the radiating forms already described. A fluidal arrangement of the feldspar is the exception though occasionally observed in indistinct form. Only in rare cases is the whole mass of the rock made up of this fine-grained mass without the large crystals. A specimen from the source of the 1843 flow belongs here.

A specimen (76) which is described as the "ordinary ancient lava of the eastern brink of the crater" is a dark colored, coarsely vesicular rock (G.=3·00), with chrysolite abundant in large grains, and augite and feldspar also in large individuals, the amount of the fine-grained dark base of later formation is relatively small and the augite is somewhat radiated. A peculiar feature of the section is the inclusion by the augite of large plagioclase individuals not regularly orientated and giving the whole augite a peculiar mottled appearance.

Specimens of glass.—The Mauna Loa collection includes a large number of specimens of the scoria, many pumice-like specimens, some of them of extreme lightness and also specimens of glass. Several of the glassy kinds were examined microscopically. One of them (103) was a dense black compact mass uniformly glassy on one side, but on the other largely devitrified; the smooth surface of the glass was roughened by minute projections due to the chrysolite crystals. Its specific gravity is 2·91. Under the microscope the glass had a uniform brown color, and amorphous character, except for numerous minute doubly refracting points scattered through it. Here and there were clusters of small chrysolite crystals, having sharp outlines and perfectly clear except for occasional inclusions of the glass and minute black iron crystals.

A section cut transversely showed with great beauty the gradual transition from the amorphous glass to the largely devitrified lava. The pale yellow-brown glass of the border contained here and there elongated microlites, of dark brown color due to the glass immediately surrounding them, and also minute crystallites like those described below. In the intermediate zone the microlites were more numerous and were surrounded by a brown oval aureole of somewhat deeper color than the rest of the glass, this having a beautiful spherulitic structure in polarized light. The nucleus was sometimes

5.



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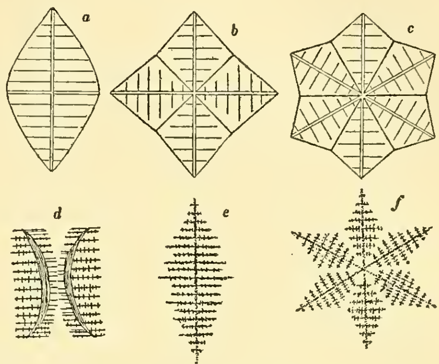


5. Feldspar microlite surrounded by dark filaments within an oval of brown glass (× 90).
6. Crystallites of various forms (× 160). All from basaltic glass, Mokuaweoweo.

transparent (feldspar) and about this were curious dark brown processes thrown off in curved lines (see fig. 5). The highly devitrified portion consisted of a nearly continuous mass of dark brown spherulites and crowded among them numbers of whitish nearly opaque crystallites. Many of the spherulites have a distinct nucleus of chrysolite or feldspar, and sometimes there is a medusa-like mass of dark brown bands radiating out from the nucleus.

The crystallites (see fig. 6) have sometimes a simple oval form with a faintly indicated structure transverse to the longitudinal axis; there are also compound forms with axes crossing at 90°, making a four-rayed star (*b*), or at 60° and these last when repeated making a regular six-rayed star (*c*). Rarely these forms are resolved into a delicate skeleton form of the types indicated (*d*, *e*, *f*) and of many other less regular shapes. Similar forms of "crystalloids" are figured by Vogelsang in plate VII of his work, "Die Krystalliten."

Chrysolite is distributed through the section in isolated crystals or in clusters. These crystals often enclose a considerable amount of the brown glass, and while sharp in outline have sometimes peculiar forms (fig. 4, *g*) which are interesting in connection with the corroded forms met with in the highly crystalline basalts which have already been described. Feldspar is present in the more highly devitrified portion; augite not distinctly except as some of the microlites are to be referred to it.

Another specimen was lithoidal in character and showed throughout a distinct spherulitic structure. The nearly opaque spherulitic ground-mass contained many light brown transparent spherulites, and grains of chrysolite were scattered through as in the other

Lava streams from Mauna Loa.—A considerable number of specimens are at hand from the streams of Mauna Loa of different dates, and taken from points at various altitudes. For the most part they are simply the surface scoriaceous portions and consequently without distinctive features. The flows of 1852, 1855–56, 1859 are thus represented. There are also specimens of the normal crystallized lavas of the stream, 1881, at Hilo; of that of 1843 taken from near its source which has been already alluded to, and of 1868, 1880–81, 1882 and 1887. These are all dark colored chrysolitic lavas, vesicular in a high degree, especially that from near Hilo (1881) and their characters are those of the vesicular forms spoken of on page 450. The specimens of the flows of 1868 are to be mentioned as particularly rich in chrysolite.

2. *Lava Stalactites from caves in the Mt. Loa lava streams.*

Perhaps the most interesting and remarkable formations connected with the lava flows from Mauna Loa are the delicate stalactites and stalagmites of lava which ornament the caverns. The specimens in the collection are mostly from a cavern in the lava stream of 1881, near Hilo, as described on page 109 of the last volume of this Journal. Figures of some of the forms of similar stalactites from the caverns of Kilauea are given by Brigham as more particularly mentioned later. They are of so great interest as to demand a minute description.

According to the accounts given, the flowing lava stream, crusted over at the surface, leaves behind it, when the molten material has flowed by, long caverns usually eight or ten feet in height, having a roof of one to three or more feet in thickness and a floor of the solidified lava. In the caverns are found hanging from the roof the slender lava stalactites. In the Hilo cavern they were from a few inches to twenty or thirty in length, and in some places only six to eight inches apart. The diameter, which seems to have been determined by the size of the drop of the liquid material, does not vary much, being usually about a quarter of an inch. Beneath the stalactites, from the floor below, rise the clustered groups of the stalagmites. These delicate forms are so fragile that they hardly bear transportation, and it is consequently difficult to preserve the longer specimens in their original form.

Through the kindness of Mr. Baker, the writer has received an admirable series of them, part of which are shown, one-third of the natural size, in the accompanying plate. These specimens were collected with great care and skilfully packed in moss and although fractured at many points when they arrived in New Haven, and thus divided into sections an inch or two in length, it was found possible to cement them together in their original positions.*

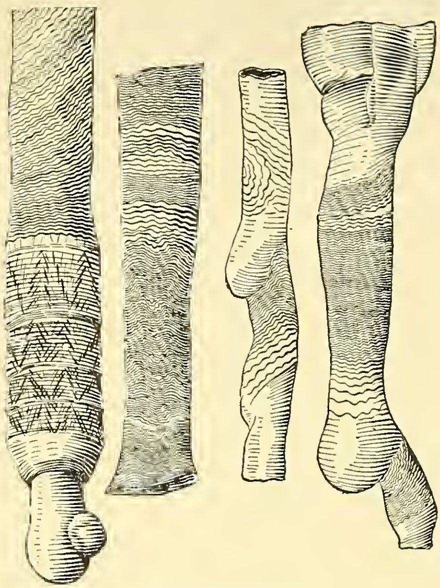
The general aspect of the stalactites and stalagmites is so well shown in the series of figures on plate XIV that but little description is needed. It will be noticed that while some are straight and nearly uniform, others are curiously gnarled and knotted, especially near their lower extremities. The end has often a little process thrown off at right angles, a little hook, or a close spiral of two or three turns often tangled or knotted together. The simple rods are usually round, not often flattened except when there is a sudden change in direction, when they may be pinched together like a glass tube bent when hot. The surface is exquisitely ornamented with most delicate markings. The stalagmites, formed by the droppings from above, are intricate clusters or piles of simple drops several inches in height as well represented in figures *a* and *b* on the plate.

The exterior of the stalactites has usually a more or less bright metallic luster, and, though sometimes dull and fine granular, the surface often reflects the light brilliantly from a multitude of crystalline facets; these sometimes separate into distinct scales, shown to be largely hematite by their reddish streak, though magnetite is also present. Minute rounded crystals, apparently also of hematite, are sprinkled often thickly over the surface. Sometimes the metallic covering is very thin, or is not continuous, forming patches on a brown surface. Occasionally at the ends it is altogether absent, and the exterior is thus brown and glassy in aspect, but still retains the polyhedral crystalline aspect; this glass-like crust polarizes light and is probably augite. Over portions of the rods—and in the case of the straight uniform ones (see the plate) over the whole length—the surface is transversely ribbed or corded in the most delicate manner. The beauty and perfection of these little ripplemarks, as seen under a hand-glass, are beyond description or adequate representation. They are parallel and symmetrical for a limited distance, but vary in fineness and form with every change in direction of the stalactite itself. Their flow is especially varied about each little projecting knob.

* For this skillful work as well as for the drawing of the plate, and of figs. 1–4 and 7, the writer is indebted to Dr. E. H. Barbour, recently of Yale University.

Figure 7 will give some idea of the transverse markings, but details of the structure can hardly be reproduced.

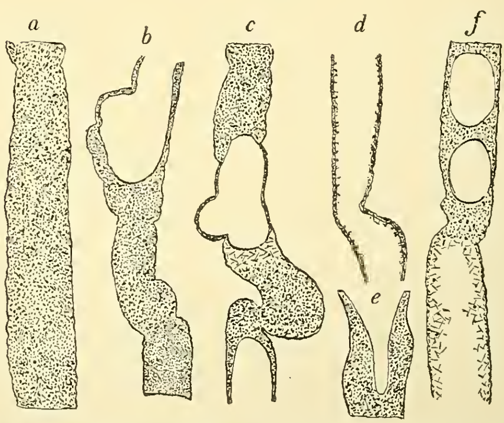
7.



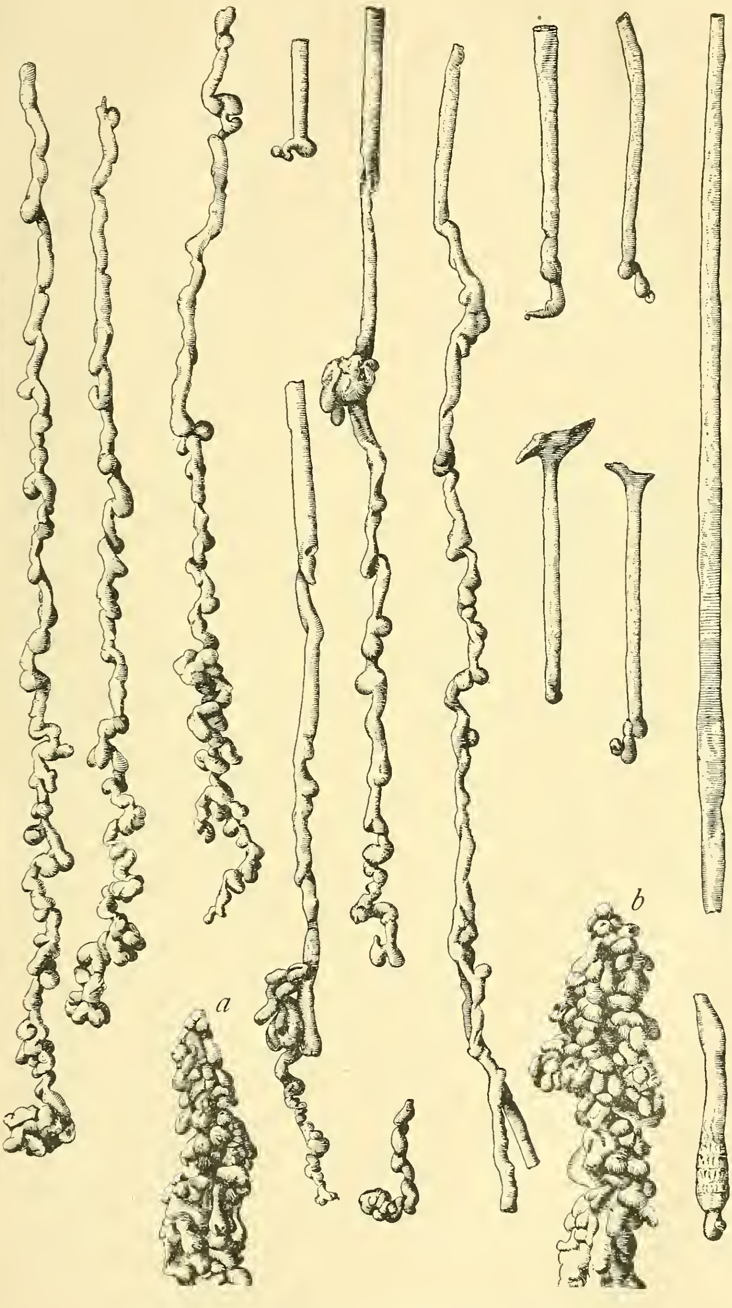
Lava Stalactites, $\times \frac{4}{3}$.

The straighter portions of the stalactites are often solid throughout, though here and there they are hollow and consist of a mere shell; often portions that are perfectly solid alternate with the cellular parts, or the solid parts contain a series of large vesicles. Figure 8 gives longitudinal cross sections through a number of typical forms. In *f*, the lower cavity was thickly lined with crystals chiefly of feldspar. The exterior crust is seen in the cross section under the microscope to be very thin, and next to it comes usually a narrow, but not always continuous, band of augite with occasional iron crystals. The solid parts contain within very slender lath-shaped

8.



Longitudinal sections of lava stalactites in outline ($\times \frac{5}{4}$) showing open and solid portions, *a* solid and *d* open throughout, *d* with crystalline lining; the lower part of *f* is thickly lined with crystals, chiefly feldspar.

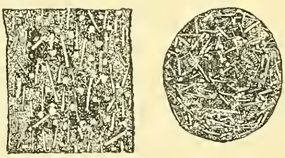


STALACTITES FROM LAVA CAVERNS NEAR HILO ($\frac{1}{3}$).

feldspars of a considerable relative length, often from $\frac{1}{4}$ to $\frac{1}{8}$ of the diameter of the stalactite, as seen in a longitudinal section. In one case they showed a marked tendency to parallelism with the axis of the stalactite, but in other cases this was less distinct. A partial concentric arrangement as seen in a transverse section was also noted. The feldspars often have black longitudinal inclusions probably of magnetite, and their cross sections, square or rectangular in outline, then have a large black center of the same form. A rather deeply colored greenish yellow augite, somewhat pleochroic, is packed in among the feldspars, and occasionally shows sharp crystalline outlines. There are also numerous grains and octahedrons of magnetite, and throughout a multitude of beautiful dendritic forms branching at angles of 90° or of 60°. This is one of the most marked characters of the sections. The areas, where these iron dendrites are crowded together, are less distinctly individualized, but no glass was noted. Chrysolite is also absent. Figures 9, *a* and *b* will convey some idea of the appearance of the longitudinal and transverse sections, though the relative amount of feldspar and augite is rather too small. The fact that the structure is throughout coarsely crystalline with the normal constituents of the basalt—except the chrysolite—is an important point.

9.

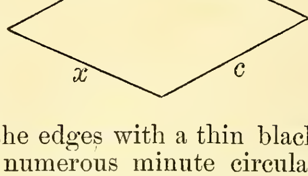
a. *b.*



Sections of lava-stalactites (×3), *a* longitudinal; *b* transverse.

The occasional cavities or open spaces in the solid parts of the stalactite are often beautifully lined with large rhombic tables of feldspar, perfectly clear, and so excessively thin as to suggest scales of mica; also dark needles of augite, often curved and wire-like, and octahedrons of magnetite. (See 8, *f*.) The feldspar plates have mostly the form of a symmetrical lozenge (fig. 10), with angles of 128° and 52°; one side is shown by the cleavage to be bounded by the basal plane, the other by the dome *x* ($\bar{1}01$). The extinction makes an angle of −7° to −9° with the basal edge which conforms to that of andesine, that is a plagioclase somewhat more acidic than that determined in the rock mass. These feldspar plates are often marked on the edges with a thin black scale, presumably magnetite, with numerous minute circular open spaces containing many black points as if the whole

10.



were formed by the drying of little bubbles. The augite crystals are often rough and black with magnetite.

Where there are vesicular cavities, often filling the whole interior of the tube, these are lined with a comparatively smooth, shining web of feldspar plates and clusters of brown augite crystals, or of augite needles alone, woven together like basket work. The dull surfaces of magnetite octahedrons are scattered abundantly among the augite and feldspar. The large quantity of magnetite is shown by the fact that the magnet picks up many of the fragments of the stalactites, even when quite large. The specific gravity of fragments of the solid portion of a stalactite was found to be 2·98.

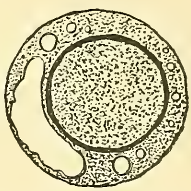
The explanation of the process by which these unique volcanic icicles have been formed is not easy to give. It is clear that further study, on the spot, of their occurrence and the circumstances of their growth is called for. It seems at first most easy to think of them as made by the rather rapid dripping of the semi-viscid lava from the roof. The evidence at hand, however, shows pretty conclusively that they could not have been the result of simple direct fusion. The fact that they hang down, from the solid crust, while the stalagmites formed by the dripping from above rise from the solid floor beneath, seems to prove that they were formed after the molten lava had passed by and the temperature had fallen below the point of fusion. If made directly from molten material, they could hardly be so perfectly crystalline throughout as they have been shown to be; we should expect to find them more like the glassy spatterings from the blow-holes of Kilauea mentioned on a later page. Moreover, the sorting out of the material is further evidence on the same side: the crystalline shell of hematite and magnetite, with its lining of augite, and within the solid crystalline mass, or the clusters of beautiful crystals chiefly of feldspar. Still again, the question has been raised as to whether the flow of a viscid liquid like the molten lava could form drops so small as the size of the stalactites show must have been present.

The fact that the lava rods or tubes of the stalactites are of nearly uniform size throughout their length, although bunched and knotted together at frequent points as has been described, is an important one.* It separates them, as to mode of origin, from the stalactites of a limestone cavern which form in a more or less conical shape from the flow down over the exterior surface of the lime-bearing solution. It seems to require that

* A stalactite from a Kilauea cavern collected by Prof. J. D. Dana is of interest here, since it forms an exception to those that have been described. About the first formed stalactite, with its rather thick magnetite shell (fig. 11) has been formed a second, somewhat vesicular and nearly concentric with it. This stalactite has the exterior coating of gypsum crystals spoken of by Brigham.

the shell should have formed first and that these tubes should have lengthened by the material carried down within them, finally resulting in their becoming solid to a greater or less extent. This is confirmed by the fact that the parts seemingly most solid often prove to have at the center minute crystal-lined cavities. The lengthening by the addition of material at the point of attachment above, the only other method that can be suggested, is difficult to conceive of.

11.



Transverse section of lava stalactite from Kilauea (×2) showing first formed stalactite within.

As the facts at hand are inconsistent with the theory of a direct formation from the melted condition, we are forced to speculate as to the power of the highly heated water vapor known to be present in large quantities, to form them from the roof by a sort of process of aqueo-fusion. This is a subject about which we know too little at present to make speculation very profitable, and the author prefers to drop the discussion here, in the hope that further observations may throw important light upon the matter. The experiments of Fouqué and Lévy in regard to the formation of basalt, with their important results, pursued the method of simple igneous fusion, and though Delesse and Daubrée have discussed the rôle of water in the formation of basalt and basaltic minerals, their investigations hardly seem to apply very closely to the present case.*

The fact that these stalactites occur also in the caverns of Kilauea has already been mentioned. Brigham describes them at some length, and although it is hardly possible to accept all his statements literally, especially as to rate and conditions of growth, his remarks are quoted here at length (l. c., pp. 462, 463):

"A formation which always excites the curiosity of visitors to Kilauea is found in many of the caves in the floor of the crater which have been undisturbed for several years. At first glance the tubes which hang from the roof and the curiously formed droppings beneath these, seem to be of igneous origin. An examination *in situ* shows that this was not the case. The roof of these caves is about two feet thick and generally unbroken; the stalactites do not occur under cracks and indeed there is often no fresh lava over the surface. The formative process may be clearly seen as the tubes form from day to day; and I have caught the steel-gray deposit in the drops on the end of the tubes upon my finger and watched its solidification. Usually the tubes are straight cylinders from one to three-eighths of an inch in

* Meunier has described the formation of chrysolite and of chondrules of enstatite, resembling those of meteorites, by the action of steam at ordinary pressures, with silicon chloride upon the red hot metal, C. R., xciii, 737, 1881.

diameter and sometimes more than two feet long. The bore is almost never continuous, and while externally they are smooth, within a mass of stony cells of considerable size is presented. As long as these tubes grow downward in the quiet upper region of the cave they hang perpendicularly, but when they reach farther down the currents of air and steam blow the deposits to one side and the tube becomes distorted; it may even return on itself. The drip in the bottom forms much thicker and more irregular stalagmites as will be seen from the figure which represents three actual forms not occurring, however, in the same cave. Specimens have been found which exceed eight inches in diameter and these are usually low and flat topped. The more slender ones sometimes rise to a height of two feet; and so rapidly is the silica deposited that they seldom increase in diameter but are true acrogens, none of the suspended silica running down the sides. In one cave the growth of the stalactites was at about the rate of an inch a week but owing to the varying amount of water or steam the production is quite irregular. They are often coated with beautiful white crystals of gypsum, sometimes tipped with needle-like transparent crystals of the same mineral when the cave is high. The natives collect them with the upper open joint of a long bambu."

The following analysis of the solid stalactite, by John C. Jackson, is given by Brigham:

	SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O
G. = 2·9	51·9	13·4	15·5	0·8	9·6	4·8	3·0	1·1=100·1

3. *Lavas of Kilauea.*

The specimens in hand from the volcano of Kilauea, which have been examined microscopically, include four specimens (12, 16, 17, 18) of the recent lava from the bottom of the crater, six specimens of the older lavas, two (13, 15) from Waldron's ledge on the northeast side and four (14, 19, 20, 26) from the wall west of Halemaumau; finally a number (1–11) from the ejected masses on the borders of the crater, especially on the west side. There are also a number of glassy and scoriaceous kinds.

1. *The recent lavas.*—The specimens of the recent lavas were taken from the stony part of the layer below the inch or more of glassy crust. They are dark colored, vesicular basalts, containing chrysolite but not in very large amount. The irregular grains of chrysolite are often aggregated together with augite crystals and to a limited extent with the lath-shaped feldspars, these constituents obviously representing those which first separated from the magma. The mass of the solid portion of the rock is of uniform character, consisting of augite and feldspar with the interstices between them black with the crowded grains or plates of magnetic and titanic iron;

about the borders of the vesicles the iron is especially dense. It is very interesting to note that these specimens are the only ones among those from Kilauea which show distinctly the stellate feather-like forms of the augite and feldspar so characteristic of many of the Mauna Loa lavas (as shown in fig. 1, *d*, p. 443). The augite forms here are usually smaller, and less varied, but there is the same grouping in parallel bundles diverging off at the ends into dendritic forms. The association between the augite and feldspar is also very close, as if the crystallization of the two had been almost simultaneous. Thus the feldspar not only forms in some cases the outer extremities of the feather but sometimes also is a central rib flanked on both sides by the augite.

Occasionally the chrysolite appears in the long slender forms noted as common among the Mauna Loa lavas. One of these is shown in figure 4, *k*, which also exhibits the peculiar feature of many of these rocks—often noted in other regions*—the grouping of the titanic iron in parallel position about the chrysolite, normal to the vertical axis. An arrangement of the elongated forms of the titanic iron in parallel position over small areas is sometimes noted where there is no evident relation to the other constituents. Usually, however, the chrysolite is the controlling influence and the individual often bristles with these little iron rods about its whole outline as seen in the section. Although these specimens were taken from so near the glassy crust there is little or no glass shown in the thin section. A specimen from the bottom of the Little Beggar, the lowest part of Kilauea, shows very considerable alteration, the surface being covered and the vesicles filled with crystals of gypsum; the mass is rendered red and nearly opaque by the oxidation of the iron.

A specimen of partially devitrified glass shows the presence of spherulites, like those mentioned in similar specimens from Mauna Loa, increasing in number where the devitrification is most complete. Crystals of chrysolite and microlites of feldspar are also present in large numbers. Some curious specimens from the spatterings about a blow-hole exhibit a vesicular glass with crystals of chrysolite and aggregates of augite and feldspar. The chrysolite encloses large amounts of glass, often in curiously arranged symmetrical bands. One of the crystals is represented in fig. 4, *l*.

2. *The older lavas.*—Of the ancient Kilauea lavas, one specimen from Waldron's Ledge (13) is remarkable for its highly chrysolitic character, as its unusual density (G.=3·18) well shows. It is a grayish compact rock thickly sprinkled with greenish yellow chrysolite grains. Under the microscope the chrysolite is seen to be in large individuals, usually irregular

* Cf. Rosenbusch, Mass. Gesteine, p. 722, 1887.

grains, though also in indistinct crystals and occasional rod-like forms. These often contain abundant glass inclusions. The grains are often packed about with a poorly defined border of augite and it is in this zone particularly that the little rods of titanic iron are regularly orientated, standing out from the chrysolite in the manner already described. Besides this, it is a granular mixture of augite and plagioclase not showing any glass. The other specimen (15), from the foot of Waldron's Ledge, is a light-gray cellular rock, highly crystalline, the minute cavities lined by plates of feldspar and tables of titanic iron. It is much like some of the specimens described from Mauna Loa (p. 448), and with them is characterized by the same milk-white spherical mineral in the cavities, provisionally referred to phacolite.

The lavas from the west wall of Kilauea west of Halemaumau are all closely similar in character among themselves; they are dark-gray in color, vesicular, and contain a fair amount of chrysolite. The structure is throughout crystalline, rather coarsely granular, and the chrysolite is marked by its usual bristling border of titanic iron. One or two of these show something of the radiating augite forms.

3. *Ejected masses on the border of Kilauea.*—The specimens from the borders of Kilauea are supposed to have been ejected at an explosive eruption about a century since. The larger part of the masses are described by Professor J. D. Dana as being of a fine-grained, gray, slightly vesicular lava. Other specimens* are reddish or chocolate-colored, coarsely granular and highly crystalline. In the latter, the chrysolite is present in very large amount and has suffered from alteration, probably by the action of heated water vapors, so that the fractured surface is either dull-red and opaque or else slightly iridescent. The feldspar crystals are clear and glassy, and where there are cavities they often project in distinct transparent plates from the walls. The crystals have an angle of extinction of $-14°$ with the b/c edge, and hence conform to labradorite, like those of similar occurrence among the Mauna Loa specimens. Under the microscope the chrysolite is seen to be surrounded with a deep-red border, and the iron oxidation has penetrated into the mass of the crystal sometimes along broad fracture-lines, and more generally in a network of fine wavy lines giving it a peculiar feathery aspect. Not infrequently the oxidation has gone so far that the chrysolite is perfectly opaque and by reflected light is bright brick-red.

Specimens 6, 7, 9† are examples of the light-gray lavas but of peculiar characters. No. 9 is a light-gray rock conspicuous among all those under examination for its beautiful crystalline

* Here belong Nos. 3, 8 with G.=3·18, 10 with G.=3·15.
† For 6, G.=3·15; for 9, G.=3·10.

structure. It is very light and porous and in each little cavity there are groups of crystals of feldspar in the usual rhombic plates, with minute slender needles of a pale yellow augite iridescent on the surface, and thick tables of titanic iron showing large rhombohedral planes ($cr=56°$). These last have bright faces, often cavernous, and with a bluish steel-like tarnish. The augites are flattened parallel to the orthopinacoid, as shown by the parallel extinction and the oblique optic axis. Chrysolite is present in the mass of the rock but hardly appears in the sections.

No. 7 is a similar rock, but more compact except for parallel lines of cavities partially filled with black glass. No. 6 shows the same structure in part, but the mass of the specimen has a base of a very black glass with crystals of feldspar, augite, and broad plates of titanic iron running through it. In the large cavities the crystals of these minerals project out, though the surface of the cavity is lined with a glassy web. One of the sections under examination is cut across the junction and shows both the uniform fine-grained crystalline portion and the glassy part with its large enclosed crystals. A curious feature of the glass is the presence of a swarm of minute apatite needles running through it in every direction. These do not extend into the crystallized parts. Apatite usually appears as one of the very earliest secretions from the magma, and why it should be thus localized in these patches of glass while absent from the crystalline parts of the rock, it is difficult to explain. In general, apatite has been found to be a rare constituent of the Hawaiian lavas.

Two others of the specimens (4, 7) are gray compact rocks extremely fine-grained except for occasional chrysolite grains. No. 1 is peculiar in having small uniformly-distributed patches of a dark colored slightly opalescent glass, which is deep brown and nearly opaque in the thin section except as it is penetrated by apatite needles which here also are confined to it.

With the specimen from Kilauea proper belong those collected by Mr. Baker from Nanawale and Makaopuhi, the former chiefly remarkable for their chrysolitic character, the latter sparingly so. Several of the latter specimens are remarkable for that crystalline structure that has been several times remarked upon, and one of them contains the white zeolitic mineral.

Former observers have dwelt at length upon the features of the glassy forms of the lava and the presence of glass in the partly crystalline varieties. This is probably to be explained by the fact that the specimens which first present themselves to the collector on his visit to the interior of Kilauea are the superficial more or less scoriaceous or glassy forms which constitute merely a crust and do not represent the true character of the average lavas. The writer has found glass only a comparatively insignificant element in the normal rocks and *often wholly absent*, even from those of recent eruption.

4. *Relation between the rocks of the Summit crater of Mauna Loa and those of Kilauea.*

In general, the lavas of the summit crater and of Kilauea, so far as examined by the writer, are strikingly similar in character, all being augitic basalts, varying chiefly as regards the amount of chrysolite present. The clinkstone-like rock of Mokuaweoweo has not been observed at Kilauea; but the feathery grouping of augite and feldspar which characterizes it belongs to the recent Kilauea lavas as well. The darker colored vesicular basalts, which are highly chrysolitic and hence of high specific gravity, are alike from both craters. Writers on volcanoes have attempted to draw conclusions in regard to the distribution of the heavier and lighter lavas according to altitude, limiting the former to the lower levels. This is a natural inference on *a priori* grounds, but it does not rest on observation as the facts already stated sufficiently show. It is a striking fact in connection with the mechanics of volcanic eruptions that lavas of the heaviest character (3·15 and 3·20) should have been raised to an altitude of nearly 14,000 feet above sea-level.

The chemical composition* of the Kilauea lavas is well shown by the series of analyses (14 in number,) given by Silvestri, and also those—chiefly of glassy forms—given by Cohen.

Of these analyses, three by Silvestri, (A, B, C), and two by Cohen (D, E), are quoted here, viz:—

A. Recent vitreous basalt, fresh and unaltered.
B. Older basalt, also fresh;
C. Older basalt, much altered;
D. Compact basalt-obsidian;
E. Pele's Hair:

	A.	B.	C.	D.	E.
	G.=2·97	G.=3·01	G.=2·80	G.=2·75	G.=2·66
SiO_2	49·20	48·82	48·60	53·81	50·82
TiO_2	1·72	1·16	----	2·01	*undet.*
Al_2O_3	14·90	15·22	25·45	13·48	9·14
Fe_2O_3	4·51	5·72	17·55	3·02	7·33
FeO	12·75	9·65	1·20	7·39	7·03
MnO	0·28	0·67	*tr.*	*tr.*	0·38
CaO	9·20	10·40	2·20	10·34	11·63
MgO	3·90	4·55	0·98	6·46	7·22
Na_2O	1·96	2·10	} 1·38	3·23	1·02
K_2O	0·95	0·90		0·64	3·06
P_2O_5	0·42	*tr.*	*tr.*	----	----
H_2O	0·10	----	1·87	0·57	1·74
	99·89	99·19	99·23	100·95	99·37

* The remark made by Professor J. D. Dana must be repeated here that the early analyses published in the Geological Report of the U. S. Exploring Expedition, having been made for him by an inexperienced analyst, are entirely unreliable and should not be quoted.

Of other specimens from the island of Hawaii there are two specimens from Punaluu, one from the outside of a bomb and the other from an *a-a* flow. The interesting point about these is the strongly accentuated flow structure as shown in the feldspar microlites as they find their way around the occasional large crystals of chrysolite and augite—the fluidal character is as a rule entirely absent from the specimens before described, and in general is not so common in basic as in acidic lavas.

Specimens from western and northwestern Hawaii, Kawaihae and Mahukono are again more or less vesicular chrysolitic basalts. Of these rocks that from Kawaihae is the most noteworthy because of the large clusters of glassy feldspar crystals which give it a striking porphyritic aspect.

5. *Lavas of Maui.*

From the island of Maui about a dozen specimens have been subjected to microscopical examination, of which three were collected by Rev. S. E. Bishop. The most recent lavas of Haleakala are represented by three specimens, all somewhat scoriaceous. One of these is from the summit at an altitude of nearly 10,000 feet, the others from the bottom floor. They are all very highly chrysolitic, and of high specific gravity (G.=3·10). The similarity of the hand specimens is so great that they might almost have been taken from the same block. They are dark colored, very vesicular, and highly porphyritic with both chrysolite and augite. The large and well-formed crystals of augite often have a narrow external zone of deeper color (violet-brown) and are distinctly pleochroic. They are usually mottled with inclusions of glass or iron. The chrysolite shows but few inclusions. The ground mass is thickly sprinkled with iron grains making it nearly opaque; small triclinic feldspar needles and a secondary augite in minute form are seen. In these specimens the feldspar must make up but a very inconsiderable proportion of the whole. These recent chrysolitic basalts in Haleakala are much more porphyritic and otherwise quite different from the basalts of Mauna Loa and Kilauea.

More different still are several specimens of the older lavas. One of these (29) is from within the crater. It is a very fine-grained, dark bluish gray rock of uniform texture, perfectly fresh and showing but few minute cavities. It is a feldspathic rock presenting under the microscope a rather confused aggregation of feldspar and augite, the latter in minute grains, the whole thickly sprinkled with grains of iron. Chrysolite is occasionally noted in peculiar elongated forms, generally forked at both ends, and having a border of titanic iron grains as before noted (fig. 4, *m*). The most marked peculiarity is the presence of minute scales of a dark brown mineral, probably biotite, which, however, is only present very sparingly.

Another interesting specimen (30) which was obtained from the top of Haleakala is a thin, almost schistose rock, light gray in color and presenting the same sort of an aggregation of feldspar and augite under the microscope. Chrysolite, however, is a prominent constituent especially in the hand specimen. There are also large elongated but usually ill-defined aggregates of magnetite grains marking the presence of original large individuals, biotite or hornblende, which have been re-absorbed into the magma. Occasional remnants of the original mineral are noted but in very small amount. Another curious feature of this rock is the presence of a zone of augite about the grains of chrysolite. One case of this is illustrated by fig. 4, *n*. The chrysolite crystal though separated into different parts has throughout the same optical orientation as indicated by the shading, while that of the augite varies from grain to grain. The mantle of magnetite grains about the upper end of the chrysolite seems to represent the remains of the augite which has disappeared. This re-absorption of augite is not commonly observed, but this case, and still more another one where of a single augite crystal alone a large part has disappeared in this way, places the matter above doubt. This zonal arrangement of the augite about the chrysolite has been noted by other observers in a number of cases.*

The structure and composition of both these last mentioned rocks suggest that they should perhaps be classed among the augite-andesites rather than the basalts. To decide this point we have the silica determinations, for which I am indebted to Mr. Henry L. Wheeler of the Sheffield Scientific School. He found in the first (No. 29) 48·42 p. c. SiO_2, and in the other 50·44 p. c., which conform to that of normal basalt.

The remaining specimen from the top of Haleakala is a dark gray, almost black, rock of the finest grain, very compact and breaking with a conchoidal fracture. It is characterized by the large amount of iron in minute grains very thickly distributed, so as to make the section nearly opaque unless extremely thin. The feldspar microlites are the most prominent constituent, and these show a rather distinct fluidal arrangement. The two specimens from Paia on Maui are much like those from Haleakala just mentioned, especially No. 29, and like it they bear the same resemblance to andesite. A curious point about them, is their readiness to alter, the exposed surfaces passing into a soft earthy mass of a light brown color.

The specimens from Western Maui, collected by Rev. S. E. Bishop, are rocks of peculiar and interesting character. Mr.

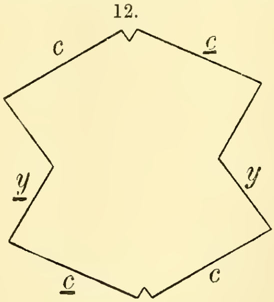
* See F. D. Adams, Amer. Naturalist, 1087, 1885, G. H. Williams, this Journal, xxxi, 35, 1886.

Bishop says that they are "crusts and soft interiors of the same formation (apparently flowing lava) found on Launiupoko hill, 3 miles S. of Lahaina. A precisely similar formation occupies the front of Mt. Ball, 2½ miles above Lahaina. The crusts are often rolled under the gray, soft material. Many crusts of grotesque form lie about, from which the softer part has been washed away. Many portions of the gray, soft mass are of great thickness. Much building stone has been hewn from it. It presents no appearances of being the result of any decay, being compact and of uniform texture, except the hard crusts, many of which are crumpled up as if in flowing, like pahoehoe."

One of the specimens (28) is a whitish gray compact rock, whose surface is worn out into a series of deep holes between projecting ridges nearly one inch in height. The texture, though appearing closely compact at first sight, is seen by the glass to be minutely porous, and the surface is speckled with very small rusty spots. Under the microscope it is seen to consist almost exclusively of plagioclase, here and there porphyritically developed; there are also the remnants of a bright green pleochroic mineral present in traces only and obviously the original mineral whose disappearance has left the rusty spots; it seems to be hornblende. A little biotite is also present. Iron is scattered through the mass rather sparingly in minute grains; no augite was noted. Another specimen shows the transition from the firm rock to a soft chalky condition powdering under the fingers. The section is very like the other just described, though the feldspar is much clouded and an occasional red crystal of chrysolite is noted.

A third specimen (32) is a flake from a large bowlder (8×5×4 feet) found one mile S. W. of the summit of Mt. Ball. Mr. Bishop remarks that, in the eroded cliff, bowlders occur cemented by mud, being ejectamenta from Mt. Ball. The specimen is finely schistose and so soft and friable as to separate easily into thin silvery scales, and by handling it is soon reduced to a fine powder. Microscopic examination shows it to be very nearly the same in material with the others, but having a distinctly fragmental appearance. There is more chrysolite present in small broken fragments of crystals; there is also a little brown biotite in scales. The mass is made up of penetration twins of plagioclase according to the Carlsbad law mostly arranged parallel to

12.



the brachypinacoid and hence showing no other kind of twinning. The form of one of these groups is shown in fig. 12. The cleavage marks the position of the basal plane and the angle of the section (about 80°) shows that it is bounded by the planes *c* (001) and *y* ($\bar{2}$01). The extinction makes an angle of a few degrees with the basal edge, varying + or − with a slight change in the direction of the section. This optical character and the further fact that the acute bisectrix is nearly normal to the brachypinacoid would make the feldspar an oligoclase. Occasional feldspar individuals are cut more nearly parallel to the basal plane and have the usual elongated form, and show the twinning like the other specimen, but as a rule they all lie nearly parallel to the brachypinacoid. The amount of silica present, as determined by Mr. Wheeler, is 61·63 p. c., which corresponds to the microscopic determination. This remarkable feldspathic andesite is a totally different rock from any other which has been as yet obtained from the islands, and the writer hopes to be in the position later to give a more minute account of its occurrence and composition.

5. *Lavas of Oahu.*

Of the specimens in hand from the island of Oahu, six (33, 36, 40, 41, 44, 45) are from the Kaliuwaa valley, near Punaluu on the north side of the island; four (27, 38, 39, 43) are from the Waialua plain; one (42) from a point just north of Kahuku Bluff; another (37) from a gulch beyond Monolua, 4 miles west of Honolulu; and, finally, there are a number of specimens of the tufa from the Punchbowl near Honolulu. Among these specimens, two are forms of highly chrysolitic basalts; these are the specimens from Kahuku Bluff and one of those from near Waialua. In the first of these (42) the chrysolite makes up probably two-thirds of the mass of the rock; it is present in distinct isolated crystals, having the characteristic form, each crystal having a rather broad, rusty border, though the interior is for the most part clear and unchanged. The chrysolite incloses grains of iron, but very little glass. The ground mass is a fine-grained mixture of augite and plagioclase with considerable iron, the augite being the more prominent constituent.

In the specimen from Waialua (43) the chrysolite is also prominent; its specific gravity is 3·06. With the chrysolite, the augite and feldspar also occur in large individuals besides being present in the base. The feldspar here contains dark-colored glassy inclusions in large numbers arranged parallel to the vertical axis. The base is a confused mixture of dirty brown augite and feldspar, with iron in considerable amount. The specimen (33) from a dike in the upper part of the Kaliuwaa Valley is a very compact, nearly black basalt, unusual in showing occasional grains of pyrite. The feldspar is fresh, but the augite is more or less altered and its place taken by a serpentinous substance, while occasional cavities are filled with a light colored radiating zeolitic mineral showing feeble double refraction. Besides the usual magnetic iron, which is scattered through in grains or octahedral crystals, there are also curious aggregations of iron ore in very slender rod-like forms, sometimes crossing each other at right angles, but usually matted together with a confusedly reticulated structure, sometimes forming nearly opaque spherical aggregates. Specific gravity 2·90.

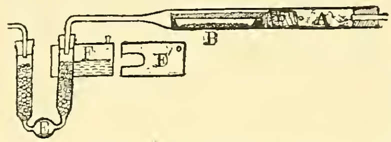
Chrysolite is present very sparingly in the remaining rocks, the hand specimen showing only here and there an isolated grain, and sometimes close search is needed to detect it. They are all light bluish gray basalts, with specific gravity ranging from 2·86 to 2·91. No very close study has been made of these specimens, but with a number of them their aspect, their highly felspathic character, and the microscopic structure, made it seem as if they might more properly belong to the andesites; a silica determination of one of them (36, G.=2·86) by Mr. Wheeler gave, however, only 50·55 p. c. SiO_2. Several of these rocks show more or less alteration, and in one of them (36) the occasional crystals of chrysolite have entirely passed into serpentine. For the most part they are highly crystalline, but one of the group (45, G.=2·88) is exceptional in showing numerous patches of a dark brown glass; this specimen is the most highly chrysolitic of the number, it being present in minute grains among the feldspar and augite, each grain having its orientated fringe of titanic iron. No nepheline basalt was detected among the specimens in hand.

Résumé.—The chief points brought out and discussed in the preceding pages are, the characters of the clinkstone-like basalt with its novel forms of feather-augite, and also of the heavy chrysolitic basalt, each from the summit crater; the general similarity between the lavas of Mauna Loa and of Kilauea and the crystalline character of both, even of the recent forms; the structure and origin of the stalactites in the caverns of the Mauna Loa lava stream, like those in the caverns of Kilauea, offering new problems in the formation of igneous rocks. It is shown further that the lavas in hand from Maui—with the exception of the andesite from the western part of the island—and also those from Oahu, belong to the basaltic type, though often approaching andesite in appearance; furthermore, that the lavas of Hawaii show extensive alteration but only so far as the iron oxidation is concerned, while some of those of Maui and Oahu, especially the latter, are much more profoundly changed.

Art. XLVII.—*The Determination of Water and Carbonic Acid in Natural and Artificial Salts;* by Thomas M. Chatard.

The following method and apparatus having been used for the analysis of a large number of natural and artificial alkaline carbonates, have been found to give results which are satisfactory not only as to accuracy but also as to ease and rapidity.

A is a combustion tube drawn out and bent at a right angle, B is a platinum boat which contains the salt to be examined and rests upon the thin sheet of asbestos paper C used to prevent adhesion between the platinum and the glass when heated. D is a roll of asbestos paper wrapped with thin platinum wire, which fits loosely in the tube and prevents back-currents of air during the heating.



The bent end of the combustion tube enters one limb of the U-tube E which is my own form and differs, as shown by the drawing, from those at present on the market, by having an especially large bulb at the bottom. The two limbs of the tube are filled with glass beads wet with strong sulphuric acid. Sufficient acid should be put in to fill the narrow tubes up to the bends, compelling the air-current to bubble through.

In using the apparatus the combustion tube is thoroughly heated and then allowed to cool, a current of perfectly dried air being continually passed through it and the part of the tube where the boat is to be placed being protected by a semi-cylindrical trough of sheet iron lined with asbestos paper. The U-tube, having been weighed, is now attached to the combustion tube as shown and the air current is regulated. The platinum boat, previously heated and then cooled in a desiccator, is weighed and about one gram of the salt put into it and spread evenly along the bottom; the salt should be very finely pulverized to prevent decrepitation. The boat with its contents should, after weighing, be at once inserted into the tube and the asbestos plug D which should have been highly heated and still be hot, shoved in close behind the boat.

The tube is now heated gradually beginning at the plug. As the water in such salts is driven out, in great part, at a low temperature the heating must be cautiously done and the air current must not be too slow else water may condense in the cold part of the tube back of the plug. When heating salts containing sodium bicarbonate, the regulation of the air current is the more difficult since the acid CO_2 of the bicarbonate is set free simultaneously with the water, but upon this regulation and the gradual heating depends the success of the operation.

The water bath F, of which F′ is a top view, is now put into position, as shown, so that one limb of the U-tube fits into the curved recess in the side of the bath. A small alcohol lamp keeps the bath hot so that the water driven out of the salt may not condense in the upper part of the limb. By the use of this bath the time required for the operation is much shortened.

As soon as that part of the tube, which contains the boat, appears free from condensed water, it should be highly heated until all the moisture has disappeared from the drawn out portion. This will generally take from twenty minutes to half an hour; when completed, the water bath is removed and the apparatus allowed to cool, the air current being still kept up. As soon as the tube is cool, the U-tube is disconnected and the boat with its contents removed and placed in a small well stoppered glass tube which has been weighed.

The increase of weight of the U-tube gives the amount of water in the sample, while the weight of the small tube, containing the boat and the calcined salt, if subtracted from the sum of the weights of the tube, the boat and the salt taken, shows a loss which is the water plus the acid CO_2 of the bicarbonate. The calcined salt which should be sintered together but not fused can then be used either for a determination of the residual CO_2 or, as is preferred, dissolved and the alkali determined by standard sulphuric acid, methyl orange being used as the indicator, the same portion being then used for the Cl determination if chlorides are present.

Many attempts were made to collect and weigh the CO_2 driven off by heat, but it was found impracticable to do so without, at the same time, sacrificing the water determination. No matter how carefully the heat and air current are regulated, the CO_2 comes off too rapidly for proper absorption in a potash bulb and if the air current is too slow, water condenses back of the plug and this determination is too low.

When no attempt is made to absorb the CO_2, the results are very satisfactory. A specimen of Urao (Na_2CO_3, $NaHCO_3$ + $2H_2O$) from Owens Lake, Cal., gave the following results:

	Salt taken.	Loss of salt.	H_2O.	Difference = CO_2.
	1·0040	29·51	20·12	9·39
	1·0490	29·58	20·09	9·49
	1·1583	29·49	20·00	9·49
Average	1·0638	29·53	20·07	9·46

Three closely agreeing determinations of total CO_2 gave an average of 38·13 per cent; two determinations of the alkali gave 40·28 per cent Na_2O equivalent to 28·58 per cent CO_2 required to make Na_2CO_3; 38·13 − 28·58 = 9·55 per cent CO_2 as the acid CO_2 of the bicarbonate present. Hence 0·09 per cent of this CO_2 was not driven off.

In another sample of Urao from same locality:

Salt taken.	Loss of salt.	H_2O.	Diff. = CO_2.	CO_2 in Res.	Sum CO_2.
1·1801	29·27	19·80	9·47	28·69	38·16
1·2297	29·35	19·83	9·52	28·64	38·16
1·2066	29·39	19·85	9·54	28·49	38·03
1·0880	29·26	19·80	9·46	28·67	38·13
1·1761	29·32	19·82	9·50	28·62	38·12

Two determinations total CO_2 gave 38·17 per cent and 38·22 per cent, average 38·19 per cent CO_2; two determinations of alkali gave 40·19 and 40·22 average 40·20 per cent Na_2O equivalent to 28·53 per cent CO_2. Hence as 28·62 per cent CO_2 was found in the residue we have 0·09 per cent acid CO_2 not driven off.

In a sample of Trommsdorff's C. P. sodium bicarbonate then was found:

Salt taken.	Loss of salt.	H_2O.	Diff. = CO_2.	CO_2 in Res.	Sum CO_2.
1·4265	36·68	10·91	25·77		
1·5995	36·81	10·90	25·91		
1·3200	36·71	10·91	25·80	26·25	52·05
1·3723	36·73	10·98	25·75	26·37	52·12
1·4296	36·73	10·92	25·81	26·31	52·09

Two determinations of total CO_2 gave average of 51·98 per cent; two determinations of alkali gave average of 36·88 per cent Na_2O equivalent to 26·17 per cent CO_2. Subtracting 26·17 from 26·31, average amount of CO_2 in residue, we have 0·14 per cent CO_2 not expelled by heating to sintering.

Comparing these amounts of excess of CO_2, retained by the residues of the ignition, with the weight of salt taken we have the following relations.

Sample.	No. of determinations.	Average wt. taken.	Average excess.	Relation of excess to weight.
Urao No. 1	3	1·0638	0·09	0·084
Urao No. 2	4	1·1761	0·09	0·077
Bicarbonate	4	1·4296	0·14	0·091
			Average	0·084

Hence we may say that if sodium bicarbonate, or a salt containing a large proportion of it, is heated till it sinters without fusing and is kept at that temperature for one hour, it still retains CO_2 in excess of the amount required to form monocarbonate with the alkali present; and that, for quantities of from 1 to 1·5 grams, this excess may be considered as one-tenth of one per cent of the salt taken.

For an analysis of sodium bicarbonate or baking soda, it is therefore sufficient to determine the loss by ignition, the H_2O, and the alkali in the ignited residue to obtain the total amount of CO_2 in the sample, adding to this amount an amount of CO_3 equal to 0·10 per cent of the weight of the samples taken. The method is much more rapid, far easier and quite as accurate as the distillation process, and may prove of value for technical purposes.

ART. XLVIII.—*Preliminary Note on the Absorption Spectra of Mixed Liquids;* by ARTHUR E. BOSTWICK.

IN 1865 Prof. Melde, in experiments on the absorption spectra of mixed liquids,* proved, as he thought, that they were not formed by simple addition of the component spectra, but that the bands shifted, a large band of one liquid seeming, in general, to attract a small band of the other, and more strongly as the proportion of the former in the mixture was increased. Dr. Shuster, in discussing these observations,† shows that where a small band falls on the slope of a large one the effect of optical addition is to shift the apparent maximum of absorption, and concludes that "Prof. Melde . . . . would have observed exactly the same phenomena if he had put his two liquids in front of each other instead of mixing them together." The experiments herein described were undertaken to find out whether or not the effect observed by Melde was due to the cause alleged by Dr. Shuster; they appear to prove that while a small part was so due, the bands were shifted principally by a true action of one liquid on the other.

Melde's method consisted simply in observing the spectra of the liquids separately, and then that of their mixture. He made no attempt to observe that of one liquid in front of the other. The method of the writer was to observe the spectrum obtained by passing the light through both vessels, and then that obtained by mixing the liquids and pouring them again into the same vessels, thus securing exactly the same conditions except that of mixture. Common test tubes were first used, but an irregularity in results led to the discovery that the spectrum differed according as one liquid or the other was next the slit, each tube acting as a cylindrical lens. Cells

* Pogg. Ann., cxxiv and cxxvi.

† British Association Report on Spectroscopy for 1882.

with plane parallel glass faces one-quarter inch apart were therefore substituted and the spectrum found to be the same whichever liquid was next the slit. The position of the bands was measured by means of a tube bearing an illuminated slit the image of which moved over that of the spectrum as the tube was revolved around the same axis as the telescope and collimator. The amount of revolution was measured on a scale bearing a vernier reading directly to five minutes of arc, and by estimation to one minute. The cells being both in front of the spectroscope slit, a liquid in each, the image of the micrometer slit was fixed in the middle of the band whose deviation was to be measured. The liquids were then turned from the cells into a test tube, mixed there, and the mixture turned half into one cell and half into the other. The image of the slit was then seen to be no longer in the middle of the band, and to bring it there again the tube had to be revolved through from 1′ to 17′, according to the ratio of the liquids. But to avoid the effect of any unconscious bias on the part of the observer, the first band was observed with unmixed liquids, then the second, and then the two in the same order with mixed liquids, so that the observer did not know whether there were any movement, or in which direction it was, till he had fixed the micrometer and taken the reading.

The principal liquids used were those employed by Melde in his first experiments; namely, solutions in water of carmine with ammonia, bichromate of potassium, and ammoniacal sulphate of copper. The carmine and bichromate were tried first, and the former being kept at the same strength, the latter was diluted successively to $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, etc., of its first strength, which was that which just enabled the carmine bands to be seen. Dilution seemed to have no effect on the displacement of the band till the bichromate was very weak, when it fell off almost entirely. The mean of sixteen measurements, at various strengths of the bichromate, was 10′·9 displacement toward the blue end of the spectrum (absorbed by the bichromate) for the least refrangible carmine band, and that of ten measurements for the most refrangible was 8′·8. The measurements, which were all in the same direction, ranged in the first case from 19′ to 6′ and in the second from 14′ to 5′, a result due probably both to the difficulty of fixing the slit exactly in the middle of the band and to the variation in strength. An arc of 1′ in this place corresponds to a difference of wave-length of about ·4 millionths of a millimeter. The width of the bands was about 40′ so that the average displacement was about one-quarter of the width, an amount plainly evident without measurement.

Carmine and ammoniacal copper sulphate were now tried in like manner, and the bands were displaced toward the red, that is, toward the part absorbed by the sulphate. The position of the bands with the carmine solution alone was measured frequently. The mean of from nine to twelve observations at different strengths gave: displacement due to simple superposition, 2·2′ and ·4′; additional displacement due to mixture, 5′ and 7·5′. The displacements due to mixture varied from ·1′ to 12′ for different strengths of the sulphate, and seemed in many cases to increase as the mixed liquids were allowed to stand. In some instances a flocculent precipitate was formed. As in the case of the carmine and bichromate, the displacement did not decrease gradually as the sulphate was diluted, but at a certain stage of dilution disappeared almost entirely. In the case of the copper sulphate and carmine this occurred when the ratio of the two substances by weight was about unity.

Fuchsin and aniline blue in alcohol were next tried, but the effect of mixture was the same as that of simple addition. With fuchsin and picric acid the fuchsin band either disappeared altogether on mixture or was much weakened and blurred at the edges. With a mixture of aniline blue and picric acid, the aniline band was much widened and perhaps shifted toward the blue. These substances were all tried by Prof. Melde. In the case of the aniline substances last tried, the writer's experiments indicate that Melde's results were due to simple addition, but in the case of the others an actual and very considerable motion of the narrow band toward the wide absorption area is indicated.

The writer hopes that he may be able rigorously to investigate the laws of this displacement at some future time, determining the substances which have on each other a real effect of the kind mentioned, and the dependence of the effect on the ratio of the substances, their temperature, and the time after mixture. With regard to the sudden diminution of the displacement at a certain stage of the dilution, it is easily understood if we suppose that the influence of the molecules, in producing the effect we view as a displacement of absorption bands, is proportional to a higher inverse power of their distances than the square, and that when those of one substance largely outnumber those of the other the more numerous are arranged in clusters about each of the others. Then dilution at first may have merely the effect of removing the outer members of these clusters, whose effect on the displacement is small, but when the inmost layer of the cluster is reached the case is different, and the effect of dilution shows itself at once. Our ignorance of the state of a physical molecule in solution prevents the direct test of this hypothesis by experiment.

Art. XLIX.—*Notes on Metallic Spectra;* by C. C. Hutchins.

In the work herein described an attempt has been made to determine the wave-length of several metallic lines with something of the precision with which wave-lengths of solar lines are known and tabulated.

It has been repeatedly pointed out that wave-lengths of metallic lines from the determinations of the best observers are liable to errors of one part in 3000 or 4000; while Rowland has given us the position of a long list of solar lines correct to one part in 500,000. It is too often forgotten that Thalen used a single bisulphide of carbon prism in his researches, and that consequently, his places can in no sense be considered standards of precision for the more powerful instruments of the present time.

The spectroscope employed in the present work has a large flat grating with ruled space 5^{cm} by 8^{cm}. Upon the margin of this grating Professor Rowland has written: "Definitions exquisite." The collimator and view telescope are combined in a single lens, an excellent objective by Wray, six inches in diameter, eight and a half feet focus. The radius of curvature of the back surface of this lens equals its focal length, so that the ray reflected from this surface passes back to the slit, and any objectionable illumination of the field is avoided. All parts of the instrument are so contrived that it is operated without the necessity of the observer leaving his seat at the eyepiece. A heliostat and achromatic lens of five feet focus form an image of the sun upon the slit. Thus arranged the instrument easily performs all tests of spectroscopic excellence with which the writer is familiar. To produce the metallic spectra an eight inch spark condensed by a number of jars having about 6 sq. feet of coated surface, has been employed. The spark is produced immediately before the slit, the jaws of which open equally. The coil is operated sometimes by a dynamo, and sometimes by the current from a storage battery. A review of all the spark spectrum lines has been made with the arc, and a few lines added to those that the spark gave. A steam jet* was employed to increase the luminosity of the spark. The work has been confined to the lower portion of the spectrum, where it still appears that eye observations have advantages of the photographs.

The position of a metallic line is determined by bringing the crosswire of the micrometer upon it, letting in the sunlight, and moving the crosswire to one of the standard lines

* This Journal, Feb., 1889.

of Rowland's tables. The true wave-length of the metallic line can then be computed from a previously determined micrometer constant. As a check to the result so obtained the metallic line has been interpolated, with the micrometer, between two of the standard lines in the same field of view, and the whole process has been repeated on different days until it became assured that positions of the metallic lines were as precise as those of the standard lines themselves.

Copper Spectrum.

The subjoined table gives the results as obtained for the spectrum of copper. The first two columns contain respectively the wave-lengths and intensities as given by Thalen; the third, the wave-lengths as determined in the present work.

Copper Spectrum.

Thalen λ.		Corrected λ.	Remarks.
6379·7	2	6380·899	Surrounded by continuous spectrum. Reversed in sun.
6218·3	5	------	No line seen.
5781·3	2	5782·285	Reversed in arc. Reversed in sun.
5700·4	1	5700·442	Reversed in arc. Reversed in sun.
		5535·64	Reversed in sun. Seen only in the arc.
		5555·119	Seen only in the arc.
5292·0	2	5292·68	Reversed in sun.
5217·1	1	5218·308	Reversed in arc. Reversed in sun.
5152·6	1	5153·345	Reversed in arc. Reversed in sun.
5104·9	1	5105·663	Reversed in sun.
5011·4	4	------	No line seen.
		5016·86	Seen only in the arc.
4955·5	3	------	No line seen.
4932·5	3	4933·181	Reversed in sun.

Zinc Spectrum.

The examination of the zinc spectrum is here limited to five lines; many of the remaining lines being mere dots close to the poles of the metal, others very broad and nebulous, and in general too ill defined to admit of measurement with the apparatus employed. In strong contrast to the remaining lines these five are very bright and sharp, and may be called the representative lines of the metal within those limits.

Zinc Spectrum.

Thalen λ.		Corrected λ.	Remarks.
6362·5	1	6362·566	Reversed in sun.
		6204·708	Faint but very sharp. Reversed in sun.
5893·5	2	5894·454	
4809·7	1	4810·671	Very bright. Reversed in sun.
4721·4	1	4722·306	Very bright. Reversed in sun.

Results of comparison with Solar Spectrum.—It will be seen by inspection of the tabulated results that nine out of the eleven lines of copper are reversed in the sun, and four of the five of zinc. The conclusion reached in each of these cases was after repeated examination when the conditions were such as to show a clear space between the components of the E line. The latest available authority* gives copper among the doubtful elements in a list of those found in the sun, and on the same list zinc does not appear at all. The present investigation makes it quite probable that zinc, and almost completely demonstrates that copper exists in the solar atmosphere.

Bowdoin College, March 14, 1889.

ART. L.—*On Allotropic Forms of Silver;* by M. CAREY LEA, Philadelphia.

SILVER is capable of existing in allotropic forms possessing qualities differing greatly from those of normal silver. There are three such forms, or rather three modifications of one form, differing from each other in many respects, but all more nearly related to each other than any one of them to normal silver. One of these forms is soluble in water, passing readily to an insoluble form, and this last may, by the the simple presence of a neutral substance exercising no chemical action upon it, recover its solubility. Another form closely resembles gold in color and lustre.

Whether metallic silver shall be reduced from its compounds in its normal or in an allotropic form, depends upon the reducing agent applied, so that it cannot be said with any certainty whether it exists in its compounds in its ordinary normal form, or in an allotropic condition: the latter alternative seems at least equally probable.

These allotropic forms of silver are broadly distinguished from normal silver by color, by properties, and by chemical reactions. They not improbably represent a more active condition of silver, of which common or normal silver may be a polymerized form. Something analogous has already been observed with other metals, lead and copper.

Much having been written, especially within the last few years, on the products of the reduction of silver compounds, a brief summary of what has appeared may be desirable before proceeding further. The study of this subject has led to remarkable divergencies of opinion on the part of the

* Young's General Astronomy.

chemists engaged in it. Almost all the views advanced have been successively disproved by each subsequent publication. It follows that what has obtained a place in the text books is almost wholly incorrect.

The earliest experimental work was Faraday's, but his product has been proved to be a mixture.* The next was the well known paper of Wöhler published in 1839. It is not my purpose here to enter upon a criticism of this memoir. If this illustrious chemist succeeded in obtaining by the means employed a true citrate of silver hemioxide,—as would appear from his analyses—no chemist since his time seems to have done so. The next publication to Wöhler's was that of Von Bibra, who used Wöhler's method and, whilst affirming that he obtained a similar citrate, found an entirely different constitution for the corresponding chloride. For instead of obtaining a hemichloride Ag_2Cl, he gives, as the result of 15 concordant analyses, the constitution of his product as Ag_4Cl_3.† A citrate, to yield such a chloride, (if such a chloride exists,) by the simple action of hydrochloric acid, could scarcely have the constitution assigned to it by both Wöhler and V. Bibra.

In 1882, Pillitz published two papers.‡ He commences by disputing the probability of the existence of Ag_4O on grounds of valency; namely as implying that oxygen may be quadrivalent. Although it is very doubtful that any one has up to the present time obtained Ag_4O, the argument seems futile as are many arguments deduced from supposed laws of valency. Similar reasoning would make Ag_2Cl impossible, which substance undoubtedly exists, and it would also deny the existence of K_2Cl which stands upon such authority as that of Rose, Kirchhoff, and Bunsen.§ Pillitz carefully examined the so-called hemioxide precipitated by alkaline solutions of antimony and tin and could find no trace of Ag_4O in any of them. He did not examine Wöhler's products.

The first person to deny categorically the existence of Wöhler's series of hemi-compounds of silver appears to have been Dr. Spencer Newbury. In two interesting papers,‖ he describes a repetition of Wöhler's methods and declares it to be impossible to obtain products of constant composition. The red solution taken by Wöhler to be argentous citrate, Dr.

* G. H. Bailey and G. J. Foster, Chem. Soc. 1887, 416. Bericht D. Ch. G., xx, Ref. 360.

† Erdmann, J. prakt. Chim. 1875, 120, 39. Von Bibra precedes his paper with a brief summary of the conclusions reached by previous chemists on the subject of the action of light and chemical reducing agents on silver compounds. The collection is interesting as showing to what inconsistent and even contrary opinions careful observers have come on these reactions.

‡ Zeitschrift für Ann. Chemie, xxi, p. 27, p. 496.

§ Gmelin Kraut, ii, 1, 72.

‖ Am. Chem. Jour. vi, 407; viii, 196.

Newbury concludes to be a suspension of finely divided silver. Muthmann* after a careful examination of Rautenberg's products concludes that that chemist was wholly in error in asserting the formation of compounds of chromic, molybdic and tungstic acids with silver hemioxide. He next studies the red liquid obtained by Wöhler's process and comes to the same conclusion as Newbury, that it consists of finely divided silver suspended in water.

I shall not dispute the correctness of this opinion in the case of the liquid examined by these two chemists. At the same time I cannot accept the tests of solution employed by Muthmann. That a substance will not pass through a dialyser shows that it is colloidal and is no proof whatever that it is not in solution. Animal charcoal takes up many substances from true solutions. Decolorization by animal charcoal is no proof whatever that the color removed was not in true solution. By freezing, the molecular condition of a substance may be changed. Muthmann found that when the red liquid was mixed with gum water and precipitated by alcohol, the precipitated gum carried down with it the red substance, thence deducing that it was only in suspension. This conclusion is scarcely justified. A solution of litmus was mixed with gum water and precipitated with alcohol: the mass of the litmus went down with the gum, a trace only appeared in the filtrate. With Hoffmann's violet, the same result. Yet no one, I think, will assert that these two substances do not make true solutions in water. Even however, if these arguments could be admitted they would not apply to the solutions presently to be described, which can be proved by optical means to be true solutions. I propose presently to show that silver may exist in a perfectly soluble form, dissolving easily and abundantly in water. Starting from this, it may show all degrees of solubility down to absolute insolubility, still however, existing in an allotropic form and quite distinct from normal or ordinary silver. The solutions formed are as perfect as those of any other soluble substance.

Wöhler's process was next repeated by G. H. Bailey and G. J. Foster, who came to the conclusion that no citrate of hemioxide was formed, and that Wöhler's results must be rejected.

Von der Pfordten† endeavored to obtain hemi-compounds of silver by acting on the nitrate with an alkaline solution of sodium tartrate, and also with phosphorous acid. His determinations were made volumetrically, based on an opinion that a permanganate solution acidified with sulphuric acid would dissolve silver hemioxide, but not metallic silver. Previously to receiving his paper I had found that sulphuric acid, even

*Bericht der D. Ch. Ges., xx, 983. † Ibid., xx, 1458.

diluted with ten times its bulk of water, was capable of acting on finely divided normal silver and of dissolving an easily recognized quantity. V. d. Pfordten's conclusions were thus vitiated entirely. It should however be remarked that the difficulties of the subject are extremely great. In his last paper* this chemist abandons his views as to the existence of silver hemioxide; so that at the present time the formation of Ag_4O by Wöhler's method, or by any other known metnod, is admitted by no one. That such an oxide may exist appears by no means improbable. The existence of Ag_2Cl and K_2Cl seems almost to involve that of Ag_4O and K_4O. This latter product Davy believed that he had obtained. The black substance which V. d. Pfordten formerly regarded as Ag_4O he now takes to be silver hydrate Ag_4H_2O.

The reduction products described by V. d. Pfordten are strongly distinguished from those which I shall presently describe by two decisive reactions:—

1. None of his products could be amalgamated with mercury (l. c., 2296). All of mine readily amalgamate.
2. None of my products give off the slightest trace of gas when treated with dilute sulphuric acid. All of his do so. (l. c., 2291.)

Moreover, the difference of appearance is extremely great.

Early in the year 1886, I took up the study of the reduction products of silver in connection with that of the photosalts. I commenced with Wöhler's process, giving it up after a few trials as affording no satisfactory results, and sought for a more reliable means. This I found, in March 1886, in a reaction which I still use; namely the reduction of silver citrate by ferrous citrate. At first, however, the results obtained were most enigmatical, the products very unstable, and impossible to purify. Much time was lost and the matter was given up more than once as impracticable. Eventually, by great modifications in the proportions, stable products, and capable of a fair amount of purification were got. Even the earlier and less pure forms were exceedingly beautiful; the purer are hardly surpassed by any known chemical products.

The forms of allotropic silver which I have obtained may be classified as follows:—

A. Soluble, deep red in solution, mat lilac, blue, or green whilst moist, brilliant bluish green metallic when dry.

B. Insoluble, derived from A, dark reddish brown while moist, when dry somewhat resembling A.

C. Gold silver, dark bronze whilst wet, when dry exactly resembling metallic gold in burnished lumps. Of this form there

* Ber. D. Ch. Ges., xx, 2288.

is a variety which is copper-colored. Insoluble in water, appears to have no corresponding soluble form.

Properties possessed by all the varieties in common and distinguishing them all from normal silver.

All these forms have several remarkable properties in common.

1. *That of drying with their particles in optical contact, and consequently, forming a continuous film.*—If either is taken in a pasty condition and is spread evenly over paper with a fine brush, it takes on spontaneously in drying a luster as high as that of metallic leaf. C when so treated would be taken for gold leaf. But this property is much better seen by brushing the pasty substance over glass. When dry, an absolutely perfect mirror is obtained. The particles next the glass, seen through the glass, are as perfectly continuous as those of a mercurial amalgam, and the mirror is as good. A and B form bluish-green mirrors, C, gold or copper-colored mirrors.

2. *The halogen reaction.*—When any of these allotropic forms of silver are brushed over paper and the resulting metallic films are exposed to the action of any haloid in solution, very beautiful colorations are obtained. The experiment succeeds best with substances that easily give up the halogen, such as sodium hypochlorite, ferric chloride, iodine dissolved in potassium iodide, etc. But indications are also obtained with alkaline salts such as ammonium chloride etc., though more slowly and less brilliantly. With sodium hypochlorite the colors are often magnificent, intense shades with metallic reflections, reminding one of the colors of a peacock's tail. Blue is the predominating tint. These are interference colors, caused by thin films, but whether of a normal silver haloid or a hemi-salt, cannot be said. When silver leaf (normal silver) is fastened to paper and a comparative trial is made, the contrast is very striking.—This matter will be more particularly examined in the 2d part of this paper, and is mentioned here as one of the reactions distinguishing allotropic from ordinary silver.

3. *The action of acids.*—The stronger acids, even when much diluted, instantly convert the allotropic forms of silver into normal gray silver; even acetic acid, not too much diluted, does this. It is important to remark that this change takes place absolutely without the separation of gas. I have more than once watched the whole operation with a lens and have never seen the minutest bubble escape.

4. *Physical condition.*—All these allotropic forms of silver are easily reduced to an impalpable powder. One is surprised to see what is apparently solid burnished metal break easily to pieces and by moderate trituration yield a fine powder.

A. Soluble Allotropic Silver.

A solution of ferrous citrate added to one of a silver salt produces instantly a deep red liquid. (Ferrous tartrate gives the same reaction but is less advantageous.) These red solutions may either exhibit tolerable permanency or may decolorize, letting fall a black precipitate. It is not necessary to prepare the ferrous salt in an isolated form, a mixture of ferrous sulphate and sodic citrate answers perfectly.

When, however, concentrated solutions are used with a large excess of ferrous sulphate and a still larger one of alkaline citrate, the liquid turns almost completely black. It should be stirred very thoroughly for several minutes, to make sure that the whole of the precipitated silver citrate is acted upon by the iron. After standing for ten or fifteen minutes, the liquid may be decanted and will leave a large quantity of a heavy precipitate of a fine lilac-blue color. It is best to adhere closely to certain proportions. Of a ten per cent solution of silver nitrate, 200 c. c. may be placed in a precipitating jar. In another vessel are mixed 200 c. c. of a thirty per cent solution of pure ferrous sulphate and 280 c. c. of a forty per cent solution of sodic citrate. (The same quantity of ferrous sulphate or of sodic citrate in a larger quantity of water will occasion much loss of the silver product.) I think some advantage is gained by neutralizing the ferrous solution, which has a strong acid reaction, with solution of sodium hydroxide: as much may be added as will not cause a permanent precipitate. To the quantities already given, about 50 c. c. of 10 per cent soda solution. The reaction takes place equally well without the soda, but I think the product is a little more stable with it.—The mixed solution is to be added at once to the silver solution.

The beautiful lilac shade of the precipitate is rather ephemeral. It remains for some time if the precipitate is left under the mother water, but when thrown upon a filter, it is scarcely uncovered before the lilac shade disappears and the precipitate takes a deep blue color, without losing its solubility. It may be washed either on a filter or by decantation, with any saline solution in which it is insoluble and which does not affect it too much. On the whole, ammonic nitrate does best, but sodic nitrate, citrate, or sulphate may be used, or the corresponding ammonia salts. Although in pure water the precipitate instantly dissolves with an intense blood red color, the presence of five or ten per cent of any of these salts renders it perfectly insoluble. I have usually proceeded by adding to the precipitate (after decanting the mother water as completely as may be and removing as much more as possible with a pipette), a moderate amount of water; for the above quantities about 150 c. c. Much less would dissolve the precipitate but for the salts present: this much will dissolve the greater part but not the whole, which is not necessary. A little of a saturated solution of ammonic nitrate is to be added, just enough to effect complete precipitation.

As the material appears continually to change, the amount of washing needed must depend upon the object in view. If wanted for analysis, the washing must be repeated many times until ferric salt ceases to come away, but no amount of washing will entirely eliminate it. After seven or eight solutions in pure water and as many precipitations, the material is to be thrown on a filter, the liquid forced out as completely as possible with a pump and then the ammonic nitrate washed out with 95 per cent alcohol until the filtrate leaves nothing on evaporation. The substance at this point is still soluble in water, though much less so than at first. During the washing the solubility slowly but steadily diminishes, a fact rendered noticeable by less and less ammonic nitrate being needed to precipitate it from its solution.

Analysis.—The product after thorough washing as above described with alcohol, was dried at ordinary temperatures or a little above, and was then reduced to very fine powder and washed again with water as long as anything dissolved. It was then dried at 100° C. in water bath. Three silver determinations were made.

A1	97·31	per cent silver.
A2	97·18	" "
B	97·21	" "

A1 and A2 were made with different portions of the same material, B with different material prepared in exactly the same way.

The substance therefore contained on an average 97·27 per cent of silver. The nature of the residue would decide whether the material was silver with a certain amount of impurity firmly attached to it, or whether we had to do with silver in chemical combination with other elements.

The filtrate from the silver chloride in analysis A2 was evaporated to dryness and was found to contain chiefly iron and citric acid. The iron was thrown down as sulphide, redissolved in nitric acid, precipitated hot, washed with boiling water and gave 0·8947. The residue therefore consisted of ferric oxide and citric acid, probably in the form of ferric citrate and attached so strongly that even the very careful and prolonged washing given failed to remove them. Stronger means would be required than could be used without altering the condition of the substance. The conclusion therefore seemed to be justified that the material consisted of uncombined silver simply mixed with impurity.

To verify this conclusion by additional evidence, the substance was examined as to its behavior when heated. For if any other element were chemically combined with the silver it would only be (in view of the high percentage of silver) hydrogen or oxygen. We might have to do with a hydride, analogous to Wurtz's hydride of copper, or possibly an oxide, but not probably as Ag_4O would contain only 96·43 per cent of silver.

The presence of either hydrogen or oxygen in combination with silver seems to be pretty certainly negatived by the action of dilute sulphuric acid on this (and the two other substances, B and C, to be described farther on). They are all converted into gray metallic silver without the slightest escape of gas. This seems tolerably conclusive in itself; and the result of exposing a great number of specimens of all the forms A, B and C to the action of heat was equally so. As the object was to expose the fresh and moist material to a gradually increasing heat from that of boiling water to a low red heat without interrupting the process, the following arrangement was found convenient.

A piece of Bohemian glass tube about six inches long was sealed in the lamp at one end, the other closed with a rubber cork, through which passed a small gas delivery tube and another tube passing into a small test tube partly filled with water and having another tube through the cork passing under the surface of the water, thus preventing regurgitation. The material was thus first exposed for some hours to a heat of about 150° C. in a chloride of calcium bath; this was next removed and the heat continued to low redness. Only traces of gas were evolved and this was found to be in all of the many trials made, carbonic acid, derived from the citric acid adhering. This treatment was repeated many times with all the different varieties of the substance and with the same result. The temperature was always raised sufficiently high to ensure the complete conversion of the material into normal gray silver, but in no case was oxygen or hydrogen set free.

It could not be overlooked that in all these trials the material had passed into an insoluble form before the silver determination was made. There remained therefore this possibility: that the silver, so long as soluble, might be in combination with citric acid and that its change to the insoluble condition was caused by its separating from the citric acid. It seemed desirable that this view should be tested. As the object was to determine the condition of the silver in the substance as originally formed, avoiding as far as possible to change that form by attempts at purification, the only course available was to determine the ratio between the silver on the one hand and the citric acid on the other, either excluding from the determination, or else removing, that portion of the citric acid which was combined with sodium (sodic citrate being used in excess) or with iron. The first attempt was to exclude without removing it, by using Wolcott Gibbs's ingenious method of precipitating the base by hydrogen sulphide, and determining the acid thus set free in a solution originally neutral. It was ascertained by careful experiment on weighed quantities of pure anhydrous citric acid, that exact titration could be made with the aid of phenolphthalein. The silver was next redissolved and estimated as chloride. A large number of determinations were made, but the method proved unsatisfactory. It was found that portions of the same material operated upon separately gave different (even widely different) results. In fact, this very discordance was in itself a proof that no stœchiometrical combination existed between the silver and the citric acid.

The importance of the matter led me to take it up again with different means, estimating the citric acid by Creuse's method. In this method the solution, after being reduced to a small bulk, is exactly neutralized (with ammonia or acetic acid), is treated with a slight excess of barium acetate and then mixed with twice its bulk of 95 per cent alcohol, let stand a day and filtered and washed with 65 per cent alcohol. In igniting, a few drops of sulphuric acid convert the barium salt into sulphate in which form the estimation is made. A preliminary trial with a weighed quantity of citric acid showed that this method gave fairly good results. I was obliged to vary the method somewhat: the precipitate of barium citrate carried down with it enough iron to render it ochrey in appearance. It was, therefore, after thorough washing with 65 per cent alcohol till every trace of barium acetate was removed, dissolved on the filter with dilute hydrochloric acid (acid 1, water 10) in which barium citrate is extremely soluble and washed through. This was followed by still weaker acid and finally with water. From the filtrate, sulphuric acid precipitated snow-white barium sulphate.

But this method requires that both the sulphates and the excess of sodic and ferric citrate shall first have been perfectly removed. The blue precipitate was therefore washed with dilute solution of ammonic nitrate until this was effected. The necessity for this purification was regrettable as introducing a possibility of a change during the treatment. It was, however, indispensable that the ferrous, ferric and sodic citrates present should be got rid of. The material after this treatment was still freely soluble in water, to a dark-red solution. An examination of its absorption spectrum showed it to be still a true solution. From this solution the silver was first removed by H_2S and then the citric acid was determined in the above described way. (If the silver were thrown down by hydrochloric acid, the reliability of the citric determination would be impaired.) Next, the silver sulphide was converted into chloride and weighed. The result gave the ratio

1 gram silver to ·03195 gram citric acid.

In this case washing out the sulphates, etc., was an affair of several days. The work was repeated, reducing the time as much as possible. The material was precipitated, decanted as soon as settled, thrown upon a filter pump and the funnel kept constantly full of ammonic nitrate in dilute solution by a wash bottle. By using very thick paper and a powerful pressure the entire washing was rapidly finished so that in about six hours from first precipitation the material was thoroughly washed, redissolved and again filtered and placed under the action of H_2S. The result was

1 gram silver to ·0130 citric acid.

When these relations are reduced from weights to equivalents, they become:

No. 1, 1 equiv. citric acid to 55·63 equivs. silver.
No. 2, 1 " " 193·7 "

indicating both that the proportion of citric acid present is variable and that it is certainly not in stoichiometrical combination with the silver in the substance examined.

It has been already said that these solutions before being acted upon by H_2S were examined optically and found to be true solutions. The inference therefore seems to be very strong that there exists an allotropic form of silver freely soluble in water. This is a property so exceptional in a metal that I have admitted it with much hesitation. The principal arguments are as follows:

The content of silver in the various products was very carefully, and I believe I may say quite accurately, determined: it was extremely high, always above 97 per cent. As already remarked, this virtually excludes the presence of all elements except hydrogen and possibly oxygen. These elements were carefully searched for, but their presence could not be detected. To suppose that we had to do with a mixture in which some compound of silver was mixed with metallic silver was not possible, for as the whole was soluble we should still have to admit the solubility of silver.

We have consequently to deal with a substance containing over 97 per cent of silver, and neither hydrogen nor oxygen in combination with it, the remaining 2 or 3 per cent fully accounted for by ferric oxide and citric acid determined as present as accidental impurity; the substance itself readily amalgamating with mercury by simple friction, nevertheless abundantly soluble in water. If I had been able to find any other explanation for these facts without admitting the solubility of silver, I should have adopted it. But none presented itself.

Whether in solution it exists as a hydrate, that is, in more intimate combination with one or more equivalents of water, cannot be said with entire certainty; but the easy amalgamation with mercury seems hardly to favor that view. No means could be found for settling the question absolutely. Certainly at 100° C. all water is expelled, but this is of course not an argument. All the water is not expelled by indefinite exposure to a vacuum over sulphuric acid. But the proportion left is very small.

The material examined was in all cases as nearly as possible the same as that originally precipitated, but absolute identity could not be obtained. The purification absolutely necessary effects some change. This is shown by the color. The freshly precipitated material dissolves to a blood red liquid, by great dilution yellowish red. The purified substance gives a darker red solution, which with dilution remains still red. Of the nature of the substances in the condition in which they were analyzed, I can speak with some positiveness, and these include a substance soluble in water and nevertheless appearing to be nearly pure silver.

The constitution of the lilac blue substance at the moment of formation and whilst still under its mother water is a matter of more difficulty; it could not be said with certainty that it was not in some way altered in the purification. Much time and labor were spent in endeavoring to settle this point, without entirely satisfactory results, and I am at present engaged in the search for a better method.

When this blue soluble substance, purified either by washing very moderately by ammonium nitrate, or by washing with pure water, using those portions which remain undissolved after most has been carried through the filter, is brushed over paper and dries rapidly, it exhibits a very beautiful succession of colors. At the moment of applying it appears blood red; when half dry it has a splendid blue color with a lustrous metallic reflection; when quite dry this metallic effect disappears and the color is mat blue. Examined with a polarizer it shows the same characters as to two reflected beams of light polarized in planes perpendicular to each other that are described further on under B.

When the blue substance prepared in either way dries more slowly in lumps the result is very variable; sometimes it is bright bluish metallic; sometimes dull lead color, with a metallic reflection only where it has dried against a smooth surface.

B. *Insoluble Form of the foregoing.*

The solution of the blue product just described is influenced in a remarkable way by the addition of almost any neutral substance. So far I have not found any that does not precipitate it. Not only saline solutions do this, but even a solution of gum arabic.

Neutral salts may precipitate the silver in either a soluble or an insoluble form. Alkaline sulphates, nitrates and citrates throw down the soluble form, magnesium sulphate, cupric sulphate, ferrous sulphate, nickel sulphate, potassium bichromate and ferro cyanide, barium nitrate, even silver nitrate and other salts throw down a perfectly insoluble form. The soluble form constitutes a blue or bluish black precipitate; the insoluble, a purple brown, which by repeated washing, by decantation or otherwise, continually darkens.

What is very curious is that the insoluble form may be made to return to the soluble condition. Many substances are capable of effecting this change. Sodium borate does so, producing a brown solution, potassium and sodium sulphate produce a yellowish red solution and ammonium sulphate a red one. None of these solutions has the same blood-red color as the original solution; the form of silver seems to change with the slightest change of condition.

The solutions used must be extremely dilute, otherwise the silver, though rendered soluble in pure water by them, will not dissolve in the solution itself, a singular complication of effects. So that if a moderately strong solution of one of the above substances is poured over the insoluble silver substance it does not dissolve, but by pouring off the saline solution and replacing it with pure water, the substance now dissolves readily. The insoluble substance is also readily soluble in ammonia. The solution has a fine red color, and not the yellowish red of the sodium sulphate solution.

Most neutral salts act in one or other of the ways just described, precipitating the solution of the blue substance A in either the soluble or the insoluble form, the latter soluble in ammonia, but sodium nitrite is an exception; its solution effects an entire change and renders the substance wholly insoluble, probably reconverting it to normal silver.

Sometimes the substance will spontaneously pass into a soluble form. A specimen, rendered insoluble by precipitation with ferrous sulphate, after much washing began to run through, not only as a suspension, which often happens, but as a solution, clearing itself, after a day or two, of insoluble portions and furnishing a rose-red solution. I have kept this solution in a corked vial for eight months, during which time it has remained unchanged.

The general properties of this substance can be much better observed in the thin films obtained by brushing the moist substance over paper than in the lumps. The films thus obtained are bright greenish metallic, and this green evidently results from a mixture of blue and yellow, as in some lights the blue, in others the yellow, is most evident. When these films are examined by light reflected from them at a large incidence with the normal and a Nicol's prism or an achromatized prism of calc-spar is interposed between the film and the eye, it becomes at once apparent that the blue and yellow light are oppositely polarized. The yellow light is polarized in the plane of incidence, the blue light perpendicularly to that plane. All specimens show the yellow light, but the quantity of blue light is very variable and is directly connected with the amount of washing applied to the precipitate. The more it is washed the more the yellow predominates. To see the blue form in its full beauty, a little of the red solution may be precipitated with a very little magnesium or aluminium sulphate and be thrown on a filter. As soon as the liquid has drained off and without any washing, the deep bronze-colored substance is to be brushed over paper. On drying it has all the appearance of a bright blue metal with a remarkable luster. The mirrors obtained by brushing the substance over glass are so beautiful and so perfect that it seems as if this property might have useful applications, especially for silvering irregular surfaces. Much care, however, would be necessary in the preparation to obtain a permanent product.

Crystallization.—On one occasion this substance was obtained in a crystalline form. Some crude red solution had been set aside in a corked vial. Some weeks after, it was noticed that the solution had become decolorized, with a crystalline deposit at bottom. The bottle was carefully broken; the deposit, examined by a lens, consisted of short black needles and thin prisms. Evidently the saline matters present had balanced the silver in solution so nearly as not to cause an immediate precipitation, but a very gradual one only. The mother water was drained off and a few drops of pure water were added. No solution took place, the crystals were therefore of the material B, the insoluble form. The contact of pure water instantly destroyed the crystallization and the substance dried with a bright green metallic luster. Contact with pure water evidently tends always to bring this form of silver into the colloidal state, sometimes soluble and sometimes not; whilst the contact with certain neutral salts renders it crystalline.

The extraordinary sensitiveness which allotropic silver shows to external influences contrasts strongly with the inertness of normal (probably polymeric) metallic silver. When we place this fact alongside of the well known sensitiveness of many silver compounds to light, heat and (as I have elsewhere shown) to mechanical force,* we are led to ask whether silver may not exist in this form in these very sensitive compounds.

To obtain the substance in a pure condition suitable for analysis, it is necessary to choose a precipitant not giving an insoluble product with either citric or sulphuric acid. Magnesium sulphate or nickel sulphate answers well; I have generally used the first named. A very dilute solution is made of it and the red solution of A is to be filtered into it. The precipitate soon subsides. A large quantity of water is to be poured on, and then washing by decantation can be continued to three decantations, after which the substance remains suspended. It can be made to subside by adding a very small quantity of magnesium sulphate; one four-thousandth part (0·25 gram to one liter) is sufficient. The substance may then be thrown on a filter and washed with pure water.

Analysis.—A specimen dried in vacuo over sulphuric acid gave

No. 1	97·17	per cent silver.
No. 2	97·10	" "

A specimen dried first in vacuo and then at 100° C., lost in the second drying ·88 per cent water.

So that the substance dried at 100° contained 97·96 per cent. of silver. The remaining 2·04 per cent consisted of ferric oxide and citric acid.

C. Gold-Yellow and Copper-colored Silver.

It has been long known that golden-yellow specks would occasionally show themselves in silver solutions, but could not be obtained at will and the quantity thus appearing was infinitesimal. Probably this phenomenon has often led to a supposition that silver might be transmuted into gold.† This yel-

* Production of an image on silver iodide capable of development by simple pressure.

† I have a little volume published in Paris in 1857 by a chemist named Tiffereau who was firmly convinced that in many reactions, minute portions of silver are converted into gold, especially with the aid of powerful sunlight. In Mexico, he affirmed, he had artificially produced several grams of gold, a portion of

low product, however, is only an allotropic form of silver, but it has all the color and brilliancy of gold, a fact which was apparent even in the minute specks hitherto obtained.

By the means presently to be described, silver can be converted wholly into this form. It is a little curious that its permanency seems to depend entirely on details in the mode of formation. I found many ways of obtaining it, but in a few months the specimens preserved changed spontaneously to normal silver. This happened even in well closed tubes. The normal silver produced in this way is exquisitely beautiful. It has a pure and perfect white color like the finest frosted jewelers' silver, almost in fact exceeding the jeweler's best products. I found, however, one process by which a quite permanent result could be obtained. Specimens made by it in November of 1886 are now, at the end of thirty months, unchanged.

In forming the blue product which I have called A, very concentrated solutions were necessary. C on the contrary is best obtained from very dilute ones. The following proportions give good results.

Two mixtures are to be prepared: No. 1, containing 200 c. c. of a ten per cent solution of silver nitrate, 200 c. c. of twenty per cent solution of Rochelle salt and 800 c. c. of distilled water. No. 2, containing 107 c. c. of a thirty per cent solution of ferrous sulphate, 200 of a twenty per cent solution of Rochelle salt and 800 of distilled water. The second solution (which must be mixed immediately before using only) is poured into the first with constant stirring. A powder, at first glittering red, then changing to black, falls, which on the filter has a beautiful bronze appearance. After washing it should be removed whilst in a pasty condition and spread over watch glasses or flat basins and allowed to dry spontaneously. It will be seen that this is a reduction of silver tartrate by ferrous tartrate. The metallic silver formed by reduction with ferrous citrate and ferrous tartrate is in an allotropic condition; with ferrous oxalate this result does not seem to be produced.

Although the gold-colored silver (into which the nitrate used is wholly converted) is very permanent when dry, it is less so when wet. In washing, the filter must be kept always full of water: this is essential. It dries into lumps exactly resembling highly polished gold, especially the surfaces that have dried in contact with glass or porcelain. For this substance has in a

which he presented to the French Academy with one of his papers. To his great disappointment he did not succeed in repeating these experiments in Paris, with more than an infinitesimal result. All gold in his opinion had been originally silver, and this belief, he affirms, is universal amongst Mexican miners. The book has for title "*Les Métaux sont des Corps composés.*"

high degree the property already described in forms A and B —that of drying with the particles in optical contact. When the thick pasty substance is extended over glazed paper, it dries with the splendid luster of gold leaf, with this essential difference, that these allotropic forms of silver B and C assume spontaneously in drying the high degree of brilliancy which other metallic surfaces acquire by elaborate polishing and burnishing. By brushing a thick paste of this substance evenly over clean glass, beautiful gold-colored mirrors are obtained; the film seems to be entirely continuous and the mirror is very perfect.

By continued washing the precipitate changes somewhat, so that in drying it takes on a coppery rather than a golden color, and is rather less lustrous, though still bright and permanent.

Two silver determinations by conversion into chloride made in Nov., 1886, gave:

No. 1	97·81	per cent silver.
No. 2	97·86	" "

Recently these experiments have been repeated and the washing was more successful. Ferric tartrate adheres very obstinately and after a time washing with water ceases to remove it. Stronger means cannot be employed without affecting the substance itself. These last determinations gave:

No. 1	98·750	per cent of silver.
No. 2	98·749	" "

The residue of No. 2 was examined and consisted almost wholly of ferric citrate.

Chestnut Hill, Phila., April, 1889.

NOTE.—The editors have received, from the author of the above paper, samples of the three allotropic forms of silver which he describes, and also strips of glass and paper coated with them. Mr. Lea is to be congratulated on his very important results. The coated strips, including the gold-colored mirror made with the "gold-silver," answer fully to his description. The mirror is remarkable for its perfection and brilliancy.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Composition of Water.*—LORD RAYLEIGH has communicated to the Royal Society the results of an attempt at an entirely independent determination of the relative weights of oxygen and hydrogen, by actual combustion of weighed quantities of the two gases. Dumas weighed only the oxygen and the water produced. Later investigators have weighed the hydrogen, either in the gaseous state as in the experiments of Cooke and the author, or occluded in palladium as in those of Keiser. As to the second weighing it is not material whether it relates to the water, as in the investigations of Cooke and Keiser; or to the oxygen as in the present experiments. In principle the method adopted by Rayleigh is very simple. Globes of the same size as those employed for the density determinations were filled to atmospheric pressure with the two gases and were then carefully weighed. By means of Sprengel pumps, the gases were exhausted into a mixing chamber, sealed below with mercury, where they were fired by electric sparks in the usual way. After sufficient quantities of the gases had been withdrawn, the taps of the globes were turned, the leading tubes and mixing chamber were cleared of all remaining gas, and, after a final explosion in the eudiometer, the nature and amount of the residual gas were determined. The quantities taken from the globes can be found from the weights before and after the operations. From the quantity of that gas which proved to be in excess, the calculated weight of the residue was subtracted. This gave the weight of the two gases which actually took part in the combustion. In practice, the mixing chamber, originally filled with mercury, was charged with equivalent quantities of the two gases; the oxygen being first admitted until the level of the mercury had dropped to a certain mark and then the hydrogen down to a second mark. The mixed gases might then be drawn off into the eudiometer and the chamber refilled; but to save time the chamber was replenished and the eudiometer filled from it simultaneously, the proper proportion of the gases being preserved by means of mercury manometers which indicate the pressures at any time in the globes. To obviate an accumulation of residual gas in the eudiometer, two sparking places were provided, one above the other, the lower one being generally used. When the tube contained excess of oxygen down to a point somewhat below the lower spark-wires each bubble of explosive gas readily found its way to the sparks and there was no tendency to a dangerous accumulation of mixed gas before an explosion took place. In consequence of the difficulties encountered, five results only have been obtained, representing the atomic ratio of oxygen and hydrogen as deduced immediately from the weighings with allowance for the unburned

residue. These are: 15·93, 15·98, 15·98, 15·93, 15·92; the mean of which is 15·95. Correcting for buoyancy, the final number for the atomic mass of oxygen is 15·89.—*Nature*, xxxix, 462, March, 1889. G. F. B.

2. *On Diamide hydrate and other salts.*—CURTIUS and JAY have continued their researches upon diamide N_2H_4, the compound isolated in 1887 by the former chemist.* Its intense attraction for water has rendered its preparation in the anhydrous condition extremely difficult; especially since water is also set free in all the reactions by which it is produced. On distilling diamide hydrochloride $\left\{\begin{matrix} NH_2 . HCl \\ NH_2 . HCl \end{matrix}\right.$ with caustic lime in a silver retort, furnished first with a U-tube and then with a horizontal tube filled with quicklime, the liquid hydrate collected in the receiver. A strong solution of potassium hydrate, however, gave a larger yield. Diamide hydrate is a fuming liquid which boils without change at 119° and has a high refractive power. Glass is attacked by it readily and it rapidly destroys cork or caoutchouc. It is strongly alkaline, has a taste like ammonia, with a burning after-taste. It appears to be the strongest reducing agent known. It precipitates silver from a cold concentrated solution in fine compact crystalline masses and if the solution is dilute, in splendid mirror-like films. Platinic chloride is completely reduced by it with separation of metallic platinum. When dropped on mercuric oxide it explodes violently. The salts of diamide are well-marked and very stable. The di-hydrochloride $\left\{\begin{matrix} NH_2 . HCl \\ NH_2 . HCl \end{matrix}\right.$ strongly resembles ammonium chloride, crystallizing in cubes and giving in films feathery crystals; but it is deliquescent. On heating to 198° it fuses, evolves hydrogen chloride, and leaves a clear glass of mono-hydrochloride $\left\{\begin{matrix} NH_2 \\ NH_2 \end{matrix}\right. . HCl$. This on further heating breaks up into ammonium chloride, nitrogen and hydrogen. The normal hydrochloride gives no precipitate with platinic chloride but reduces it to platinous chloride, with evolution of nitrogen. Diamide sulphate $\left\{\begin{matrix} NH_2 \\ NH_2 \end{matrix}\right. . H_2SO_4$ crystallizes in forms which are optically bi-axial. It is only sparingly soluble in cold water and is thrown down when sulphuric acid is added to solutions of its salts. It fuses at 254° and is decomposed almost explosively, evolving sulphurous oxide, hydrogen sulphide and sulphur and leaving ammonium sulphite. The carbonate, nitrate, acetate and oxalate have also been obtained, all crystallized except the first, and all having strong reducing properties. When any salt of diamide is mixed with a nitrite, free nitrogen is evolved almost explosively.—*J. pr. Chem.*, xxxix, 27, 107; *Ber. Berl. Chem. Ges.*, xxii, 134 (Ref.), March, 1889. G. F. B.

3. *On the Synthesis of the Glucoses and of Mannite.*—By the action of barium hydrate upon acrolein dibromide E. FISCHER and

* This Journal, III, xxxiv, 226, Sept., 1887.

TAFEL obtained some time ago, two sugar derivatives in the form of their osazones, produced by precipitating with phenyl-diamide, which they called α-acrosazone and β-acrosazone respectively. The former these chemists have now further examined. By the action of hot concentrated hydrogen chloride, the α-acrosazone dissolves to a clear dark red liquid which on cooling deposits crystals of phenyl-diamide hydrochloride. The mother liquor is diluted, neutralized with lead carbonate, decolorized and precipitated with barium hydrate. The precipitate contains the α-acrosone, having the formula $CH_2 . OH . (CHOH)_3CO . COH$; which is an oxidation product of a simple sugar. The lead compound was decomposed with sulphuric acid, treated with barium carbonate, decolorized and evaporated to a syrup, which in the cold solidified to an amorphous mass. By warming the dilute solution of α-acrosone with zinc dust and acetic acid, it was reduced readily; and after removing the zinc by hydrogen sulphide, evaporation and extraction with absolute alcohol, ether produced a precipitate of the new sugar α-acrose in colorless flocks which soon deliquesced to a syrup. This substance shows the closest analogy with the glucoses. It tastes sweet, reduces Fehling's solution, and ferments with yeast. Moreover on reduction with sodium amalgam it yields a substance closely resembling mannite which the authors call acrite. Both acrose and acrite, however, are optically inactive; and this is the only respect apparently in which the former differs from the glucoses or the latter from mannite.—*Ber. Berl. Chem. Ges.*, xxii, 97, January, 1889. G. F. B.

4. *On Geometrical Isomerism.*—WISLICENUS and HOLZ have described a striking instance of geometrical isomerism in the case of the dibromide of crotonylene. In this form of isomerism, the compounds are precisely similar in their constitution and differ only in the relative positions of their atoms in space. By the direct action of bromine upon crotonylene $CH_3 . C ⋮ C . CH_3$, a dibromide $CH_3 . CBr : CBr . CH_3$ is formed the atoms of which as the authors show, are arranged in space thus:

$$\begin{array}{c} CH_3 . C . Br \\ \| \\ CH_3 . C . Br \end{array}$$

the two similar groups being symmetrical with respect to an assumed plane between them. If, however, a dibromide be formed either by removing from crotonylene tetrabromide two of its bromine atoms, or by withdrawing from one of the tribrombutanes $CH_3 . CHBr . CBr_2 . CH_3$ a molecule of hydrogen bromide, the new dibromide is found to be quite a different substance from the first. While it has necessarily the same empirical formula, its boiling point was found to be about 3° higher than the other dibromide and it behaved quite differently on reduction with zinc dust. The authors can explain these differences only on the assumption that the arrangement of its atoms in space is centro-symmetrical

$$\begin{array}{c} CH_3 . C . Br \\ \| \\ Br . C . CH_3 \end{array}$$

; and they give the name isocrotylene dibromide to this compound. Both bodies on addition of bromine give the same tetrabromide $CH_3 . CBr_2 . CBr_2 . CH_3$.—*Ann. Chem. Pharm.*, ccl, 224, 230, Jan., 1889; *Nature*, xxxix, 467. G. F. B.

5. *On Aluminum acetyl-acetonate.*—COMBES has recently produced an organic aluminum compound of some interest, since it seems likely to settle the disputed question of the valence of this metal. This compound is aluminum acetyl-acetonate, a white crystalline solid melting at 193°–194° and distilling unchanged at 314°–315°. Two density determinations by V. Meyer's method in nitrogen and at the temperature of boiling mercury gave values corresponding to the molecular masses 325·5 and 324·2; the molecular mass of $Al(C_5H_7O_2)_3$ being 324·5. Hence the triad formula is the only possible one even at this low temperature. There was no trace of decomposition.—*C. R.*, cviii, 405, Feb., 1889; *Bull. Soc. Chim.*, III, i, 343, March, 1889. G. F. B.

6. *Correction of Regnault's results upon the weight of gases.*—J. M. CRAFTS, following up the suggestion of Lord Rayleigh in regard to the effect of the presence of the atmosphere upon the vessel in which the gases were weighed by Regnault, finds the following corrected values for Regnault's results for density:

	Regnault.	Corrected.	Corrected value for weight of a liter.
Air	1·00000	1·00000	1·29349
N	0·97137	0·97138	1·25647
H	0·06977	0·06949	0·08988
O	1·10564	1·10562	1·43011
CO_2	1·52910	1·52897	1·97772

—*Comptes Rendus*, cvi, p. 1662–64, 1888. J. T.

7. *Iron spectrum.*—H. KAYSER and C. RUNGE have issued a paper giving a catalogue of 4500 lines of iron based upon the absolute wave-length determinations of Rowland and Bell. Each line is characterized in the catalogue by its peculiarities as to sharpness and reversed nature, etc. The wave lengths were measured by Rowland's gratings and the limit of accuracy is $0·01\mu\mu$. The authors believe that the iron lines will serve as reference lines for other workers in spectrum analysis. They hope to connect the spectra of other elements to the iron spectra by certain equations.—*Beiblätter Annalen der Physik und Chemie*, No. 2, p. 78, 1889. J. T.

8. *Electrical currents arising from deformation.*—The subject of the effect of torsion of bending and pressure upon the production of thermo-electric currents has been exhaustively studied by various writers. FERDINAND BRAUN has lately studied the subject anew and finds a remarkable example of these phenomena in nickel.—*Annalen der Physik und Chemie*, No. 5, pp. 97–127, 1889. J. T.

9. *Electrical dilatation of quartz.*—J. and P. CURIE continuing their work upon this subject have constructed a manometer consisting of plates of quartz which are connected to a quadrant electrometer and are subjected to pressure. The sensitiveness of the apparatus is very great. With crystal plates having

7 square centimeters of base and a column of 10 centimeters in height the sensitiveness was such that the difference of potential corresponding to a striking distance of 1 millimeter between balls six centimeters in diameter gave a deviation of 25 centimeters upon the scale. The authors describe certain modifications of the apparatus. They are able to obtain instruments which are sensitive to 5 volts, and can serve to measure 1000 to 1500 volts. By altering the thickness of the plates of quartz, instruments of almost any suitable range can be constructed. The authors reply to a remark, that an optical manometer depending upon interference fringes might be made more sensitive than the *manomètre piézo-electrique*, which they describe, by stating that admitting that one can measure to $\frac{1}{100}$ of a fringe in the compensator of Babinet one could obtain a manometer sensitive to a pressure of three kilograms; whereas their electrical manometer is six hundred times more sensitive and indicates a pressure of five grams.—*Journal de Physique*, April, 1889, pp. 149–168. J. T.

II. Geology and Natural History.

1. *Triassic Plants of Eastern North America.*—Dr. Stur has reviewed (Verh. G. Reichsanst. July 31, 1888) the plants of the Triassic beds of Virginia described by Prof. Fontaine, with specimens before him, received, as he states, from Prof. Fontaine. He publishes the following list of species identified by him with species from the Lettenkohle, the lower division of the Upper Trias of Germany.

Clover Hill, near Richmond, Va.	Schists of Lunz.
Equisetum Rogersi Schimper.	*Equisetum arenaceum* Jæger.
Schizoneura Virginiensis Font.	*Calamites Meriani* Brgt.
Macrotæniopteris magnifolia Rogers.	*Tæniopteris latior* and *T. simplex* Stur.
" *crassinervis* Font.	?
Acrostichides Linnææfolius Bunb.	?
" *rhombifolius* Font.	*Speirocarpus Lunzensis* Stur.
" *densifolius* Font.	" *Rutimeyeri* Heer.
" *microphyllus* Font.	" *microphyllus* Stur.
Mertensides bullatus Bunb.	*Oligocarpia robustior* Stur.
" *distans* Font.	" *Lunzensis* Stur.
Asterocarpus Virginiensis Font.	*Asterotheca Meriani* Brgt.
" *platyrrachys* Font.	" "
" *penticarpus* Font.	" "
Lonchopteris Virginiensis Font.	*Sperocarpus Haberfelneri* Stur.
Clathropteris platyphylla Font.	*Clathropteris reticulata* Kurr.
Pseudo-danæopteris reticulata Font.	*Heeria Lunzensis* Stur.
Ctenophyllum Braunianum Font.	*Pterophyllum Riegeri* Stur.
" *grandifolium* Font.	" *Haueri* Stur.
Podozamites tenuistriatus Font.	?
Sphenozamites Rogersianus Font.	" *Bronnii* Schenk.

Relations are also shown between other American and German species, and the conclusion reached that the American beds are equivalents of the Lettenkohle.

In the same paper, Stur presents facts from the European Permian flora favoring the view that the Glossopteris flora of India, Afghanistan, Australia, and South Africa, is Permian.

2. *The Geological and Natural History Survey of Minnesota for the year* 1887. 504 pp. 8vo, with plates and other illustrations, N. H. Winchell, State Geologist: containing two reports on the Original Huronian rocks, and others referred to the Huronian, including the Animike group, the iron-bearing series, and underlying crystalline rocks, one by Prof. N. H. WINCHELL, and the other by Prof. A. WINCHELL; and also a report on the crystalline rocks by H. V. WINCHELL.

Field Studies in the Archæan Rocks of Minnesota with accessory observations in Ontario, Michigan and Wisconsin, by ALEXANDER WINCHELL. 504 pp. 8vo, Ann Arbor, 1889.

The second of these volumes consists of the reports of Prof. A. Winchell for the years 1886 and 1887 to the Minnesota reports of those years. The investigation of the "Original Huronian" by Professors N. H. and A. Winchell has led them to similar conclusions. The results are here cited from the report of the latter. The section made conforms in most points with the descriptions by Logan in 1863, and on his map of 1865. The succession of rocks commencing with the oldest, and excluding, as igneous, the chlorite rocks and greenstones, is stated to be as follows:

1. Missisagui quartzyte, 3750 feet thick; 2, Bruce limestone 100 ft; 3, Lower slates or argillyte, conglomeritic and siliceous, 7400 ft; 4, Red felsyte, granulyte and quartzyte, 100 ft; 5, Upper Slates or argillyte; 6. Otter-tail cherty limestone, 100 ft; 7, Thessalon quartzyte, red and gray, 5000 ft; 8, Otter-tail quartzyte, white, 4000 ft. None of the rocks are crystalline, except locally at a contact with an eruptive. The White quartzyte, the uppermost stratum, occupies the north shore as far as St. Mary's River and along part of St. Joseph's island. Here it is overlaid directly by a siliceous fossiliferous limestone, apparently the Chazy, and hence it is probably Lower Cambrian.

From a study of the Marquette iron region, the conclusion is deduced that the rocks underlie the true Huronian, and are unconformable to it, while "not separated from the Laurentian by a structural unconformability." The Animike formation, on the north shore of Lake Superior, which stretches from Thunder Bay nearly to Duluth, and is recognized still farther west, is essentially argillitic, with siliceous layers, and with some iron-ore (magnetitic beds) in the upper part, and is generally nearly horizontal in bedding. It is made the equivalent of the "slate conglomerate" of the typical Huronian. The Kewatin series of argillitic, sericitic, chloritic and micaceous schists, high in dip, occurring about Vermillion Lake and elsewhere (and including the so-called Vermillion series), is an independent system older than and unconformable to the Animike. The Ogishke conglomerate of the vicinity of Ogishke-Muncie Lake, with the associated slates, is perhaps of the Animike series, but probably underlies it.

Many important facts are detailed and illustrated in the reports with regard to the relations of granite to the schists, and to breccia granite, and conglomerate granite, and also to gradual transitions between the schists of various constitutions—such as from "earthy and sub-crystalline schists to gneiss"—facts which no mode of applying pressure will explain.

In a general section of the Huronian and older formations, concluding the paper, the "Marquettian" iron-bearing system, consisting of sericitic and argillitic rocks with the Ogishke conglomerate, is introduced below the typical Huronian (Cambrian) and over the older crystalline rocks (Vermillion series, etc.) of the Archæan. The authors also conclude from their study of the crystalline rocks that the older crystalline schists, or the Archæan, were originally sediments, and that this is true of the gneisses, even those fading into granite.

3. *Bömmelöen og Karmöen med omgivelser geologisk beskrevne* af Dr. Hans Reusch. 422 pp. 8vo, with 3 colored maps and 205 illustrations in the text. A summary of the contents in English occupies pages 385 to 422. Published by the Geological Survey. Kristiania, 1888. (P. F. Steensballes).—This very instructive contribution to the geology of crystalline rocks is the result of a thorough investigation of the islands at the mouth of the Hardanger Fiord, on the coast of Norway, just south of Bergen, embracing Bömmelö, Karmö, and others in the vicinity. The rocks are granite, gneiss, dioryte, mica, hydromica, hornblende, argillitic and other schists, quartzytes, conglomerates, limestone, gabbro, with serpentine, diabase and other kinds. The granite and gneiss are in part Archæan. The other rocks are found to be in part Primordial and Upper Silurian by the presence of fossils, which occur as reported in Dr. Reusch's memoir of 1862, in the finer schists and limestone. The Primordial localities occur 130 kilometers to the eastward; but the schists are probably the same that exist in the Bokne fiord east of Karmö. The Upper Silurian fossils (of which figures are here given) were found near Bergen and in the southern parts of the islands of Storen and Bömmelö. The various details with regard to the structure of the rocks are described and well illustrated—their transitions, irregularities of flexures and faults, pressure-deformation producing elongations and compressions of pebbles, crystals and fossils, pressure-made breccia in the granite and gneiss, and other rocks, and bowlder-made granite, veins of various forms and irregularities, dikes, alterations of the rocks, diabases altered to hornblende rocks, and also to potstone, gabbro to serpentine, and so on. The rocks are regarded as for the most part of one geological series; and the conclusion is presented that the region "participated in the great post-Silurian folding-process of the Scandinavian peninsula," the main trend of whose axis was N.E. The occurrence of granite inter-bedded with masses of amphibolyte, serpentine, calciferous crystalline schists, limestone is regarded as evidence that the granite as well as the other rocks were originally of fragmental origin. The author recognizes the fact that "in some cases, originally sedimentary rocks may be regionally metamorphosed and at last be protruded as true eruptives."

4. *Composition of a brick from the brick-yard of S. P. Crafts, at Quinnipiac, three miles north of New Haven, Ct.;* by O. H. DRAKE.—The brick-clay used for making the bricks is from the bed of stratified drift in which were found bones of the Reindeer, mentioned in volume x (1875) of this Journal. The brick was one of the overbaked kind, much distorted, and highly vesicular or scoria-like, and the texture within indicated complete fusion. The clay had been mixed with coal-dust before the heating, as now usual at brick yards. The analysis of the vesicular semi-glassy portion afforded

SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	K_2O	Na_2O
65·89	18·98	2·97	1·32	0·22	2·29	2·56	3·15	2·96=100·32

The large percentage of potash and soda shows that the clay contained much undecomposed feldspar, which is natural in view of the fact that the crystalline rocks that were its source border the Connecticut valley through its whole distance to New Haven. The vesiculation is supposed to be due to the coal dust.

5. *International Congress of Geologists.* (From a communication from the Secretary of the American Committee, Professor H. S. Williams, to the Editors.)—The Organizing Committee of the International Congress of Geologists met in the National Museum, Washington, D. C., on the 19th of April last. Present, Professor J. S. Newberry (in the chair), J. P. Lesley, N. S. Shaler, O. C. Marsh, C. H. Hitchcock, J. J. Stevenson, G. K. Gilbert, James Hall, A. Heilprin, J. R. Proctor, A. Winchell, C. D. Walcott, R. P. Whitfield and H. S. Williams.

Professor J. S. Newberry of Columbia College was elected Permanent Chairman, G. K. Gilbert of the U. S. Geological Survey, Vice-Chairman, and H. S. Williams of Cornell University, Secretary.

There were added, by election, three new members to the Committee, T. Sterry Hunt, Persifor Frazer and E. D. Cope, making a total of twenty-seven.

It was resolved that the Chairman appoint three committees, viz: (1) a Committee on the Scientific programme of the Congress, (2) a Committee to arrange for the longer excursions, (3) a Local Committee to make arrangements for the holding of the meeting in Philadelphia. The names of the members of these sub-committees will be announced later.

The Committee adjourned to meet at Philadelphia at the time, in November, of the meeting of the National Academy.

6. *Brief notices of some recently described minerals.* METASTIBNITE.—This name has been proposed by Becker for the red sulphide of antimony which he has observed among the deposits of the Steamboat Springs, California. It is brick-red in color, dull in luster, apparently amorphous, and occurs mingled with silica and sulphide of arsenic. It seems to be identical with the chemically precipitated Sb_2S_3.—*U. S. Geol. Surv., Monograph* xiii.

HELIOPHYLLITE, RHODOTILITE.—Two new minerals from Pajsberg, Sweden, described by G. Flink. Heliophyllite is a sulphur-yellow mineral, with foliated structure, and optically shown to belong to the orthorhombic system. Hardness = 2; specific gravity = 6·886. An analysis yielded:

As_2O_3	PbO	MnO, FeO	Cl
11·69	80·70	0·54	8·00 = 100·93

The formula deduced is $Pb_4As_2O_7+2PbCl_2$. It is probably identical with a mineral noted by Nordenskiöld as occurring with ecdemite at Långban.

Rhodotilite is a rose-red radiated mineral with silky luster; it is referred on the basis of an optical examination to the triclinic system. Hardness = 4 – 5; specific gravity = 3·03. An analysis yielded:

SiO_2	MnO	FeO	CaO	MgO	PbO	H_2O
43·67	37·04	1·11	9·38	0·15	0·77	7·17 = 99·29

The formula deduced is $2(Mn,Ca)SiO_3+H_2O$.—*Œfv. Ak. Stockh.*, Nov., 1888.

Inesite.—A hydrated silicate of manganese and calcium, apparently the same mineral as that later called rhodotilite by Flink. It occurs in fibrous radiated forms of a flesh-red color with other manganese ores in the Dillenburg region, Germany. It is referred to the triclinic system as the result of the optical examination. Hardness, 6–7; specific gravity, 3·103. Analysis:

SiO_2	MnO	FeO	CaO	MgO	H_2O	Al_2O_3
43·92	38·23	0·69	8·00	0·28	8·49	0·29=99·85

Described by A. Schneider in *Zeitschr. Geol. Ges.*, vol. xxxix, 829, 1888. Cf. also Flink, *Œfv. Ak. Stockh.*, Jan. 9, 1889.

Caryopilite (Karyopilite).—A hydrated silicate of manganese allied to inesite. It occurs in botryoidal or reniform shapes, having a matted fibrous structure, at the Harstig mine, near Pajsberg, Sweden. The color is brown, the hardness 3·5, and the specific gravity 2·83–2·91. Analysis:

SiO_2	MnO	MgO	CaO	PbO	Fe_2O_3	Al_2O_3	Alk.	H_2O	Cl
36·16	46·46	4·80	0·28	0·37	1·33	0·35	0·20	9·81	0·09=99·85

Approximate formula, $4MnO.3SiO_2.3H_2O$. Described by A. Hamberg in *Geol. För. Förhandl.*, vol. xi, 27, 1889.

Ochrolite.—An antimonate of lead from Pajsberg, isomorphous with heliophyllite (see above). It occurs in tabular orthorhombic crystals, of a sulphur-yellow color, and adamantine luster. An analysis gave: PbO 76·52, Cl 7·72, Sb_2O_3 17·59 (as loss), leading to the formula $Pb_4Sb_2O_7+2PbCl_2$. Described by G. Flink in *Œfv. Akad. Stockh.*, Jan. 9, 1889.

Facellite.—Described by E. Scacchi (Rend. Accad. Napoli. Dec. 1888) as a new mineral from Mt. Somma. It occurs in colorless and slender acicular crystals, optically uniaxial, and probably belonging to the hexagonal system. Hardness about 6; specific gravity 2·493. An analysis yielded:

SiO_2	Al_2O_3	K_2O	Na_2O
37·73	33·09	29·30	0·37 = 100·49

This corresponds to the formula $KAlSiO_4$ or $K_2O.Al_2O_3.2SiO_2$. The author has evidently overlooked the description of *Kalio-*

philite (cf. this Journal, xxxiii, 423) by Mierisch, which is from the same locality and is doubtless the same mineral.

PAPOSITE.—A hydrous iron sulphate from the Union mine near Paposa, Atacama. It occurs in dark red crystalline masses having a fibrous radiated structure. Its composition is expressed by the formula $2Fe_2O_3 . 3SO_3 . 10H_2O$. DARAPSKY, Jahrb. Min., i, 23 ref., 1889.

7. *Mazapilite.*—Dr. KOENIG has continued his investigation of this species from Mazapil, Mexico (see vol. xxxvi, p. 391). It proves to be orthorhombic with a prismatic angle of 119° 50′. An analysis gave :

As_2O_5	Sb_2O_5	P_2O_5	Fe_2O_3	CaO	H_2O
43·60	0·25	0·14	30·53	14·82	9·83 = 99·17.

It thus approaches very close to arseniosiderite, and may be identical with it.—*Proc. Acad. Nat. Sci. Philad.*, 45, 1889.

8. *Gahnite, Columbite.*—Dr. GENTH describes gahnite from Smedley's quarry, Delaware Co., Penn., and columbite from Mineral Hill. The latter mineral is especially interesting as being a nearly pure niobate with Nb_2O_5 76·26 p. c., Ta_2O_5 0·83 p. c.; the specific gravity, 5·26, is correspondingly low.—*Proc. Acad. Nat. Sci., Philad.*, 50, 1889.

9. *Stibnite from Canada.*—In the Annual Report of the Geology of Canada for 1887, G. CH. HOFFMANN, chemist to the Survey, announces the occurrence of stibnite at Foster's Bar, about 23 miles from Lytton, Br. Columbia.

10. *Mineralogy of Pennsylvania*, Part I. Easton, Penn.—Professor JOHN EYERMAN has prepared this pamphlet as a continuation of Dr. Genth's volume on the same subject issued in 1875. The finding of euxenite is announced, but from an unknown locality, also of erythrite at the French Creek mines. The following analysis is given of the calamine from Friedensville : SiO_2 24·32, ZnO 65·05, H_2O 7·86, Fe_2O_3 2·12=99·35.

11. *Note on Sinter-forming Algæ.*—A collection of Algæ from the hot springs of the Yellowstone National Park, has been placed in the hands of Professor W. G. Farlow, for examination. The result of his study will be published on the completion of the work together with such facts concerning the occurrence of the plants as Professor Farlow may care to use. The specific determination of Calothrix, and of Leptothrix, given in the article on the "Formation of Siliceous Sinter," in this volume, were not made by him, and are subject to correction in his report.

W. H. WEED.

12. *Results obtained by etching a sphere of quartz and crystals of quartz with hydrofluoric acid;* by Dr. OTTO MEYER and SAMUEL L. PENFIELD.—Starting with a sphere of quartz, shown by its pyro-electrical behavior to have been cut from a simple right-handed crystal, the authors have studied the effects of exposing it to the action of hydrofluoric acid for different periods from four days to eight weeks. Two excellent plates reproduce with wonderful fidelity the delicate etchings exhibiting the tetar-

tohedral symmetry of the crystal, which were obtained in the successive steps of the process. Perhaps the most remarkable point brought out is the resistance to attack at an extremity of each of the three lateral axes, while in the direction of the vertical axis the solution went on very rapidly. Thus in the later stages of the process, after seven weeks, the sphere was flattened to about one-half its original diameter vertically, while in the transverse direction it had almost a triangular form.—*Trans. Conn. Acad.*, vol. viii, 1889.

13. *Seventh Annual Report of the Directors of the United States Geological Survey*, W. POWELL, 656 pp. roy. 8vo.—After a review of the organization of the Survey, and a statement of the work in progress and partly accomplished, and the reports for the year 1886 of the heads of divisions, this report contains the following elaborate papers : The Rock-Scorings of the Great Ice-Invasions, by T. C. CHAMBERLIN ; Obsidian Cliff, Yellowstone National Park, by J. P. IDDINGS ; Geology of Martha's Vineyard, by N. S. SHALER ; Classification of the early Cambrian and pre-Cambrian formations—a brief discussion of principles illustrated by examples drawn mainly from the Lake Superior Region, by R. D. IRVING ; The Structure of the Triassic formation of the Connecticut Valley, by W. M. DAVIS ; and the Geology of the Head of the Chesapeake Bay, by W. J. MCGEE. There is also a valuable paper on Salt-making processes in the United States by T. M. CHATARD. Many fine plates and cuts, mostly from photographs and maps, illustrate these papers. Those of the paper by Chamberlin are very beautiful and effective ; so also those of the Obsidian Cliff showing its columnar features, its lithophyses and spherulites ; and those of the other papers have great interest. Portions or abstracts of the papers of Iddings, Irving, Davis and McGee have appeared in this Journal. A general map of glacial striæ in the United States accompanies Mr. Chamberlin's paper.

14. *Journal of Morphology.*—The number just issued (No. 3 of vol. ii), of the always excellent Journal of Morphology, of Boston, (published by Ginn & Company), contains an elaborate and admirably illustrated paper by C. S. MINOT on the uterus and embryo, I, Rabbit, II, Man ; another, of like character, by E. P. ALLIS, JR., on the anatomy and development of the lateral line system in Amia Calva ; the two covering 228 pages and illustrated by many plates and figures in the text ; besides shorter papers on the organization of atoms and molecules by Prof. A. E. DOLBEAR ; some new facts about the Hirudinea by C. O. WHITMAN, and Segmental sense-organs of Anthropod[illegible] WM. PATTEN.

15. *On the Development of Manicina areolata ;* by [illegible] V. WILSON.—This is another of the profound researches publi[illegible]d in the Journal of Morphology, in vol. ii, No. 2. The pap[illegible] thesis for the degree of Doctor of Philosophy, at th[illegible] Hopkins University, honored by the University a year since. It is a study of the embryological development of the species of

coral mentioned, during the spring of 1887, at the Marine Laboratory of the University stationed on the island of New Providence, Bahamas. It is illustrated by seven folded plates.

16. *The Anatomy of Astrangia Danæ.* Six lithographs from drawings by A. Sonrel, Natural History Illustrations prepared under the direction of Louis Agassiz, 1849. Explanation of plates (20 pages 4to) by J. Walter Fewkes. Published by the Smithsonian Institution, 1889.—The beautiful plates here issued were drawn in 1849 under Prof. L. Agassiz's direction from material collected during the first dredging trip of Prof. Agassiz under the auspices of the U. S. Coast Survey. The vessel, the steamer Bibb, was under the command of Lieut. C. H. Davis, and the collections of Astrangia were made near Nantucket. The memoir was left unfinished by Prof. Agassiz.

III. Miscellaneous Scientific Intelligence.

1. *The International Congress of Electricians* will meet in Paris during the week from the 24th to the 31st of August next. The subjects to be considered are Measurements, Machines, Electrochemistry, Lighting, Telegraphy, Telephony and other economic applications of electricity and Electrophysiology. The fee for membership is twenty francs. All communications relative to the Congress should be addressed to M. Mascart, President of the Committee of Organization, 44 Rue de Rennes, Paris. The purpose of the meeting is to continue and complete the work of the Reunion of 1881.

2. *Geological Society of France.*—The Special Reunion of this Society will be held this year at Paris, commencing with August 18th. There will be excursions to the various localities of interest about Paris, and also under the guidance of MM. Michel Lévy and Barrois, in Auvergne and Brittany. Communications should be addressed "Secretariat de la Société geologique, 7 Rue des Grands-Augustins." American geologists have been invited, through Major Powell, President of the American Association, to attend the reunion.

3. *The Botanical Society of France*, according to a circular recently issued over the signature of M. H. de Vilmorin, President of the Society, will have a Reunion during the latter half of the month of August. M. Maury is Secretary of the Committee of Organization.

4. *American Geological Society.* The regular meeting of this Society will be held at Toronto, Canada, on the 28th and 29th of Aug[illegible]xt. The circular issued by the Secretary, Prof. J. J. Ste[illegible] of the University of the City of New York, requests tha[illegible]mber having a paper to read should send him an abstract of i[illegible]ontents and an estimate of its length before the 10th of Au[illegible]and where the author of a paper will not be present, that [illegible] paper be sent to him, by the same date, that it may be submitted to a meeting of the Council.

5. *J. A. Berly's Universal Electrical Directory and Advertiser.*—The electrician's *vade mecum*, containing a complete record of all the industries directly or indirectly connected with electricity and magnetism, and the names and addresses of manufacturers in Great Britain, America, the Continent, etc. 437 pp. 8vo. London, 1889: Wm. Dawson & Sons.—This is the eighth annual issue of this valuable directory. Its comprehensive character can be inferred from the title.

6. *Stellar Evolution and its relations to Geological Time*, by JAMES CROLL, LL.D., F.R.S., author of "Climate and Time," "Climate and Cosmology," "Philosophy of Thesim," etc. 118 pp. 12mo. 1889. London (E. Stanford).—The subjects of this volume by Dr. Croll, are: the probable origin of meteorites, comets and nebulæ, and the source from which the sun derived his energy; secondly, the evidence in support of the theory advocated derived from the testimony of geology and biology as to the age of the sun's heat; and thirdly questions relating to the pre-nebular condition of the universe, and the bearing which these have on theories of stellar evolution. Other related subjects will be considered, the Preface states, "in a future volume, 'Determinism, not force, the Foundation Stone of Evolution,' a work of a more general and abstract character, which was commenced many years ago."

7. *Graphics, or the art of Calculation by drawing lines, applied especially to Mechanical Engineering: with Atlas of Diagrams;* by ROBERT H. SMITH. Part I, 8° and 4°, Longmans. London, 1889.—The method of representing forces and other directed quantities by lines is familiarly used in every elementary text-book in statics. The determining of the magnitude of unknown quantities by geometrical constructions is older than what we know as arithmetic. But the full application of graphical methods to problems in which the quantities need be known only to two or three significant figures, particularly to engineering problems, has greatly increased since the publication of Culmann's *Graphische Statik* in 1875. That work beautifully exhibited the power which graphical construction possesses for the investigation of practical problems. A list of the more important subjects treated by Mr. Smith in this first part will show the scope of his work. He treats of Graph-Arithmetic, Graph-Algebra, Grapho-Trigonometry, Vector and Rotor addition, the Kinematics of Mechanism, flat linkages without and with beam links, and solid static structures. A second part is promised in case this volume meets with a favorable reception. It will deal mainly with synthetic problems, and with the design of structures and machines.

OBITUARY.

FREDERICK A. P. BARNARD, President of Columbia College, New York, for twenty-five years, died on the 27th of April, at the age of eighty.

INDEX TO VOLUME XXXVII.*

* This Index contains the general heads BOTANY, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY, ROCKS, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.

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