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ERRATUM.

Page 19, the top line should read:

"a stop cock in the tube *f* is then turned, cutting off the Sprengel pump;"

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[THIRD SERIES.]

ART. I.—*The Effect of a Warmer Climate upon Glaciers;* by Capt. C. E. DUTTON, U. S. Ordnance Corps.

INQUIRY into the possible causes which could have produced a great extension of glaciers has been involved in the following difficulty. While it cannot be doubted that the climate of the Glacial period was in some important respects different from the present climates the moment any attempt is made to ascertain what would be the effect, if any one of the determinants of climate were to undergo a marked variation, it is found to be so intricately interwoven with many other conditions and determinants that the ingenuity of the investigator is generally baffled in his endeavors to assign a just and proper weight to them all. The intricacy of the problem is very great and its difficulties are analogous to those which would beset the investigator who should endeavor to ascertain what would be the effect of altering the size or adjustment of any one of the parts of a very complicated machine of which the structure and operations were very imperfectly understood. Apart from this intrinsic difficulty, which is a sufficient excuse to any investigator who may have failed to reach satisfactory conclusions, there has been on the part of some inquirers a want of care and an inaccuracy of method which is not so excusable. Some of them have ventured to offer conclusions as to what would be the result of modifying one part of the machine without troubling themselves to inquire what coördinate modifications would be required by the other parts, or even whether any such modifications were at all necessary. A conspicuous instance of this faulty method is furnished by those who argue that in order to account for more extended glaciers than we now have we must infer that a more copious snowfall prevailed in the Glacial period; that to provide this more copious snowfall we must infer that the air was more moist, the evaporation greater and the temperature of the atmosphere at large higher than now; in brief, that the climate of the earth was then warmer than at present; probably by reason of a greater rate of solar radiation. The questions which this hypothesis raises are much more limited and less complex than those brought up by other theories of a glacial climate, though even here the complexity is considerable. I believe that it can be brought to the test of a decisive argument founded upon known laws and relations, and to a conclusion which will not admit of any dispute. In that conviction the following argument is submitted:

(1.) It is agreed on all sides that glaciers can form only, and will always form when, the annual snowfall is for a long term of years greater than the annual dissipation of snow by liquefaction and evaporation. It is taken for granted that nobody will question the assumption that a warmer climate will increase the annual liquefaction and evaporation. It remains to inquire whether it will also increase the snowfall; and increase it to an extent which shall more than compensate the increased dissipation.

(2.) It is sufficiently obvious that the amount of snowfall in any given locality in one year will depend upon the two following quantities: 1st, the number of days or hours during which snow is falling; or, more simply, upon the *time* of precipitation; 2d, upon the average *rate* at which it falls. The product of these two unknown quantities will express the total quantity of snow during any period. They are sufficiently general to cover all possible conditions which can affect the amount of snowfall, and the question is thus resolved into the subsidiary ones: 1st, will a warmer climate cause in any locality any increment in the time of snow precipitation in an average year; 2d, will it cause any increase in the average rate? These will, so far as practicable, be considered separately. It will be most convenient to examine. first, the rate of precipitation. But before doing so it will be well to advert to two or three familiar but most essential facts. They are truisms, indeed, but are necessary for the continuity of the argument.

(3.) Precipitation takes place when saturated air is cooled; never otherwise. If the two limiting temperatures between which cooling takes place are both above zero (centigrade) the precipitation is necessarily all rain; for the precipitate must take the temperature of the menstruum. If the two limiting temperatures are both below zero the entire precipitation is snow. If one limit is above and the other below zero a part of the precipitation is rain and the other part snow. From this it follows that *whatever moisture air may contain in excess of the quantity which is necessary to saturate it at zero can fall only as rain; and the only available supply which can form snow is a portion of the moisture which is required to saturate air at zero.*

(4.) To avoid circumlocution it will be considered, unless distinctly specified otherwise, that the air is saturated with moisture at all temperatures. The amount of precipitation is an increasing but complicated function of the amount of fall of temperature. Without such a fall there can be no precipitation. But equal falls do not give the same amount of precipitation in different parts of the temperature scale. Thus a fall from 20° to 19° precipitates much more than a fall from 10° to 9°, and this much more than from 0° to −1°. The exact form of the function representing the relation of precipitation to equal heat-changes is not known, but it may be given very approximately at practical temperatures by the ordinary empirical curve of saturation used as a graphic representation. In reality, the amount of precipitation is the integral product of two variables, one expressing the amount of heat-change (or number of degrees fall of temperature), the other expressing the part of the temperature scale in which the cooling occurs.

(5.) In proceeding to investigate the questions formulated as above we are met at the outset with a difficulty which must be at once disposed of. This is the extreme irregularity of precipitation not only in different parts of the year but as between different years. In most places not one day in four is wet. The intervals of dry weather vary from a few hours to months. The storms are of the most unequal duration and copiousness. In any two consecutive years there is no correspondence in the calendar dates on which the storms occur, nor is the yearly or monthly or seasonal precipitation the same. How then can there be said to be any such thing as a rate of precipitation, or any rationally expressible time of snowfall? The answer is, that a great glacier is the work of centuries of accumulation. These factors, seemingly so lawless and so heterogeneous from day to day and from year to year, and so frequently altogether discontinuous, have, in the course of many centuries, each an average, and these averages are susceptible of perfectly rational expression. Suppose we had thrice-daily observations for a thousand years of all the meteorological conditions of a locality. The average of these observations would, in respect to each factor, give perfectly definite values and relations. Let us therefore consider an imaginary year which shall represent the average conditions of a thousand years. It would have such characteristics as the following: In most localities every day in the year would show some precipitation, but with one or more maxima in one or two parts of the year, and a corresponding number of minima. In a few localities it is just possible that some part of the year might show no precipitation at all, the function becoming discontinuous. Each day in the year would have some definite rate of precipitation (quantity divided by the time). Each day would have its proper seasonal temperature and variations of temperature and all would follow some expressible law determined by the general and local conditions operating upon the climate of the locality in question. It is just these averages which determine the annual rate of growth or decline of a glacier in any locality, or whether there shall be any glacier there at all.

(6.) Let us now proceed to consider the effect of a change of the amount of solar radiation upon rate of precipitation—not snowfall just now, be it observed, but the entire precipitation both rain and snow. We shall separate the snowfall afterwards. This is quite necessary, for the omission to consider the total effect of a general increase of climatal temperatures has been the stumbling-block of quite a number of those who have appealed to it.

The *rate of precipitation* (i. e. quantity of precipitation per unit time—which time-unit may be taken very small, say one hour, or even less,) depends upon three factors: 1st. The quantity of air which undergoes cooling; 2d. Upon the rate of cooling; 3d. Upon the temperature at which the cooling begins. These three factors involve, either explicitly or implicitly, all known conditions which can possibly affect the rate of precipitation, except physical constants, which, of course, need not be considered. Thus the *amount* of cooling, i. e. number of degrees fall of temperature, is implied in the second factor; for this amount is simply the rate multiplied by the time, and the time is now unity.

(7.) The quantity of air which at any time is yielding moisture to any locality is that quantity which blows over it as wind. If the atmosphere were always motionless its hygrometric changes over the land would be limited to evaporating and condensing the same water over and over again; and by absorption into the earth or by running into the sea even this water would soon go out of reach and precipitation would cease altogether. The winds are the vehicles which bring moisture, and as fast as one body of air is depleted another body of it takes its place. The quantity of air, then, which is to yield moisture is simply proportional to the velocity of the wind.

There is no doubt that the faster saturated air is supplied to a locality where it is cooled the faster (*ceteris paribus*) the rain or snow will fall. But the ratio of increment of wind velocity to increment of precipitation is not a simple one. It will be given farther on. Just here we are merely concerned with the inquiry, How would this air-supply or wind-velocity be affected by a warmer climate? Would it be increased? and, if so, in what ratio? Undoubtedly it would be increased. As regards the ratio, an answer will be attempted presently. The velocity of the wind is intimately associated with the second factor, rate of cooling, and it is first necessary to have the entire range of facts before us so as to dispose of the matter in its entirety.

(8.) Let us, then, consider the second factor which affects the rate of precipitation, viz: the *rate at which air cools;* and let us afterwards inquire how it would be affected by a change of climate consequent upon increased solar radiation. There are four known ways in which the cooling of air occurs: (1) by the work done in expansion; (2) by contact with colder surfaces; (3) by commingling with colder air bodies; (4) by excess of radiation over absorption of heat.

(9.) A moment's reflection will convince us that the first three modes of cooling are dependent altogether upon movements of air. In order that air may expand it must move upward; so, also, in order that it may be brought into constantly renewed contact with colder surfaces or may continuously intermingle with colder air bodies, it must have movement, and, therefore, velocity. The rates of expansion, contact and commingling are plainly proportional in a simple ratio to the velocities of the respective movements which cause them. Again comes up the subject of the cause, quantity and rates of these movements and here is the place to inquire how such movements would be affected by a warmer climate. This subject can be reached only by going back to the causes.

(10.) In an ultimate analysis the cause of air-movements is found in the incessant and unequal disturbances of the thermal equilibrium of the atmosphere. The sun's radiant energy falls unequally at any instant upon different places. It falls unequally at morning, noon and night; unequally upon different zones of the earth. It falls upon surfaces in the same zone which are heterogeneous with respect to their coëfficients of absorption; as, for example, land and sea. It penetrates an atmosphere which has unequal absorptive capacity in its different strata. The result is a disturbance of the temperature-equilibrium of the atmosphere in numberless places at once and incessantly. Consequent upon this is a disturbance of the statical equilibrium of the air; and further consequent is the rush of air to find a new equilibrium. Any disturbance of a body from a position of stable equilibrium which it seeks to reëstablish, is a case of the conversion of kinetic into potential energy. The radiant energy which falls upon the earth is partially converted into potential which is in turn expended in producing the movements of the air. Having referred these movements back to their cause and having put the conditions of the question into the most general and comprehensive form, we may now ask again, would the wind-potential be greater if solar radiation were to increase? Undoubtedly it would. But in what ratio? To this latter question, I believe, a sufficiently approximate answer can be given. The problem is purely a thermodynamic one.

(11.) The atmosphere, considered with reference to its winds, may be regarded as a series of thermodynamic engines operated by an expansible and nearly perfect gas receiving heat and converting it into work. The amount of energy available for this work is directly proportional to the difference (in any given case) between the *absolute* temperature which the body of air performing work possesses, and the absolute temperature which is necessary for its statical equilibrium. We have seen that the causes which determine these differences of temperature—the sphericity of the earth, its rotation and seasons, its heterogeneous surface—are in the main fixed in nature and constants; while the motive power is the sun's radiant energy. And since the solar radiation and the temperature-differences of the air are both heat-quantities, pure and simple, we have, apparently, no alternative but to conclude that they are proportional to each other. But the exact form of the ratio is unknown. Nevertheless, if we assume it to be a simple ratio for any range of variation in the amount of solar radiation which could be reasonably postulated in connection with the present discussions, we shall certainly commit no large error. Still less shall we err if we assume that the inequalities in the heating of the air are proportional in a simple ratio to the mean absolute temperature of the air at the earth's surface, and if that temperature were raised by increased solar radiation the inequalities which cause the winds would increase in the same ratio.

(12.) How great an increase in the mean temperature of the earth's climates would the advocates of a warm glacial climate be disposed to postulate? Would 20° C. be sufficient? Taking the mean temperature of the earth's atmosphere at the surface to be (274°+16°) C. and adding 20° to it, we have 310°, and the ratio of 290 : 310=1·07, or an increment of seven per cent in the absolute temperature of the atmosphere. Assuming that the wind potentials are every where increased in like ratio, and remembering that the velocity of the wind is proportional to the square root of the energy expended in producing it, the resulting mean velocity of the winds would be $\sqrt{1{\cdot}07}=1{\cdot}035$, or about three and one-half per cent greater than at present. But suppose the wind potentials increased in a geometrical ratio with the temperature of air. The result would of course depend altogether on the form of this ratio. But taking it in its simplest form (logarithm of the potential simply proportional to the absolute temperature) the increment in the wind-velocity, resulting from 20° increase of mean temperature, would be less than six per cent. Larger geometrical ratios can of course be arbitrarily postulated, but they would require a very stalwart defense to entitle them to a hearing.

(13.) Let us now go back and review our first two factors which determine the rate of precipitation; (1) air supply, (2) rate of cooling. We have seen that both are dependent—the first wholly and the second in great part—on the velocity of the winds. The first factor, air-supply, is evidently directly proportional to the velocity with which the winds move. But we have found reason to believe that this velocity would not be very much increased, though it would to some extent, by an increment in the mean temperature of the atmosphere which most thinkers would probably consider very large. The same conclusion attaches to the second factor, rate of cooling, in so far as it is dependent upon the velocity of the wind. But we have noted that this second factor depends for its value upon four subordinate or component factors, commingling, expansion, contact, and excess of radiation over absorption of heat. The first three depend for their value upon the velocity of air movements solely. The fourth component (excess of radiation over absorption) presents other considerations.

(14.) In the long run, radiation and absorption of heat by the atmosphere are equal. For if one or the other predominated continuously the air would grow continuously warmer or colder. Practically during any short period of time, and in every locality one or the other does predominate; but the ratio of the two perpetually oscillates to and fro about an equality. Now if air were motionless for a long period of time this oscillation of temperature would soon cease to precipitate moisture upon the land though the vibration might still continue. But in reality fresh air laden with new supplies of moisture is constantly replacing the bodies of air which have been depleted. Again we find that the movement of air is a vital consideration. But the nature of the dependence of that portion of the cooling caused by excess of radiation upon the velocity of the wind is different from that of commingling expansion, etc. In the latter operations their efficiency is proportional in a simple ratio to the velocity. Not so the efficiency of radiation. The law in this case is a more complex one and the ratio has less value than a simple ratio. Inasmuch as it can be made intelligible only by the use of an algebraic expression, the analysis of it is given in the appended note.* The general result of that analysis is that when air moves from a warmer to a colder place, where it is cooled by radiation, the amount of cooling (by radiation simply) over any given area, does not increase in the same ratio as the velocity of the wind, but in a ratio which itself diminishes rapidly as the velocity increases.

(15.) We have thus examined the essential features of the first two factors which determine the rate of precipitation with reference to the changes they would probably undergo if the earth's climates became warmer. These changes we find to be very small for any increase of warmth which would be postulated. So small are they that hereafter they will be considered as unimportant.

(16.) The third factor which determines the rate of precipitation depends for its value upon the temperature at which the cooling of saturated air begins. It is by far the most important factor of the three. Its value is directly proportional to the maximum density of water vapor considered as a function of temperature, and it is well known that this density increases with the temperature, in a very rapid ratio. A roughly approximate idea of it may be derived from the fact that at such temperatures as we are most concerned with, this density, or, what is equivalent, the so-called capacity of air for moisture, is about doubled for an increase of 10° C. in the temperature of

* Let us consider an area of unit width over which air is passing. Suppose that while it is passing, some cause, the nature of which need not be specified, determines an excess of radiation over absorption of heat. It must have some "potential," which is measured in this case by the excess of the temperature of the air over that temperature at which radiation and absorption would become equal. The law is that the rate of radiation at any instant is proportional to the instantaneous value of the potential. But as the air cools, this potential is constantly diminishing. Let then P be the initial value of the potential when the air first reaches the supposed area and let p be its value after any time t, during its passage over it. Then the change dp in the value of the potential during any time dt (taken so small that during its duration p may be regarded as sensibly constant), is expressed by the Eq. $-dp=pdt$. Integrating this Eq. between the values P and p for the potential and between the corresponding values of 0 and t for the time, we have $\log p - \log P = \log \frac{p}{P} = -t$, and $p = P\varepsilon^{-t}$. Now the total cooling during the time t of any unit volume of the air is equal to its loss of potential; that is, $P - p = P(1-\varepsilon^{-t})$. If t be taken as the whole time of passing, and if v represent the velocity, then $t=\frac{1}{v}$. Substituting this expression for t, we shall have the amount of cooling of unit volume of air by radiation while passing over area of unit width with the velocity v. But the quantity of air which passes is directly proportional to the velocity, and multiplying the expression by v we obtain the Eq.: Total cooling over given area $=Pv(1-\varepsilon^{-\frac{1}{v}})$. The examination of this term shows the general result stated in the text. The potential P may also be a variable and have a slightly increased value under a warmer climate, but any such increment would of course be very small.

the atmosphere. So obvious are the considerations which arise from this fact that no further discussion of it is necessary.

(17.) We find then that a warmer climate would probably have the effect of increasing the rate of precipitation from causes which may be grouped into three categories. First, the quantity of air which supplies the moisture would move a little more rapidly to the places when it cools. Second, the rate of cooling which causes precipitation would be a little faster. Third, since the cooling would occur in a higher range of temperature, the amount of precipitation per unit volume of air per unit degree of cooling would be rapidly increased. The last factor is very much more important than the other two. Hence the rate of precipitation would be largely increased by an increment in the mean temperature of the earth's climates. The general conclusion indeed is much too obvious to be disputed. But it has been deemed essential to go over the ground upon which it rests and analyze the component causes because they will come into service in the subsequent discussion.

(18.) Having found that the mean *rate* of precipitation would be largely increased by a warmer climate, the next step is to inquire whether the *time* of precipitation would also be increased by the same cause. Here as before we must recur to the causes and conditions, which fix for any locality, the number of rainy days and hours of the average year; but we only need to advert to them in their most general forms. We may recall again the statement that precipitation takes place when saturated air is cooled—never otherwise. It cools when it moves from a place where the local conditions make it warmer, to a place where the local conditions make it cooler. Again we find that the movement of air becomes an inseparable consideration. And in truth, we know by the commonest experience, that in almost all regions except very arid ones, the winds from certain directions bring wet weather, while those from other directions bring dry weather. The logic of it is, that the former winds come from warmer places laden with moisture and are cooled, while the latter come from places where they were colder, and become warm and therefore dry. The causes then which control *the directions* of the winds are the determinants of how much of the year shall be foul weather and how much fair. It may also be suggested that the relative humidity of the air is another determinant. But upon inspection it will appear that this possible factor is partially implied in the other, and we must not try to make our factors do double duty. In part, however, it presents independent considerations which will be adverted to presently.

(19.) The question then is how would a warmer climate affect the directions of the winds in any locality, and their relative humidity? There are some winds like the monsoons, the trades and anti-trades which appear to be governed by general laws, which (for better or for worse) have been formulated by theorists. But it seems quite certain that the trades and anti-trades would blow as unceasingly, and in the same directions under a warmer climate as under the present one; that the monsoon winds would begin and end at the same times of the year as they do now; and that this is true of all winds which have the seasonal or monsoon character. And they would presumably bring the same quota of rainy and dry days—neither more nor less. There are also what may be termed irregular winds of which the cyclone class are examples, but for the caprices and anomalies of which no law has been found. In high latitudes the winds are vacillating and their vagaries are still more obscure. Have we any reason to suppose that these winds as yet anomalous would yield any more wet days if the climate were warmer? I see none. Their alternations might be a little more rapid, and there might be a greater number of them in the course of the year, but the same reasoning would lead to the inference that the average duration of each oscillation would be diminished in exactly the same ratio that their number was increased, and so the total time would be unchanged.

(20.) As regards the humidity of the air it would seem as if the advocates of a warm glacial climate had confounded absolute humidity with relative. If it could be made to appear that the relative humidity would be greater under a warmer climate, the proof of it would have great weight. For no doubt cooling air often fails to precipitate because its relative humidity is low: and greater relative humidity would obviously cause a certain number of rainy or snowy days, where now there are merely cloudy ones. But there appears to be no reason for supposing it would be any greater. Indeed, is there any greater relative humidity to-day in tropical regions than in extra tropical, in the air as it leaves the ocean, or in air which has passed through equivalent changes and travel over the land?

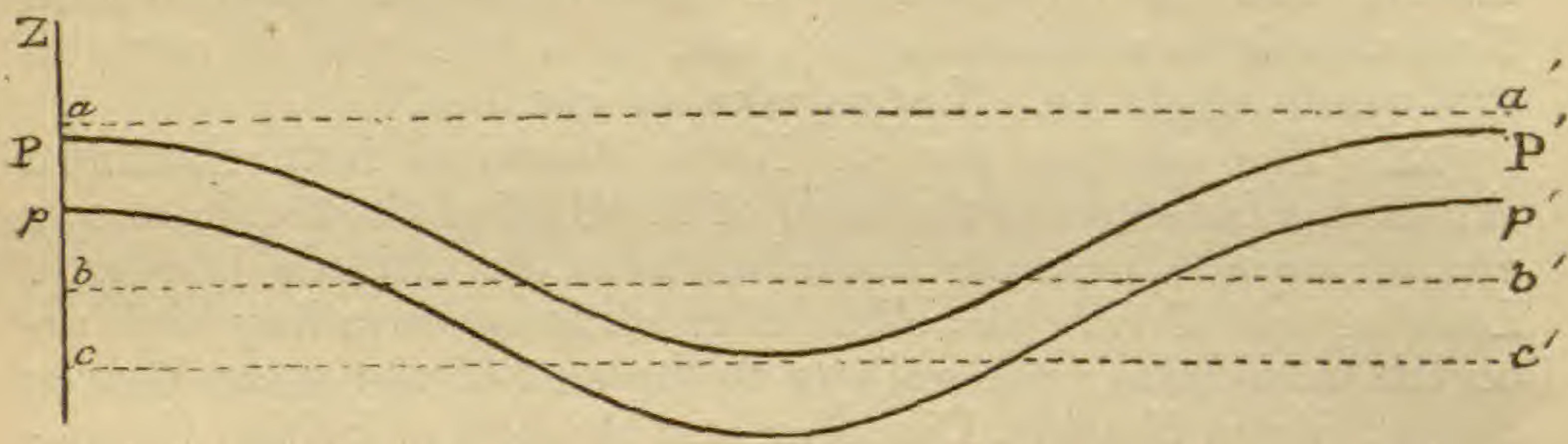
(21.) We do not find then any reason to suppose that either the directions or relative humidity of the winds has any relation whatever to the intensity or degree of solar radiation; but that so far as known laws can guide us they depend upon conditions which are exclusively terrestrial and therefore constant for all values of solar radiation. And as I am unable to conceive any possible cause of change in the time of precipitation which is not directly referrable to these two determinants I see no reason *founded on known causes* to suppose that a warmer climate would affect the time of precipitation in any manner whatever. Possibly other inquirers may be more ingenious and more fortunate. Possibly the unknown operations of the intricate machinery of the winds might be made to yield another result to more subtle analysis. And indeed I am tempted to suggest here a line of thought which if carefully pursued might lead to some modification of the above provisional conclusion; though having had no opportunity to give it proper consideration I am unable to venture any opinion as to what the character of that result might be. Let us take an instance.

(22.) The western part of North America, from Southern Alaska as far south as the head of the Gulf of California, shows climates which increase in moistness as the latitude increases. Leaving out of view the climatal conditions prevailing high up on the mountains; the valleys to the east of the great barrier ranges, Sierra Nevada, Cascades, and Rockies of British Columbia, grow dryer toward the south. The rainfall—the number of rainy days or time of precipitation decreases with the latitude. The explanation of it I have suggested in a former paper of this Journal about as follows. In the northern portions of the region above specified the adjoining tracts of the Pacific Ocean are relatively warmer than the land; in the southern portions they are relatively colder. The prevailing winds are from the west. In the northern parts they are, during the greater part of the year, cooled as they pass into the interior of the continent, while in the southern parts they are heated. Hence at the north the same wind from the same ocean is a wet wind while in the south it is dry. Now it is quite conceivable (though from want of full consideration I should not dare to offer it as a probable result) that if solar radiation were to vary, the temperature-relations as between land and sea would also be profoundly changed. It is conceivable if the solar radiation were greater that the land at the north might heat the Pacific winds instead of cooling them. It is conceivable that they might cool them instead of heating. Both the winds and the lands would be warmer, but which of the two would have received the larger increment of temperature is the indeterminate question.

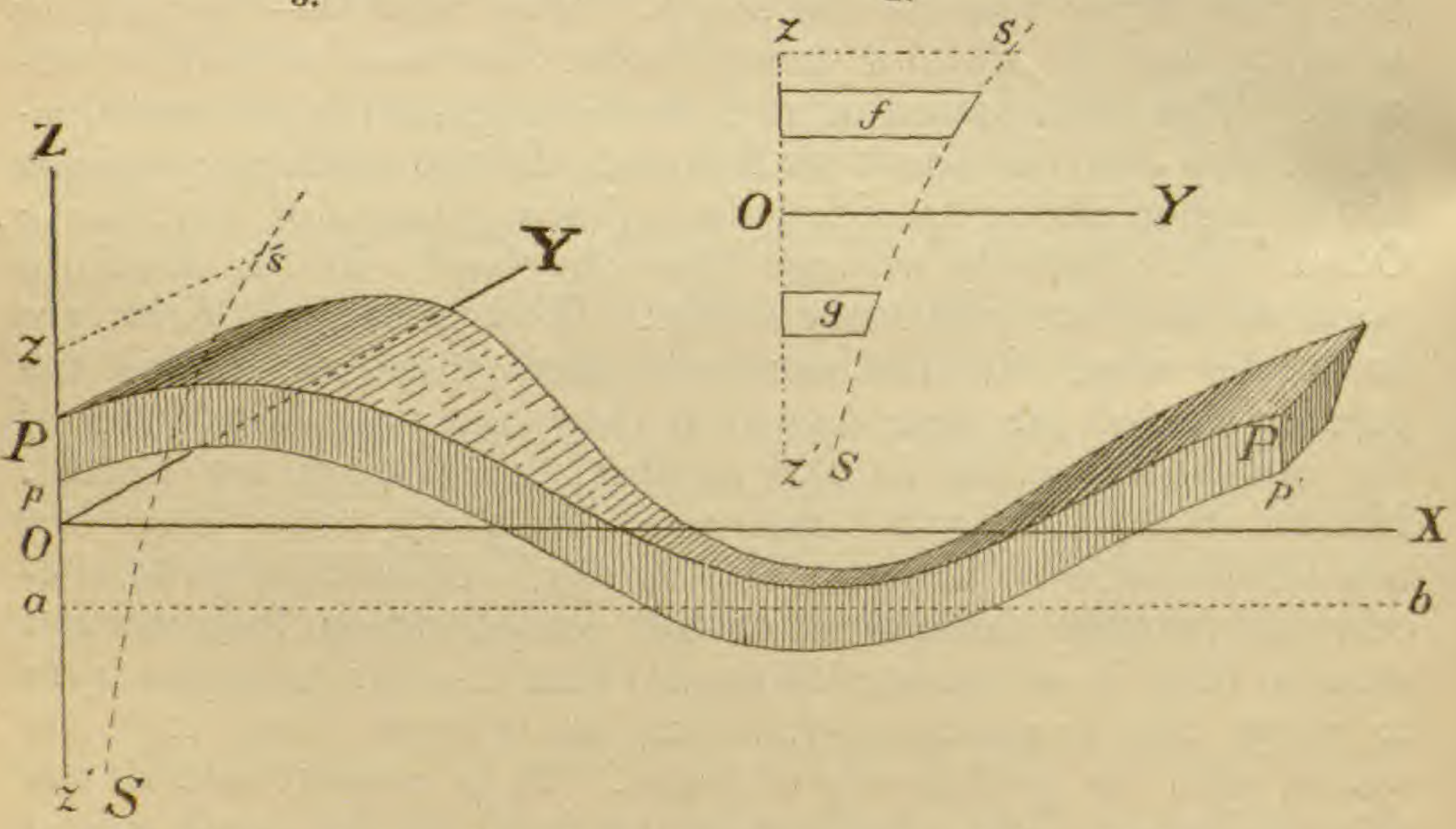
(23.) But for the present the only logical course which is open to us is to confine ourselves to plain and obvious results of physical laws. It is idle to argue about things which might be, or about things which in the present state of human knowledge are indeterminate. We have no apparent resource but to assume that a warmer climate would have no effect whatever in the way of increasing or diminishing the number of wet days and hours of an average year, and this is the assumption here made. The burden of proof is upon those who would argue otherwise.

(24.) We may now proceed to separate the snowfall from the rainfall. In a preceding paragraph attention was invited to the very obvious fact that moisture cannot be condensed in the form of snow at temperatures above zero. This fact with equally obvious ones connected with the changes of seasons are sufficient for whatever separation is required. In fig. 1, let the

1.



3. 2.



axis of Z be the scale of temperatures, and let PP′ represent the temperature of precipitation throughout an average year—the higher parts of the curve corresponding to summer and the lower parts to winter months. Draw *pp′* below PP′ at such a distance as will adequately represent in all parts of the year the temperature to which the air falls in cooling. The two curves need not be exactly alike nor nearly so symmetrical as they are drawn. The forms here given merely express their general nature. The space between the two curves expresses the integral amount of cooling which the air undergoes in order to precipitate. If now the point *b* on axis Z be selected as the position of zero temperature, then so much of the space between the curves as lies below *bb′* represents the integral amount of cooling available for snow. If the climate to which the foregoing is applicable be rendered warmer then the position of zero must be taken at a lower point on Z, as at *c*, or what amounts to the same thing the curves must be drawn higher up relative to the zero line. Then the integral amount of cooling available for snow will be represented by the space below *cc′* and within the two curves. It is evident that according to this construction the warmer climate would decrease the amount of cooling available for snow except in the case of one so cold that the temperature is always below zero—which may be represented by drawing the zero line above both curves at *aa′*.

(25.) But the same amount of cooling produces different amounts of precipitation in different parts of the temperature scale. While the amount of cooling available for snow has been diminished the efficiency of what remains has increased. In fig. 2, let Z, as before, be the axis for temperatures, and let *Ss* be the curve of saturation or maximum vapor density of water considered as a function of temperature. Let the vertical dimensions of the figures *f* and *g* represent equal amounts of cooling. Then their areas will exemplify the different amounts of precipitation in different parts of the temperature scale produced by equal amounts of cooling. To combine the two factors three axes are necessary.

(26.) In fig. 3, draw the three rectangular coördinate axes, OX, OY, OZ. Upon the plane YZ draw a convenient portion of the saturation curve *Ss*. Conceive the plane figure *Sszz′* to be a generatrix moving along the axis OX in positions always parallel to ZY. The line *zz′* will generate a vertical plane face, the line *zs* a horizontal plane face, and the line *Ss* a curved face of an indefinite solid. Conceive now two corrugated cutting edges similar to that of a sheet of corrugated iron and having the curvature generally expressed in fig. 1, by the curves PP′ and *pp′* be passed into the indefinite solid, moving parallel to YZ, so as to cut out of it the shaded solid as drawn. This definite solid represents graphically the annual precipitation regarded as a function of the temperature and seasonal changes. The axis Z represents temperature; and let the zero point be arbitrarily fixed at the origin O. To represent the effect of an increased general temperature it would not be proper in this case to locate the zero point lower down on Z, but the solid must be cut anew from the indefinite solid by passing into it the corrugated edges higher up. The amount of snowfall is represented by that portion which lies below the plane XY.

(27.) In this graphic representation the annual precipitation is made to depend upon three functions between two variables. The two variables are temperature and time. The argument is that precipitation takes place only when saturated air is cooled. The quantity of precipitate which cooling air will yield (per unit volume of air) is dependent upon the extent or amount of cooling, i. e., the difference between its initial and final temperature, and upon the temperature at which the cooling begins. This is expressed by the length and positions of the vertical lines in the front face of the solid. The curved line PP′ represents the locus of these initial temperatures for every day in the year, and the line *pp′* represents similarly the locus of the final temperatures. I have drawn them about equally apart for the whole year. As a matter of fact they should be unequal, most probably; for the range of cooling is not ordinarily uniform in the storms of different parts of the year. But it will appear farther on that this is of no consequence so far as the final conclusion is concerned. The reader may imagine the intervals between PP′ and *pp′* to be arranged in any way he likes provided it conforms better in his judgment to the facts in any case. The final conclusion will cover every admissible modification. Perhaps it will be said that at any given *phase* of the year when two consecutive years are compared there will be no definite initial and final temperatures and the amount of cooling even on corresponding dates will be very different. Quite true; but the illustration contemplates the averages of a very long term of years—hundreds of years or even thousands—and these averages will have perfectly definite initial and final temperatures of cooling, and every day and hour of the year is thus supposed to have definite conditions suitable to rainfall—unless indeed we consider a locality where during some part of the year rain *never* falls. In that case the curves become discontinuous, as does the solid also. The z ordinates then are a simple function of the temperature.

(28.) The y ordinates represent the quantity of moisture which unit volume of air precipitates at any temperature. They are proportional to the maximum vapor density of water which may be expressed by the product of an arbitrary constant into a term involving no other variable than temperature. Hence the y ordinates are functions of temperature. They express the efficiency of the cooling at different temperatures and therefore the differential amount of precipitation which any indefinitely small cooling will produce at any temperature. They may be combined with the z ordinates so as to yield a single function expressing the instantaneous rate of precipitation. The areas of the figures f and g, fig. 2, or any other cross-section of the solid by a plane parallel to YZ, will express the rate of precipitation regarded as a function of temperature. The x ordinates represent time which is used here as the independent variable. The temperature itself, and therefore the y and z ordinates, are harmonic functions of the time, the form of which is not exactly known.

(29.) The first effect to be considered is the shortening of the time of snowfall, so far as this time depends upon the changes of seasons. It is plain that the increment of temperature due to increased radiation must pervade every portion of the earth and throughout the entire year. Quite likely the increments would be unequal in different latitudes and unequal at different seasons. Still there would be an increase at all places and at all seasons. The summer would come earlier and stay longer; that is to say, the time during which it would be cold enough to snow would begin later in the autumn and end earlier in the spring.

(30.) The second obvious effect is that the rate of precipitation, whether for rain or snow, would be increased. For by the hypothesis the precipitation would be the result of cooling air at a higher temperature than before and equal amounts of cooling cause a larger amount of precipitation, the higher the temperature at which the cooling begins. In some slight degree the supply of air yielding snow would probably be increased through a small increase in the velocity of the wind, but this increment is considered as trifling.

Thus the time of snowfall would be diminished, but the average rate of snowfall would be increased. The amount for the year is simply the product of the time multiplied by the average rate of snowfall. Since one of the factors would be decreased and the other increased by the supposed change, the question hangs upon the answer to the inquiry—which of the two factors increases or diminishes in the higher ratio with the temperature. To this final question the general answer is that *the time of snowfall would decrease in a faster ratio than the rate of snowfall would increase, and the total annual snowfall would be diminished by a warmer climate.* There is an exception or rather a class of exceptions which will presently be adverted to. The proof of the proposition is simple and conclusive.

Since the warm weather is extended further into the autumn and begins earlier in the spring the only effect of the warmer climate is to push the snowfall of October (wholly or in part) forward into November, and the snowfall of November forward into December; to push the snowfall of March (wholly or in part), back into February, and that of February back into January. The snowfall which originally belonged to December and January, has simply disappeared. Meantime the former heat of June comes now in May and the heat of July goes over into August.* Two new thermal months have made their

* It will of course be understood that I use the word "month" here to avoid a circumlocution. I use it as a general expression for a short period of time, having a variable relation to the phase of the year, and a definite relation to the distribution of temperature throughout the year. This period may be of any length, from one day to six months.

appearance, hotter than any ever known before, and add their potency to the annual liquefaction. A period of snowfall in midwinter has disappeared without compensation; a period of melting heat in midsummer has made its appearance as a clear gain to the total liquefaction. This is the net result of the warmer climate.

(31.) Let us examine this a little more in detail, taking a special case by way of illustration. Let us consider the climate of a region situated in rather high latitudes, say in the neighborhood of 50° to 55°, where the present mean temperature of precipitation touches zero on the 10th of October. For three or four weeks before and after that date the storms will sometimes yield rain, sometimes snow—the rain at first being more and then less and less frequent until nothing but snow falls. Similarly in the spring (April 15th?) there is a date at which the mean temperature of precipitation rises up to the zero line and passes above it with a period on either side in which snow and rain alternate—the snowfall gradually vanishing. Thus we have four seasons, one of summer rainfall, one of winter snowfall, and two seasons (autumnal and vernal), where the rains and snows are dove-tailed with each other. It is also necessary to remember that we are now considering an average year as before described, and we must stop a moment to consider the elements of which that year is made up. Every calendar date has a certain time, rate, temperature, and amount, of precipitation which is found by averaging the supposed observations of precipitation occurring on that date for hundreds of years. It is immaterial whether we consider any particular date as having a certain number of wet and another number of dry hours, occurring as one storm, one daily interval of clear weather, or as hundreds of short intervals of a minute or two duration alternating with as many short dry intervals.

Suppose now a warmer climate supervenes with a heat increment sufficient to postpone the time at which the mean temperature of precipitation touches zero until the 15th of November. In that case the 15th of November takes the precipitation which now pertains to October 15th, subject to a qualification which will be mentioned speedily. November 20th takes the precipitation of October 20th and so on. Thus the winter is driven forward in time. On the other hand the spring comes earlier; and, in inverse order, the winter is driven backward. The former may be called the procession of snowfall, the latter the recession of snowfall. In mid-winter the procession and recession meet and crowd out entirely a certain period of time in which snowfall formerly occurred. But the rate of precipitation during mid-winter has increased because the temperature is now higher at which precipitation takes place. But this higher rate is merely the same rate which prevailed formerly at an earlier date. In the first half of the winter, the original rates and amounts of precipitation have only been postponed to later dates without change of value. In the last half of the winter the original rates and amounts of precipitation have merely been anticipated on earlier dates without change of value. The rates and amounts which have been anticipated and postponed have taken the place of rates and amounts which have disappeared entirely and without compensation.

(32.) Let us now look at some of the qualifications to the foregoing conclusion. It is implied in the argument that during our average year, the number of wet and dry hours, respectively, would be sensibly the same on each and every date. As a matter of fact this is not true. Certain seasons are dryer or wetter than others, i. e. have more or fewer rainy hours per day or per month. How would our conclusion be affected by introducing this consideration into the argument? That will depend somewhat on the nature of the distribution of wet and dry hours throughout the year. In the first place it may be remarked that this distribution is governed and regulated partly by local causes and partly by fixed astronomical causes or relations. Presumably the causes would be constant for all values of solar radiation. If wet weather is more frequent near the equinoxes than in mid-winter, the argument would become *a fortiori*. But if wet weather has its maximum in mid-winter, the argument would be weakened and in an extreme case might be so affected as to show a greater snowfall with a warmer climate.

(33.) There is also one general exception which is independent of the distribution of wet weather throughout the year, and in which a warmer climate would produce increased snowfall. If a region exists any where on earth, such that the mean temperature of precipitation all the year round is considerably below zero, then a warmer climate will—up to a certain limit—have the effect of increasing the rate of precipitation without affecting the time, and hence there will be an increase of snowfall. But the moment the temperature of precipitation passes above zero in any part of the year, then the shortening of the time of snowfall begins and proceeds at maximum rate of shortening for any further increase of temperature, and thereafter the conversion of snow into rain will subtract more snow than the increased temperature of precipitation will add.

(34.) The possibility of obtaining a greater snowfall by a warmer climate then is limited to such localities as are now extremely cold—to localities situated either very near the poles, or at altitudes far above the present line of perpetual snow. In all other places a warmer climate would add to the rainfall and actually subtract from the snowfall, while increasing at the same time the annual liquefaction. The advocates of a warm, glacial climate have committed a most extraordinary oversight in failing to perceive that the moisture, which they would add to the atmosphere, can fall as rain only. Not until the air has discharged as rain all the moisture in excess of the quantity which saturates it at zero, can it begin to yield snow. This consideration alone ought to have deterred them from such a doctrine and its mere statement might seem sufficient to refute the idea. But it has been deemed proper to investigate the subject at some length, and to examine each component factor in its proper relations, in order to make ourselves sure that what seems to be a complete answer at the first glance, is still complete, however it may be tested in detail.

ART. II.—*On the application of Wright's Apparatus for distilling, to the filling of barometer tubes;* by FRANK WALDO, Computer O. C. S. O.

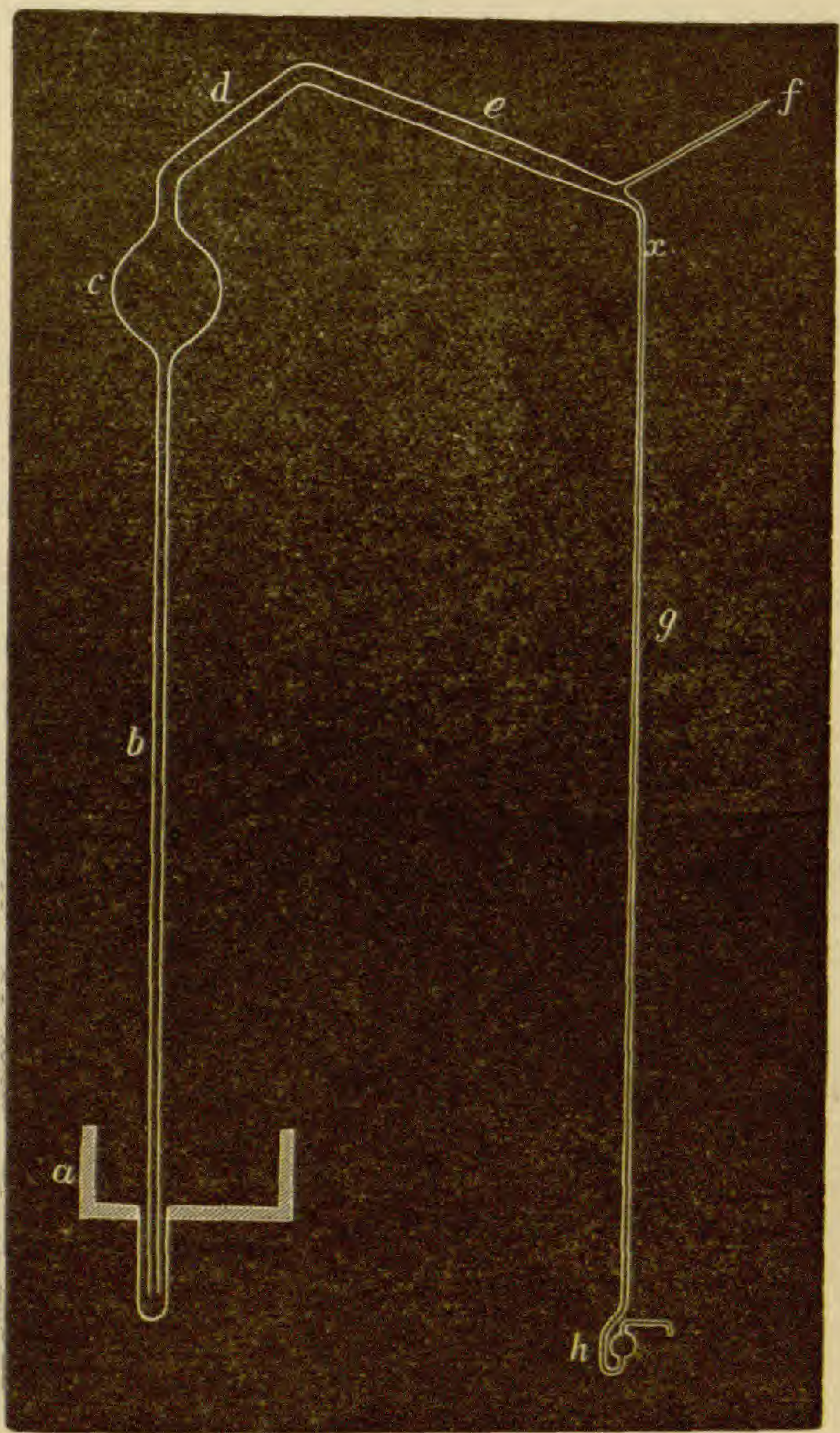
[Communicated by permission of the Chief Signal Officer.]

REFERRING to the original diagram by Professor Wright (page 480 this Journal, vol. xxii, December, 1881) and which is here reproduced by his permission, it will be seen that *a* is a vessel full of impure mercury, *b* a tube about thirty inches long; *c* an enlargement of *b*; *d* and *e* tubes inclined in opposite directions; *f* an arm for connecting with a Sprengel pump; *g* a tube a little over thirty inches long; *h* a reservoir with an outlet to the air; *h* is filled with pure mercury.

The air is now exhausted through *f*; the mercury rises in *b* and *g* until C is partially filled; a Bunsen burner is placed under *c* and the mercury distills over into *g* and flows out through *h*.

If now *g* is cut off at *x* a few inches below the junction of *e* with the arm *f* (the part *h* being no longer used) and a glass cock be inserted at *x*, then by means of a short rubber tube this cock can be connected with the open end of the barometer tube to be filled, which latter will take the general position of the whole tube *g* of Professor Wright's drawing.

The rubber tube must be covered with melted sealing wax. The impure mercury in *a* should first be washed in acids and dried before introduction. At the beginning of operations *a* is full of impure mercury, but the rest of the apparatus contains only air. The Sprengel pump is set in motion and gradually exhausts the air from *b*, *c*, *d*, *e* and the barometer tube, until no air bubbles can be seen in the running mercury of the Sprengel pump, and until the sharp click is heard when the drops of mercury fall. The tube *f* is then sealed or a stop cock in it turned, cutting off the Sprengel pump; the Bunsen burner under *c* is lighted, and the mercury will distill over into the barometer tube, which will thus be filled without allowing the mercury to come into direct contact with the air.



The barometer tube should be constantly watched in order to detect any air bubbles that may be carried over; when seen they must be cooked out by heating the tube slightly by means of a Bunsen burner. When the barometer tube has become filled with the mercury, the cock at *x* can be closed, the sealing wax broken and the tube replaced by another.

This method is similar to the one employed by Wild at St. Petersburg, only he uses the Weinhold apparatus.

Hamburg, June, 1883.

ART. III. — *A New Device for Measuring Power;* by C. F. BRACKETT, Physical Laboratory of the College of New Jersey.

THE following account of a method of measuring the energy expended on or rendered by a dynamo- or a magneto-machine will be of interest to those who have to do with the production of electricity in the large way in which it is now employed in the enterprises of the day.

The machine is so supported, on uprights, that it can freely turn through a small arc of a circle whose center lies in the geometrical axis of the armature. The support may be effected by means of knife edges or by means of smooth cylindrical bearings, attached directly to the machine or to a cradle on which the machine rests. In the latter case the cradle is made adjustable so that the bottom or floor can be raised or lowered, thus permitting machines of different construction, when placed thereon, to be brought into proper positions as regards axis of revolution and points of support. When the machine, thus mounted, is set in rotation, with closed circuit, the mechanical couple set up between the armature and field magnets tends to make the latter revolve in the same direction with the armature. The value of the couple, thus operative, and which we desire to know, will be known if we know the value of the couple, equal and opposite in direction, which is required to hold the machine fixed in its position of equilibrium. A lever arm is fixed to the machine or cradle in a horizontal position and provided with a sliding weight of known value, sufficient to hold the machine fixed in its position of equilibrium when in the performance of its duty. The couple required can thus be known in terms of lever arm and weight. We then only need to know the number of revolutions in a unit of time when we have all the data needed in order to compute the energy.

If W denote the weight, L the lever arm and n the number of revolutions in a minute, we shall have: energy $=2\pi \mathrm{W}\,\mathrm{L}\,n$, as in the case of the well-known Prony brake.

For purposes of accurate scientific inquiry, the field magnets alone may be mounted and balanced on knife edges, so as to turn freely like the beam of a common balance. By this plan all useless work is excluded from the account. Friction at the bearings and at the brushes do not in this case have any tendency to make the field magnets revolve.

In the Physical Laboratory of this institution there are several machines having the construction here pointed out. They leave nothing to be desired in point of sensitiveness or accuracy in their indications.

Princeton, Nov. 23, 1883.

ART. IV.—*On some points in Climatology. A rejoinder to Mr. Croll;* by SIMON NEWCOMB.

IN the number of this Journal for October, 1883, Mr. Croll publishes a reply to certain criticisms of mine urged seven years ago against his theory of the cause of glacial epochs. (Vol. xi, p. 263, May, 1876). The pleasure and interest with which I have read Mr. Croll's paper induces me to reply to it, notwithstanding a want of confidence on my part in the value of anything short of a purely mathematical investigation of the subject. It will be well to begin by examining the nature of the question and stating in a broad way what seems to me unsatisfactory in the foundation of Mr. Croll's method.

What we are concerned with is the inference that at some former epoch in geological history the mean temperature of the northern hemisphere was much lower than it is now. Assuming this as the basis of discussion, the question is, what was the cause of this "glacial epoch?" To speak more accurately; since we can only take the causes relatively, why was the northern hemisphere any colder then than it is now? This question Mr. Croll endeavors to answer from purely astronomical causes, combined with elementary considerations respecting the motion of heat and its relation to meteorological phenomena. His conclusion is that a great eccentricity of the earth's orbit, combined with a position of the perihelion near the northern solstice, will cause a great annual fall of temperature in the northern hemisphere, which, in such a case, would have a short perihelion summer and a long aphelion winter.

To this, my reply is, that too little is known of the laws of terrestrial radiation of heat through the atmosphere to justify the establishment of any theory of the glacial epoch, and that, taking the case up exactly as Mr. Croll does, he fails to show sound reason why the mean temperature should be different at the supposed periods. At the same time, my verdict would be, not that Mr. Croll's thesis was false, but that it was not proven. I do not deny the possibility that, when the laws of climate become thoroughly known, it may be found that epochs of great eccentricity are always glacial epochs. All I claim is that if such should be proven to be the case, it will be through the action of causes different from those adduced by Mr. Croll.

In fact, without going any further, we have at hand a *vera causa* acting in this direction which has not been considered by Mr. Croll at all. Experiments on radiation, commenced with Dulong and Petit, tend to show that Newton's theory of the proportionality between temperature and radiation is not well founded, and that, as temperature rises, radiation increases in a much higher ratio. To speak more exactly, if we take a series of temperatures in arithmetical progression, the corresponding rates of radiation of heat will not be in arithmetical progression, but in a series of which the differences continually increase. An immediate inference from this general law is that if an isolated body receive a given amount of radiant energy per annum, its mean annual temperature will be a maximum when this radiation is uniform and will be lower the more irregular the reception of heat.

Now it is well known that the total amount of heat received, not only by the earth as a whole, but by each hemisphere, is constant, notwithstanding the change in the earth's eccentricity, but in virtue of the law just stated, any portion of the earth's surface on which a large portion of the annual supply of heat is delivered during a short summer, will have a lower mean temperature than the hemisphere on which the heat is distributed more uniformly. But Mr. Croll does not, so far as I have ever noticed, adduce this law at all. On the contrary, he assumes Newton's law of radiation proportional to temperature under which the cause would not act in the way suggested.

One great source of in-conclusiveness in Mr. Croll's results seems to me to be a lack of quantitative precision in his language. Though he may use numbers wherever it seems to him they are applicable, one can hardly fail to notice that the quantitative terms he most uses are such as "great," "very great," "small," "comparatively small," and these without any statement of the units of comparison relatively to which the expressions are used. Now I deem it not improbable that the difference between a cold and a hot epoch may be due to the very small preponderance of one or the other of several antagonistic causes; and, if so, quantitative precision is necessary to lead to any reliable conclusion.

I shall now enter into some details: Mr. Croll suggests that I may have forgotten the researches of Pouillet and Herschel into the temperature of space. I reply that I regard the conclusion that the temperature of space is $-239°$ as having no sound basis. To speak with greater quantitative exactness, it has precisely the same value as a photometric estimate of the intensity of star light, founded on observations of the sky, made in full day, with an attempt to eliminate the light reflected by the sky so as to find what residue comes from the stars. The fact is, that no observations of radiant heat from stellar spaces at large can be made below the uppermost limits of the earth's atmosphere, owing to the intervention in lower regions of the radiation from the atmosphere itself.

Mr. Croll concludes, using Newton's law of radiation, that the heat received from the stars is to that received from the sun as 222 to 299. I wonder that he did not see in this a *reductio ad absurdum* either of the results of Pouillet and Herschel, or the law of radiation which he assumes. Photometry shows that the combined light from all the stars visible in the most powerful telescope is not a millionth of that received from the sun, and there is no reason for believing that the ratio of light to heat is incomparably different in the two cases.

In considering the question of the heat conveyed by aerial currents Mr. Croll quotes from my former paper so fully and fairly that I do not see any necessity to repeat my views at length. I can only say that while I now see more plainly than before some reason why a body at the upper region of the earth's atmosphere should, on the average, be colder than at the surface, I do not see that we have data for fixing the fall of temperature at 5° or 100°. If the degree of cold is greater than that due to expansion, then Mr. Croll is right in maintaining that the aerial current would not carry to the poles *all* the heat with which it left the equator, but even granting this condition I see no ground for supposing the quantity of heat conveyed to be insignificant.

I shall now consider some of Mr. Croll's reasons why the ocean should be warmer than the land. His assumed law that a body transparent for heat rays would become warmer under solar radiation than an opaque body, I passed over in my former criticism as too much opposed to the fundamental laws of thermodynamics to need much consideration. He now adduces, in support of his thesis, the fact that water is more transparent to the solar rays than the rays which it would itself radiate; and that the upper layers of water would act like the glass of a green house and thus allow the water to stand at a higher temperature than it would otherwise do. This addition to the *modus operandi* seems to me quite sound, and, therefore, to show one true cause why water might rise to a higher mean temperature than the land, though I am unable to say whether the increase would be measurable with an ordinary thermometer. But I am sorry to find that, notwithstanding his addition of a sound cause, he adheres to views so diametrically opposite to what I supposed to be the fundamental laws of thermodynamics that I feel compelled to state the case more fully. His first reason why the ocean should be warmer than the land, is in the following words:

First.—"The ground stores up heat only by the slow process of conduction, whereas water, by the mobility of its particles and its transparency for heat-rays, especially those from the sun, becomes heated to a considerable depth rapidly. The quantity of heat stored up in the ground is thus comparatively small, while the quantity stored up in the ocean is great."

As just remarked Mr. Croll substitutes a sound reason for this utterly bad one, but still seems inclined to hold on to the latter. The confusion of ideas which pervades it can best be shown by making some attempt to put the statements into quantitative language, using numbers, lengths, etc., instead of the qualifying words "slow," "considerable," "rapidly," "comparatively small" and "great." His statement would then read something in this shape: The ground stores up heat only by the process of conduction which admits of only 10 calories per square meter being absorbed in a day whereas water, by the mobility of its particles, etc., becomes heated to a depth of thirty feet at the rate of 1° Fahr. per hour (day or week as the case might be). Thus only 1000 units of heat are stored up in a cubic meter of earth, while 5000 units per cubic meter are stored up in the ocean.

When stated in this form the question how hot the ocean would get at the end of x days, weeks or years under the supposed law of heating and how the number of units of heat stored up respectively in the ground and the ocean would fix their respective temperatures would at once have arisen in Mr. Croll's own mind, and showed him the utter failure of his reasoning; but by using instead of numbers the qualifying phrases I have quoted he confuses integral quantity of heat, rate at which heat is radiated in a unit of time, heat stored up, and temperature, without destroying the apparent soundness of his argument in the mind of the uncritical reader.

The second reason is in the following words:

Second.—"The air is probably heated more rapidly by contact with the ground than with the ocean; but, on the other hand, it is heated far more rapidly by radiation from the ocean than from the land. The aqueous vapor of the air is to a great extent diathermanous to radiation from the ground, while it absorbs the rays from water and thus becomes heated."

Here again the fallacy of the reasoning will be seen by giving the respective number of degrees, or any quantitative statement of the rate at which the air was heated by radiation from the ocean and from the land respectively. The fact I suppose to be that there is no rapidity of heating in question, but that the question is simply one of stationary temperature to be ultimately reached. I must repeat that I know not the slightest authority for the statement in the last sentence quoted and can gain no clear idea from what Mr. Croll says on the subject.

In considering the third reason, which I need not quote, but which is found in Mr. Croll's reply, I suggested in my former paper what I supposed to be a *reductio ad absurdum* of Mr. Croll's method of reasoning by pointing out the apparent conclusion that two bodies could heat each other up by their mutual radiation. I supposed he would disclaim this conclusion and try to show that I had misunderstood his premises in drawing it, but he apparently accepts its possibility as a logical result of Prevost's well known theory of exchanges.

The fourth reason may be summarily disposed of in the same way as the preceding ones. Let the reader take it up as presented by the author; let him substitute quantitative statements at pleasure for the words "more freely," "greater," "greater difficulty," "more rapidly," "of higher mean temperature," etc., and let him also bear in mind that it is stationary temperatures and not quantities of heat with which we are ultimately concerned and the inconclusive character of the reasoning will be at once apparent.

I shall next pass to the question of the non-melting of snow during a short perihelion summer, in which, as I stated in my former review, calculating temperatures by Mr. Croll's formula, we should have a mean temperature ranging from 100° to 150° Fahr. I had to acknowledge some embarrassment from Mr. Croll's causes producing their effects through the two diametrically opposite modes of operation, to wit:

1st. By making the air exceedingly transparent and thus permitting radiation into space.

2d. By filling the air with fogs and thus preventing the solar heat from reaching the ground.

His reply to this is that he did not suppose the fogs and the clear atmosphere to exist at the same place and at the same time, but that in either case an inability on the part of the sun's rays to melt the few inches of snow which could have fallen during winter would have resulted.

I see no use in arguing this point for the simple reason that I do not know enough about the relations of temperature to the aqueous vapor in the atmosphere to admit of my saying anything of value on the subject. I would merely remark that I cannot see in Mr. Croll's reasoning the slightest ground for admitting that the perihelion summer radiation would produce any other effect than it does now.

I am surprised that Mr. Croll should have been willing to present reasoning so obviously inconclusive as that in which he endeavors to show that my objection to the reliableness of his dates for glacial epochs, on account of the insufficiency of the fundamental data for the secular variations of the planetary orbits, falls to the ground. My objection and his statement in reply I can leave to the judgment of the reader who chooses to refer to them.

I conceive that some general remarks on the nature of the problem will be of more value than a further analysis of Mr. Croll's reasoning. It is an observed fact that we now have a glacial epoch at a comparatively moderate height in the atmosphere and on the tops of most high ranges of mountains far removed from the equator. It is evident that if, at any former epoch, the state of things at the surface of the ground was the same that it now is at the height of two or three miles in the atmosphere, there must have been a glacial epoch. To what cause are we to attribute the cold of the upper regions of the air? There are two known causes but we cannot assign an exact quantitative effect to each.

I. The passage of air from the lower to the upper regions is accompanied by expansion, and the reverse motion by compression, which would naturally result in the upper regions being colder than the lower: the exact amount of cooling, supposing no disturbing cause to come into play, is readily computed, and has, I think, been assigned by Professor Sir William Thompson and others, but I need not now refer to the results.

II. Researches on radiant heat seem to show that the atmosphere absorbs the extreme rays of the spectrum, especially those of greatest wave length, more powerfully than the rays of mean wave length. The rays radiated by the earth are of longer wave length than the great mass of those received by the sun. The natural result of this selective absorption would be to make the temperature of the earth higher than if there were no atmosphere, or if the atmosphere exercised no selective absorption on heat rays. It seems probable that this selective absorption is due, very largely if not entirely, to aqueous vapor in the air. If this be so, an epoch of dry air would be a glacial one.

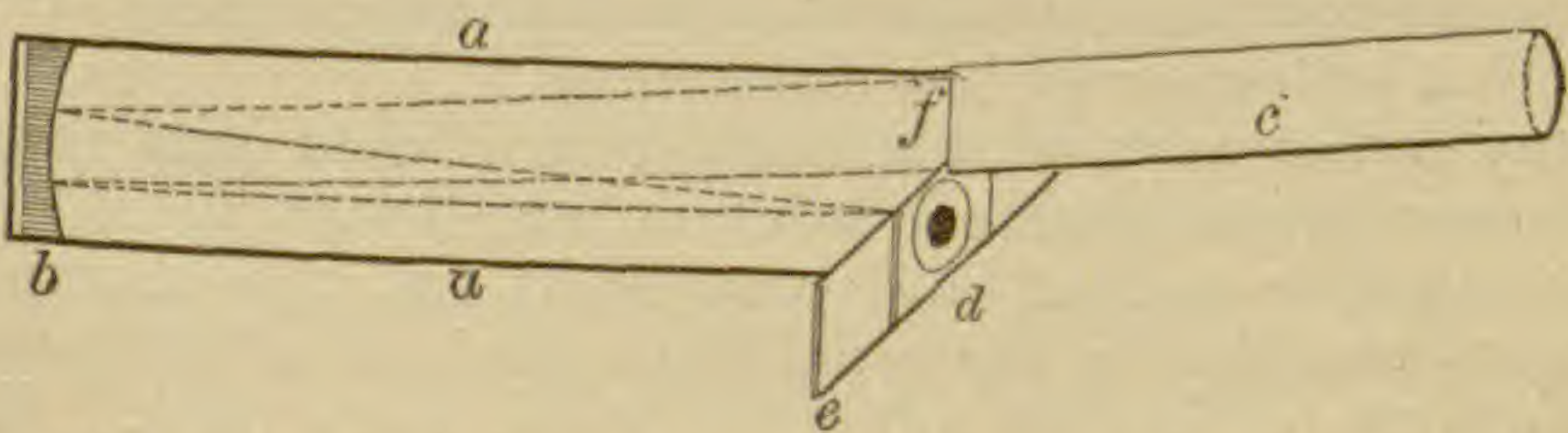
A crude test of the efficacy of the first cause might be devised. In order that it may act it is essential that there shall be a continuous interchange of air between low and high altitudes. Now if there are any high table lands so extended that in their central portions the air has not during several days an opportunity to be replenished from lower regions, such air should be warmer than that at an equal height on isolated mountains. Probably the conditions for such an observation do not exist on the earth's surface.

In conclusion I may be allowed to express my regret at not being able to make a contribution of positive value to the investigation of this subject. The state of the question is about this: A well founded theory of terrestrial temperature can be built only upon an accurate knowledge of the laws of emission and absorption of radiant energy of different wave lengths, especially in the atmosphere, and the result will appear as a numerical calculation, more or less exact, of the temperature resulting from assigned conditions, and not as the conclusion of an argument to show one thing or another.

ART. V.—*On Photographing the Solar Corona without an Eclipse;* by WILLIAM HUGGINS, D.C.L., LL.D., F.R.S.

[IN the number of this Journal for last February is a statement, by Dr. Huggins, of his method of photographing the corona of the sun without an eclipse. The following account of his more recently devised methods, and of the results obtained, was communicated to the British Association at Southport, and is furnished by him in proof from the British Journal of Photography for this Journal.]

I am indebted to Miss Lassell for the loan of a seven-foot Newtonian telescope made by the late Mr. Lassell. The speculum, which is seven and a-quarter inches in diameter, possesses great perfection of figure, and still retains its original fine polish. I decided not to use more than three and a-half inches of the central portion of the speculum—partly for the reason that a larger amount of light would be difficult of management, and partly because this restriction of the aperture would enable me to adopt the arrangement which is shown in the diagram.



It will be seen at once from an inspection of the diagram that in this arrangement the disadvantage of a second reflection by the small mirror is avoided, as is also the mechanical inconvenience of tilting the speculum within the tube, as in the ordinary form of the Herschelian telescope. The speculum *b* remains in its place at the end of the tube *aa*. The small plane speculum and the arm carrying it were removed. The open end of the tube is fitted with a mahogany cover. In this cover at one side is a circular hole *f*, three and a-quarter inches in diameter, for the light to enter; below is a similar hole, over which is fitted a framework to receive the "backs" containing the photographic plates, and also a frame with fine ground glass for putting the apparatus into position. Immediately below, towards the speculum, is fixed a shutter with an opening of adjustable width, and which can be made to pass across more or less rapidly by the use of india-rubber bands of different degrees of strength. In front of the opening *f* is fixed a tube *c*, six feet long, fitted with diaphragms, to restrict as far as possible the light which enters the telescope to that which comes from the sun and the sky immediately around him. The telescope tube *aa* is also fitted with diaphragms, which are not shown in the diagram, to keep from the plate all light except that coming directly from the speculum. It is obvious that when the sun's light entering the tube *f* falls upon the central part of the speculum the image of the sun will be formed in the middle of the second opening at *d*, about two inches from the position it would take if the tube were directed axially to the sun. The exquisite definition of the photographic images of the sun shows, as was to be expected, that the small deviation from the axial direction—two inches in seven feet—does not affect sensibly the performance of the mirror. The whole apparatus is firmly strapped on to the reflector of the equatorial, and carried with it by the clock motion.

The performance of the apparatus is very satisfactory. The photographs show the sun's image sharply defined; even small spots are seen. When the sky is free from clouds, but presenting a whity appearance from the large amount of scattered light, the sun's image is well defined upon an uniform background of illuminated sky, without any great increase of illumination immediately about it. It is only when the sky becomes clear and blue in color that coronal appearances present themselves with more or less distinctness.

In my earlier work with this apparatus I used cells containing potassic permanganate in solution, which were placed close to the sensitive surface, and between it and the shutter. I was much troubled by the rapid decomposition of the potassic permanganate under the influence of the sun's light. When apparently clear to the eye, a lens revealed minute particles which precipitated themselves upon the glass plates of the cell, and gave an appearance of structure to any coronal appearance which was in the plate; besides, any diminution of the transparency of the solution by the presence of minute particles would produce scattered light on the plate.

I then tried a solution of iodine in carbon disulphide, but the same inconvenience presented itself. Very soon, under the sun's light, the solution was found by examination with a lens to show signs of commencing decomposition.

Even when the solution was sensibly clear there was some disadvantage from the unavoidable imperfection of polish of the surface of the plates, which reveals itself under the conditions of strong light in which they are placed. If, however, the violet (pot) glass which I used at first could be obtained annealed and free from the imperfections usually present in it, it would serve most usefully as a selective screen.

For these reasons, after some months' work I decided to give up the use of absorbing media, and I came to the conclusion that the advantages they present, which are doubtless considerable, are more than balanced by the possible false appearances which they might give rise to if the solutions were not in a condition of perfect transparency.

As, for the reasons stated above, it seemed desirable to avoid placing media of any kind before the sensitive surface, the selective power upon the light had to be sought in the nature of the sensitive surface itself. The suggestion of staining the film presented itself, but after consultation with Captain Abney I decided to try an emulsion containing silver chloride only. Captain Abney kindly prepared some silver chloride emulsion for me, and the plates were developed with a solution of ferrous-citro-oxalate. The silver chloride film, according to Captain Abney, is strongly sensitive to light from *h* to H, and hardly at all beyond H. Since the middle of July these plates have been used as well as the ordinary silver bromide gelatine plates. A comparison of the two kinds of plates, when used under similar conditions, shows a decided advantage for this work in favor of the silver chloride. All the plates were backed with a solution of asphaltum in benzole.

For the purpose of screening the sensitive surface from the intensely bright image of the sun, small circular discs of thin brass were turned about $\frac{1}{50}$th of an inch larger in diameter than the sun's image. The brass disc was held close before the sensitive surface by a fine metal arm when the sun was taken in the middle of the field, and attached to the inner edge of a circular diaphragm when the sun's image was placed toward the side of the field. A comparison of photographs taken under similar conditions with and without the disc showed less advantage in favor of the disc than was anticipated. Indeed, it may be that with the short exposures given the scattered light which comes upon the plate, when the sun's image falls directly on the sensitive surface, may be favorable to the setting up of the photographic action by the comparatively-feeble coronal light.

In consequence of the number of diaphragms which it was found desirable to introduce into the apparatus for the purpose of preventing any light but that from the sun and the sky immediately around him from reaching the plate, the extent of field in which the full aperture was in use was small. For this reason it was found of advantage to place the sun's image near the margin of the diaphragm, limiting the field, and afterwards to combine the photographs taken in four different positions.

The moving shutter being placed very near the sensitive surface, and practically in the focal plane, could not give rise to effects of diffraction upon the plate; besides, the opening in the shutter was never less than half-an-inch in width, and often as much as an inch or even more, according to the sensitiveness of the plates used.

The most serious difficulty with which I have had to contend has been the absence of clear skies. On many days of bright sunshine the wind has been in a northerly direction, bringing here the smoke of London, which produces a whity condition of sky, through which it was obviously hopeless to expect the coronal light to show itself upon the plates. The few occasions of a better condition of sky were for the most part of short duration, and did not allow time for a large number of photographs to be taken.

During the summer about three dozen photographs have been obtained, which show photographic action about the sun of a more or less coronal character.

I placed these plates in the hands of Mr. Wesley, who has had very great experience in making drawings from the photographs taken during several solar eclipses, with the request that he would make a drawing for each day on which sufficient photographs had been taken, combining the results of the different photographs in one drawing. This was desirable, as, whenever a sufficient duration of sunshine permitted, photographs were taken on silver chloride films as well as on silver bromide plates. Some photographs were taken with the sun screened by the brass disc, others without it; also photographs were taken with the sun in different positions of the field. As a rule, Mr. Wesley has introduced into his drawings those coronal features only which are common to all the plates taken on that day.

The apparatus is attached to the refractor of the equatorial in such a way that the direction of the length of the plate is in that of a parallel of declination; a line, therefore, across the plate, is in a direction north and south, and from the date of the photograph the angle of position of the sun's axis can be found. On Mr. Wesley's drawings the orientation is marked, as well as the position of the sun's axis.

Four drawings accompany this paper. On one of them (August 13) are seen defined rays. As these are present in three photographs—one in which the sun is in the middle of the field and the shutter in use, a second in which the sun was nearly in the middle but the shutter remained open, and a third with the sun near the margin of the field and screened by a disc—Mr. Wesley has put them in the drawing. In most of the negatives more structure than is shown in the drawings is suspected when the plates are carefully examined.

I regretted greatly that on the sixth of May—the day of the solar eclipse—the sky here was very unfavorable.

Up to the time of writing this paper I have not seen the photographs taken during the eclipse. Mr. Wesley wishes me to say that he has not seen the photographs or any drawings of the eclipse, and that, therefore, he has been wholly without bias in making his drawings from my plates. If these drawings are compared with the photographs taken during the eclipse, it should be borne in mind that the absence of sky-illumination during the eclipse would allow a larger part of the fainter and more distant regions of the corona to be photographed, and that any peculiar conformations or detailed structure of these outer portions could not be expected to be seen on my plates. The comparison should be restricted to the regions of the corona at corresponding distances from the sun's limb. It is probable that the short-exposure eclipse negatives will be found to admit of comparison with my plates better than those exposed for a longer time.

Photographs of the sun have been taken on the days which follow:—

April	2	1 plate.	June	20	1 plate.
"	3	1 "	July	10	3 plates.
"	6	2 plates.	"	15	2 "
"	26	5 "	August	3	2 "
May	23	1 plate.	"	13	7 "
"	24	6 plates.	"	20	7 "
"	31	5 "	Sept.	4	4 "
June	6	3 "			

All these plates show a more or less distinct coronal appearance about the sun. On some of the days an unfavorable wind brought here the London smoke, which greatly increased the sky-illumination relatively to the coronal light which could reach the plate. On these days the photographic action on the plates around the sun, though distinctly coronal in character, possesses less definiteness of form. I entertain the hope that it may be possible, by a careful comparison of all the plates, to gain some information, in a general way, of the amount, and possibly also of the character, of any large changes of form or of relative brightness which may have taken place in the corona, or been due to its motion, during the period covered by the observations.

[Professor Stokes, who read the paper, also read the following letter from Mr. Lawrence, one of the observers of the eclipse of May 6th, at Caroline Island.]

"Dr. Huggins called upon Mr. Woods this morning and showed us the drawings Mr. Wesley has made of his coronas. He told us that he particularly did not wish to see our negatives, but he would like us to compare his results with ours. We did so and found that some strongly marked details could be made out on his drawings, a rift near the north pole being especially noticeable. This was in a photograph taken on April 3d, in which details of the northern hemisphere are best shown; while the details of our southern hemisphere most resemble the photograph taken on June 6th. In fact our negatives seem to hold an intermediate position. Afterwards I went with Dr. Huggins and Mr. Woods to Burlington House to see the negatives. The outline and distribution of light in the inner corona of April 3d is very similar to that on our plate which had the shortest exposure, the outer corona is, I think, hidden by atmospheric glare. As a result of the comparison, I should say that Dr. Huggins' coronas are certainly genuine as far as 8′ from the limb."

ART. VI.—*Elliptic Elements of* Comet 1882, I; by F. J. PARSONS.

THE accompanying set of elements was derived from the following six normal places:

G. M. T.	Mean R. A. 1882.0.	Prob. Error.	No. of Obs.	Mean δ 1882.0.	Prob. Error.	No. of Obs.	Time of Normal places.
March 26.5	271 36 46·9	±0·71	63	37 15 15·6	±0·41	61	Mar. 19–Apr. 3
April 12.5	281 22 16·7	±0·20	70	49 49 15·1	±0·66	70	Apr. 4–Apr. 21
May 25.5	55 55 34·2	±0·45	40	59 36 4·1	±0·28	40	May 21–May 28
June 2.5	66 45 42·3	±0·56	18	44 36 27·1	±0·53	17	June 1–June 5
July 9.5	156 59 16·35	±0·59	27	9 45 17·5	±1·3	27	July 8–July 17
August 7.5	181 46 55·5	±1·17	12	4 14 3·7	±1·3	12	Aug. 1–Aug. 16

From the 2d, 3d and 5th of these normal places a preliminary set of elements was computed according to the methods given in Gauss' "Theoria Motus," as follows:

T = June 10·52908
$\log q = 8{\cdot}7836381$
$\log e = 9{\cdot}9999998$

$\Omega = 204^\circ\ 56'\ 18''{\cdot}61$
$\omega = 208^\circ\ 59'\ 38''{\cdot}17$
$i = 73^\circ\ 48'\ 34''{\cdot}88$
} Mean eq. 1882·0.

Rectangular equatorial Coordinates

$$x = r\,[9{\cdot}9611128]\sin(126^\circ\ 22'\ 53''{\cdot}24 + v)$$
$$y = r\,[9{\cdot}8608368]\sin(61^\circ\ 11'\ 47''{\cdot}56 + v)$$
$$z = r\,[9{\cdot}9021136]\sin(196^\circ\ 51'\ 24''{\cdot}51 + v)$$

With these elements considering the eccentricity equal to unity, comparison was made with all six normal places, in order to make the final corrections to the preliminary orbit by means of a least square solution.

The differential coefficients with respect to the six elements being computed for the six normal places gave twelve equations involving the following unknown quantities,

$$x = 10000\ dT.$$

$$M \sin y = d \log q \text{ (Briggian) or } y = \frac{dq}{q \sin 1''}$$

$$z = d\chi' = d\omega' + \cos i' d\Omega' \qquad v = d\Omega'$$

$$\sin u = de \text{ or } de = \frac{u}{\sin 1''} \qquad w = di'.$$

It was not thought worth while to apply weights systematically according to the number of observations, but as the last normal place seemed to have considerably less precision than the others, the last two equations were given a weight of 0·5012 log 9·70000 as a convenient approximation to a weight of one-half.

The twelve resulting equations being solved according to the method of least squares give the following values for the unknown quantities:

$$x = 4''\cdot4771 \pm 1''\cdot468 \qquad u = -\ 2''\cdot2662 \pm 0''\cdot877$$
$$y = 2\cdot4213 \pm 4\cdot214 \qquad v = +10\cdot952 \pm 2\cdot495$$
$$z = -1\cdot4295 \pm 0\cdot875 \qquad w = +\ 9\cdot035 \pm 2\cdot739$$

Substituting these values in the equations of condition gives for the sum of the squares of the residuals $[vv] = 22\cdot02$. In the solution of the normal equations $[nn\cdot6] = 22\cdot09$.

From these unknown quantities the following corrections to the preliminary elements are found

$$dT = +0\cdot000448 \pm 0\cdot000147 \qquad de = -0\cdot00001098 \pm 0\cdot00000425$$
$$d \log q = +0\cdot0000051 \pm 0\cdot0000089 \qquad d\Omega' = +10''\cdot952 \pm 2''\cdot495$$
$$d\omega' = -8''\cdot024 \pm 2''\cdot644 \qquad di' = +\ 9''\cdot035 \pm 2''\cdot739.$$

These corrections give as the most probable values of the elliptic elements,

$$T = \text{June } 10\cdot52953 \text{ G. M. T. } \pm 0\cdot00015$$
$$\log q = 8\cdot7836432 \pm 0\cdot0000089$$
$$e = 0\cdot99998902 \pm 0\cdot00000425$$

$$\left.\begin{array}{l} \omega = 208^\circ\ 59'\ 33''\cdot72 \\ \Omega = 204^\circ\ 56'\ 29''\cdot49 \\ i = 73^\circ\ 48'\ 41''\cdot82 \end{array}\right\} \text{Mean Equinox and Ecliptic } 1882\cdot0$$

$$\left.\begin{array}{l} \omega' = 196^\circ\ 51'\ 16''\cdot49 \pm 2''\cdot644 \\ \Omega' = 210^\circ\ 29'\ 12''\cdot25 \pm 2''\cdot495 \\ i' = 52^\circ\ 57'\ 41''\cdot04 \pm 2''\cdot739 \end{array}\right\} \text{Referred to Equator.}$$

Rectangular equatorial coördinates,

$$x = r\,[9\cdot9611023] \sin (126^\circ\ 22'\ 49''\cdot33 + v)$$
$$y = r\,[9\cdot8608362] \sin (\ 61^\circ\ 11'\ 58''\cdot04 + v)$$
$$z = r\,[9\cdot9021280] \sin (196^\circ\ 51'\ 16''\cdot49 + v)$$

These elements correspond to a period of about 400,000 years.

Recomputing the position of the comet for the dates of the six normal places and comparing gives the following results, the column headed "v" being the residuals obtained by substituting in the equations of condition the values found above for the unknown quantities.

		$\delta a \cos \delta$ (C—O)	v	$d\delta$ (C—O)	v
March	26.5	+1·36	+1·34	+1·01	+1·00
April	12.5	−0·86	−0·71	−1·31	−1·31
May	25.5	+1·53	+1·52	+0·19	+0·17
June	2.5	−0·61	−0·60	+0·04	+0·03
July	9.5	+0·37	+0·38	−2·33	−2·16
August	7.5	−0·91	−0·95	+4·30	+4·24

The planetary perturbations being small have not as yet been taken into account, as I intend to make a more complete discussion of the comet when all the observations have been published.

Field Memorial Observatory, Williamstown, Mass.

ART. VII.—*The Minnesota Valley in the Ice Age;** by WARREN UPHAM.

THIS article is based upon my observations as assistant on the Geological and Natural History survey of Minnesota, from 1879 to the present time, under the direction of Professor N. H. Winchell, the State geologist. Some portions of it have been before published in the annual reports, and others are here presented in advance from manuscripts prepared for the final reports of this survey.

The Minnesota River, from which this State is named, has its highest and most remote sources upon the Coteau des Prairies, about 2000 feet above the sea. Its head-stream, after flowing eastward twenty miles, turns southerly at Brown's Valley and enters the northwest end of Big Stone Lake. Here, and in its whole extent thence to its mouth, the Minnesota River occupies a very remarkable valley, the origin of which was first explained in 1868 by General G. K. Warren, who attributed it to the outflow from an ancient lake that filled the basin of the Red River and Lake Winnipeg. This valley or channel begins at the northern part of Lake Traverse and first extends southwest to the head of this lake, thence southeast to Mankato,

* Read August 16, 1883, at the Minneapolis meeting of the American Association for the Advancement of Science.

and next north and northeast to the Mississippi at Fort Snelling, its length being about two hundred and fifty miles. Its width varies from one to four miles, and its depth is from one hundred to two hundred and twenty-five feet. The country through which it lies, as far as Carver, about twenty-five miles above its junction with the Mississippi, is a nearly level expanse of till, only moderately undulating, with no prominent hills or notable depressions, excepting this deep channel and those formed by its tributary streams. Below Carver it intersects a belt of terminal moraine, composed of hilly till. Its entire course is through a region of unmodified drift, which has no exposures of solid rock upon its surface.

Bluffs in slopes from twenty to forty degrees, and rising one hundred to two hundred feet to the general level of the country, form the sides of this trough-like valley. They have been produced by the washing away of their base, leaving the upper portions to fall down and thus take its steep slopes. The river in deepening its channel has been constantly changing its course, so that its current has been turned alternately against the opposite sides of its valley, at some time undermining every portion of them. In a few places this process is still going forward, but mainly the course of the Minnesota River is in the bottomland. Comparatively little excavation has been done by the present river. As we approach its source it dwindles to a small stream flowing through long lakes, and we finally pass to Lake Traverse, which empties northward; yet along the upper Minnesota and at the divide between this and the Red River, this valley or channel and its enclosing bluffs are as remarkable as along the lower part of the Minnesota River. It is thus clearly shown to have been the channel of outflow from a lake formerly extending northward from Lake Traverse along the Red River valley. The existence of this body of water is believed to have been due to the barrier of the receding continental ice-sheet, obstructing the natural course of drainage northward as at present to Hudson Bay; and it is therefore called *Lake Agassiz*, in memory of Professor Louis Agassiz, the first prominent advocate of the theory that the drift was produced by land-ice. The shore line of this lake, when it stood at its highest level, marked by a distinct beach of gravel and sand, upon a surface which on each side of this beach is chiefly till, has been traced continuously one hundred and seventy-five miles, from Lake Traverse easterly to Herman and thence northerly to Maple lake, twenty miles east-southeast from Crookston. The height of this beach has been ascertained at the same time, by leveling along this entire distance.

The Minnesota valley in many places cuts through the sheet of drift and reaches the underlying rocks, which have frequent exposures along its entire course below Big Stone Lake. This excavation shows that the thickness of the general drift-sheet upon this part of Minnesota averages about one hundred and fifty feet. The contour of the old rocks thus brought into view is much more uneven than that of the drift. In the hundred miles from Big Stone Lake to Fort Ridgely the strata are metamorphic gneisses and granites, which often fill the whole valley, one to two miles wide, rising in a profusion of knolls and hills, fifty to one hundred feet above the river. The depth eroded has been limited here by the presence of these rocks, among which the river flows in a winding course, crossing them at many places in rapids or falls. From New Ulm to its mouth the river is at many places bordered by Cretaceous and Lower Silurian rocks, which are nearly level in stratification. These vary in height from a few feet to fifty or rarely seventy-five or one hundred feet above the river. From Mankato to Ottawa the river occupies a valley cut in Shakopee limestone underlain by Jordan sandstone, which form frequent bluffs upon both sides, fifty to seventy-five feet high. After excavating the overlying one hundred and twenty-five to one hundred and fifty feet of till, the river here found a former valley, eroded by pre-glacial streams. Its bordering walls of rock, varying from one-fourth of a mile to at least two miles apart, are in many portions of this distance concealed by drift, which alone forms one or both sides of the valley. The next point at which the river is seen to be enclosed by rock-walls, is in its last two miles, where it flows between bluffs of Trenton limestone underlain by St. Peter sandstone, one hundred feet high and about a mile apart. This also is a pre-glacial channel, its farther continuation being occupied by the Mississippi River. The only erosion effected by the Minnesota River here has been to clear away a part of the drift with which the valley was filled. Its depth at some earlier time was much greater than now, as shown by the salt-well on the bottomland of the Minnesota River at Belle Plaine, where two hundred and two feet of stratified gravel, sand and clay were penetrated before reaching the rock. The bottom of the pre-glacial channel there is thus at least one hundred and sixty-five feet lower than the mouth of the Minnesota River.

Heights of the bluffs, which form the sides of this valley, composed of till enclosing layers of gravel and sand in some places, and frequently having rock at their base, are as follows, stated in feet above the lakes and river: along Lake Traverse, 100 to 125; at Brown's Valley and along Big Stone Lake, mainly about 125, the highest portions reaching 150; at Ortonville, 130; at Lac qui Parle and Montevideo, 100; at Granite Falls, 150; at Minnesota Falls, 165; thence to Redwood Falls, Fort Ridgely and New Ulm, 165 to 180; at Mankato, 200 to 225; at Saint Peter and Ottawa, 220 to 230; at Le Sueur and Henderson, 210 to 225; at Belle Plaine and Jordan, about 230; and at Shakopee, 210 to 220. The morainic hills through which this valley extends below Shakopee are 225 to 250 feet in height. The expanse of till through which this channel is eroded slopes from 1125 feet above the sea at Big Stone Lake to 975 at Mankato, in 140 miles; and thence it descends to 925 at Shakopee, in 50 miles. This channel or valley of the Minnesota River lies nearly midway between the belt, on its northeast side, of medial and terminal moraines, that extends from Lake Minnetonka 150 miles northwest to the Leaf hills, and the Coteau des Prairies on its southwest side; toward each of which, some fifty miles distant from this river, there is a gentle ascent, sufficient to cause drainage to follow this central line.

The height of Lake Traverse is 970 feet above the sea; the lowest point in Brown's Valley between this and Big Stone Lake is only three feet above Lake Traverse; Big Stone Lake is 962 feet above the sea, or eight feet below Lake Traverse; and the mouth of the Minnesota River is 690 feet above the sea, the descent from Big Stone lake to the mouth of the river being 272 feet.

Lakes Traverse and Big Stone are from one to one and a half miles wide, mainly occupying the entire area between the bases of the bluffs, which rise about one hundred and twenty-five feet above them. Lake Traverse is fifteen miles long; it is mostly less than ten feet deep, and its greatest depth probably does not reach twenty feet. Big Stone Lake is twenty-six miles long, and its greatest depth is reported to be from fifteen to thirty feet. The portion of the channel between these lakes is widely known as Brown's Valley. As we stand upon the bluffs here, looking down on these long and narrow lakes in their trough-like valley, which extends across the five miles between them, where the basins of Hudson Bay and the Gulf of Mexico are now divided, we have nearly the picture which was presented when the melting ice-sheet of British America was pouring its floods along this hollow. Then the entire extent of the valley was doubtless filled every summer by a river which covered all the present areas of flood-plain, in many places occupying as great width as these lakes.

General Warren observed that Lake Traverse is due to a partial silting up of the channel since the outflow from the Red River basin ceased, the Minnesota River at the south having brought in sufficient alluvium to form a dam; while Big Stone Lake is similarly referred to the sediment brought into the valley just below it by the Whetstone River. Fifteen miles below Big Stone Lake, the Minnesota River flows through a marshy lake four miles long and about a mile wide. This may be due to the accumulation of alluvium brought into the valley by the Pomme de Terre River, which has its mouth about two miles below. Twenty-five miles from Big Stone Lake, the river enters Lac qùi Parle, which extends eight miles with a width varying from one-fourth to three-fourths of a mile and a maximum depth of twelve feet. This lake, as General Warren suggested, has been formed by a barrier of stratified sand and silt which the Lac qui Parle River has thrown across the valley. He also showed that Lake Pepin on the Mississippi is dammed in the same way by the sediment of the Chippewa River; and that Lake St. Croix and the last thirty miles of the Minnesota River are similarly held as level back-water by the recent deposits of the Mississippi.

All the tributaries of the Minnesota River have cut deeply into the drift, because the main valley has given them the requisite slope. The largest of these extend many miles, and have their mouths level with the bottomland of the Minnesota River. The bluffs of all these valleys are also everywhere seamed and gullied by frequent rills and springs, many of which flow only after rains. Few of the large inlets have any great amount of sediment deposited opposite their mouths, showing that their excavation was mostly done at the same time with that of the main valley. The short ravines are more recent in their origin, and the material that filled their place is commonly spread in fan-shaped, moderately sloping banks below their mouths, which are thus kept at a height from thirty to forty feet above the present flood-plain. The road from Fort Ridgely to New Ulm runs along the side of the bluff at the only height where a nearly level straight course could be obtained, being just above these deposits and below the ravines.

The valleys of the Pomme de Terre and Chippewa Rivers, 75 to 100 feet deep along most of their course, and one-fourth of a mile to one mile in width, were probably avenues of drainage from the melting ice-fields in their northward retreat. Between these rivers, in the twenty-two miles from Appleton to Montevideo, the glacial floods at first flowed in several channels, which are excavated forty to eighty feet below the general level of the drift-sheet, and vary from an eighth to a half of a mile in width. One of these, starting from the bend of the Pomme de Terre River, one and a half miles east of Appleton, extends fifteen miles southeast to the Chippewa River near the center of Tunsburg. This old channel is joined at Milan station by another, which branches off from the Minnesota valley, running four miles east-southeast; it is also joined at the northwest corner of Tunsburg by a very notable channel which extends eastward from the middle of Lac qui Parle. The latter channel, and its continuation in the old Pomme de Terre valley to the Chippewa River, are excavated nearly as deep as the channel occupied by the Minnesota River. Its west portion holds a marsh generally known as the "Big Slough." Lac qui Parle would have to be raised only a few feet to turn it through this deserted valley. The only other localities where we have proof that the outflow from Lake Agassiz had more than one channel are seven and ten miles below Big Stone Lake, where isolated remnants of the general sheet of till occur south of Odessa Station and again three miles southeast. Each of these former islands is about a mile long, and rises seventy-five feet above the surrounding low land, or nearly as high as the bluffs enclosing the valley, which here measures four miles across, having a greater width than at any other point.

Terraces and high plains of modified drift, found in many places along the valley of the Minnesota River from New Ulm to its mouth, show that it was once filled, doubtless at the close of the last glacial epoch, with stratified gravel, sand and clay, to a depth 75 to 150 feet above the present river. The remnants of this deposit include the plateau of modified drift, about a mile long and an eighth of a mile wide, upon which the west and highest part of New Ulm is built; a terrace in section 27, Courtland, opposite the southeast part of New Ulm, more than a mile long and about an eighth of a mile wide; a larger terrace, four miles long and a half mile wide, lying also in Courtland, four to eight miles southeast from New Ulm, upon which Courtland depot is situated; a terrace extending about three miles northwest from near Minneopa falls, and varying from a few rods to a third of a mile in width; a terrace three miles long east and south of Kasota; the "Sand prairie," about four miles long and averaging a mile wide, west and north of Saint Peter; Le Sueur prairie, six miles long and from one to three miles wide, beginning east of Ottawa and reaching to Le Sueur; the plain five miles long and a mile wide, near the middle of which Belle Plaine is built; Spirit hill and "Sand prairie," southwest and northwest of Jordan; a terrace eight miles long and varying from a few rods to two miles in width, extending through San Francisco, Dahlgren and Carver; and Shakopee prairie, eight miles long and averaging one mile wide. The height of these terraces and plains at New Ulm is about 115 feet above the river; in Courtland, and near Minneopa falls, 125 to 150 feet; at Kasota, Saint Peter and Le Sueur, about 150 feet; at Belle Plaine, about 135; and at Jordan, Carver and Shakopee, about 125. Wells on the "Sand prairie" near Saint Peter and on Le Sueur prairie go through sand and gravel, sometimes with layers of clay, to the depth of 75 or 100 feet, finding till below. At Belle Plaine the sand and gravel are about fifty feet deep, underlain by till. Shakopee prairie has forty or fifty feet of this modified drift, lying upon limestone. The principal remnant of these deposits seen below Shakopee was a terrace about seventy-five feet high, an eighth to a third of a mile wide and four miles long, extending through Eagan in Dakota county, its north end being about two miles south of Fort Snelling. This valley was first excavated in till which rises in continuous bluffs on each side 50 to 100 feet above these high plains and terraces of modified drift. It was afterward filled along this distance of one hundred miles next to its mouth with fluvial deposits 75 to 150 feet thick, sloping about two feet per mile, through which the channel has been cut anew.

With this general view of the valley of the Minnesota river as it exists to-day, we are prepared to inquire more particularly what its history was during the vicissitudes of the ice age and from the close of that period until now. Its condition at the beginning of the reign of ice first claims consideration. During what ages was its pre-glacial rock-walled channel formed? This is in part answered by deposits of Cretaceous clay found in water-worn hollows of the Shakopee limestone forming the walls of this channel at numerous places in Blue Earth, Le Sueur and Nicollet counties, and by the occurrence in this valley in Courtland and New Ulm and near Fort Ridgely and Redwood Falls, of Cretaceous sandstone, clay and shale, occasionally containing lignite. It is thus known that before the Cretaceous age, when Western Minnesota and the region of the upper Missouri were depressed and covered by the sea, a deep channel had been cut by some river in the Lower Magnesian strata of the Minnesota valley. The slopes from each side toward this channel appear therefore to have been partly like those of the present day. The direction of drainage may even have been the same as now, for the northern part of the Mississippi River and valley has probably existed since the middle of Paleozoic time.

Scanty exposures of Cretaceous strata are found in many parts of Minnesota, enclosing sometimes marine shells, sometimes impressions of leaves, and at a few places thin layers of lignite. The western two-thirds of the State were probably covered until the glacial period by deposits of this age which have now been mainly eroded, with much from the underlying Paleozoic rocks, and constitute a part of the drift, irrecognizably mingled with detritus and bowlders that have been brought from Laurentian and Huronian areas far to the north and northeast. Excepting its partial submergence by the sea in the Cretaceous age, Minnesota seems to have stood wholly above the level of the ocean from the beginning of the Carboniferous period till the present day.

Before the ice age the rocks had been long subjected to the ordinary disintegrating agencies of rain and frost. Granite and gneiss were thus generally decomposed in place to a considerable depth. The loose material resulting from such decay was doubtless spread somewhat evenly over the surface, collecting to the greatest depth in valleys. Except where it had been transported by streams and consequently formed stratified deposits, the only fragments of rock held in this mass would be from underlying or adjoining rocks.

During the ice age the Cretaceous strata, mostly unconsolidated, which covered Western Minnesota, the superficial deposits and decomposed rock produced by weathering, and the alluvial beds of sand and gravel along the river-courses, were mostly plowed up by the ice and thoroughly kneaded with each other. Much detritus was also added from erosion of the harder rocks beneath. Large blocks and bowlders, often already formed by the process of weathering, were borne away, and the surface of the bed-rock was worn and striated by bowlders and pebbles, which were rolled and dragged along under the vast weight of ice, breaking up and grinding themselves and the underlying rock into gravel, sand and even the finest clay.

Ledges of decomposed gneiss and granite, found in the Minnesota valley at many points from Minnesota Falls to Fort Ridgely, with their surface changed to a soft earthy or clayey mass, resembling kaolin, and the Cretaceous beds before mentioned, both of which would readily yield to eroding agencies, show that the moving ice-sheet did not everywhere plow up all the loose material under it. A considerable depth, however, has probably been removed; and these may be scanty remnants of thick beds which covered this region generally before the glacial period. More commonly the ice-sheet removed all such material, and gathered a part of its drift from the underlying solid rocks; as is shown by their being frequently rounded, smoothed and marked with parallel furrows and scratches, called striæ. Similarly scratched pebbles and bowlders are found in the glacial drift. These were the graving tools by which the bed-rock was worn and striated. They were held firmly by being frozen in the bottom of the ice and were pushed forward by its current, which thus recorded its direction. Our observations of glacial striæ in the Minnesota valley are as follows: one to three miles southeast from the foot of Big Stone Lake, S.E.; near Odessa, S.E.; at Granite Falls, in several places, S. 45°–50° E.; at the dam of O. K. mill, Beaver Falls, S. 60° E.; one and a half miles west from Fort

Ridgely, S. 60° E.; at Redstone, one and a half miles southeast from New Ulm, S. 25° E.; at Jordan, noted by Foss, Wells & Co., in quarrying and on the site of their mill, S.E.

Within the till are frequently found layers of sand or gravel, which yield the large supplies of water so often struck in digging wells. Probably many of these veins of modified drift were formed by small sub-glacial streams and therefore cannot be regarded as marking divisions of the glacial period, nor even any important changes in the overlying ice. It appears, however, by shells, remains of vegetation, and trees, found deeply buried between glacial deposits in this and adjoining States, that the ice age was not one unbroken reign of ice, but that this retreated and re-advanced, or was possibly at some time nearly all melted upon the northern hemisphere and then accumulated anew. Thus periods of ice alternated with interglacial epochs, in which animal and vegetable life spread again northward, following close upon the retreat of the ice-fields. By each new advance of the glacial sheet much of the previous surface would be ploughed up and re-deposited; hence we find only few and scanty remnants of fossiliferous beds in the glacial drift. At the disappearance of the last ice-sheet these drifted materials, seldom modified by water in their deposition, formed a mantle 100 to 200 feet thick, which throughout the basin of the Minnesota River almost universally covered the older rocks.

[To be concluded.]

ART. VIII. — *On the so-called Dimorphism in the Genus Cambarus;* by WALTER FAXON.

THE existence of two forms of the adult male in all the species of the genus *Cambarus* was discovered by Louis Agassiz and Henry James Clark. The differences between the two forms affect more especially the first pair of abdominal appendages, organs concerned in the act of coition, but also extend to the general form and sculpture of the body. In one form (unhappily called by Dr. Hagen the "second form"), the first pair of abdominal appendages have a structure nearly like that seen in all *young* males. The hooks on the third joint of the third (in some species of the third and fourth) pair of legs are small, and in the sculpture of the shell and shape of the claws, this form approaches the female. In the other form (Hagen's "first form"), the articulation near the base of the first pair of abdominal appendages is gone and the whole member is much more highly specialized, the terminal hooks being horny, more widely separated and in every way more highly developed; in those species with bifid tips to these appendages, the branches are longer, slenderer, more widely separated and stiffer; the hooks on the thoracic legs are longer and more perfectly finished; the sculpture of the whole body is more pronounced and the claws are larger and more powerful. No intermediate conditions are found, and there is no relation between these forms and the size of the individual, the "second form" being large and the "first form" small, or *vice versa*. Hence we are forbidden to interpret the two forms as stages in ordinary development. Dr. Hagen has shown that in individuals of the "second form" the internal generative organs are smaller than in the "first form," but having only alcoholic material he was unable to determine anything concerning the presence or absence of spermatozoa. He interprets the facts as a case of dimorphism and surmises that the "second form" males are sterile individuals.

In the autumn of 1875, I received a lot of living *Cambarus rusticus* Girard, from Kentucky, males of the "first form" and females, which bred freely in confinement. After pairing, three of the males moulted and were thrown, while in the soft-shelled state, into alcohol together with their exuviæ. An examination of these specimens now reveals the fact that the soft-shelled specimens are all of the "second form," their exuviæ of the "first form!" After attaining the "first form" and after pairing, the same individual has reverted to the "second form." It is now clear that we are not dealing with a case of true dimorphism such as is well known among insects and plants, but it appears probable that the two forms of the crayfish are alternating periods in the life of the individual, the "first form" being assumed during the pairing season, the "second form" during the intervals between the pairing seasons. It is to be inferred that before the animal is again capable of reproduction, another moult will bring it again into the "first form."

The fact that large collections, made at one time and place, often contain only one or a great preponderance of one, form of the male, is now explained.

I have also before me a male specimen of *Cambarus propinquus* Girard, from Wisconsin, belonging to the Peabody Museum of Yale College, which was taken in the act of moulting. The old shell is "first form," the soft shell emerging from it is "second form."

It is remarkable that two forms of the male have not been detected in any other genus of crayfishes.

Fritz Müller (Für Darwin) has pointed out the existence of two forms of the male in the genera *Tanais* and *Orchestia* which he considers as truly dimorphic forms. It is possible that these are to be explained in the same way as the two forms of the male *Cambarus*.

Such a change as this connected with the reproductive periods is unparalleled, so far as I know, among the Invertebrata, and even among the Vertebrata; the cases of partial atrophy of the generative organs or shedding of antlers (as in the stag) after the rut is over are hardly comparable.

At the time I had the specimens alive my attention had not been drawn to the questions relating to the two forms of the males, so that I failed to make anatomical examination, and the specimens have now lain too long in alcohol to be serviceable for internal dissection. I hope, however, that naturalists who are more favorably situated will be able to throw more light on this subject.

I will add that the males of extraordinary size which I have seen, are all of the "first form." Do these very old individuals cease to moult? Do they become permanently capable of reproduction?

Museum of Comparative Zoölogy, Cambridge, Mass., Nov. 12, 1883.

Art. IX.—*Evolution of the American Trotting Horse;* by Francis E. Nipher.

In the November number of this Journal, Mr. W. H. Pickering has criticised the method of reduction used in my paper in the July number, and has reached a conclusion very different from my own. I wish to discuss his criticisms briefly.

Mr. Pickering thinks it objectionable to determine the value of $\frac{ds}{dT}$ or the change in speed per year, by taking alternate differences in s and T, and he has reduced the observations by taking the differences between consecutive values in the table. In this way he gets the values in the third column in the table below.

s	Year.	$\frac{ds}{dT}$ obs.	$\frac{ds}{dT}$ calc.	E.
145	1854·0			
		0·59	0·59	0·0
143	1857·4			
		0·55	0·56	−0·1
141	1861·0			
		0·54	0·54	0·0
139	1864·7			
		0·46	0·51	−0·4
137	1869·0			
		0·55	0·49	+0·4
135	1872·6			
		0·35	0·46	−1·4
133	1878·3			
		0·75	0·44	+1·8
131	1881·0			

Plotting the values of $\frac{ds}{dT}$ and the corresponding values of s, he then goes on to say, that the points so determined may be represented by a curve such that the value of $\frac{ds}{dT}$ increases when that of s diminishes. Assuming as I had done, that a straight line will represent the values, he determines the values of the constants, and finds that the line intersects the s axis at a point where s is -25. This would mean that the horse would finally trot a mile in less than no time.

When making the first discussion of the subject, the writer considered the propriety of determining $\frac{ds}{dT}$ by means of consecutive differences, and unfortunately rejected the method without even giving it a trial, for the reason, that the dates 1881·0 and 1878·3 were very imperfectly determined. It was clear that the additional point gained would deserve very little weight. It was thought best to smooth the line by combining these with previous and better determined dates. Properly used, one of these methods is probably as reliable as the other. But when Mr. Pickering's method is used, it becomes absolutely necessary to take into account the fact, that the different values of $\frac{ds}{dT}$ are determined with very different degrees of precision, Mr. Pickering has given them all equal weight, and this is the fatal defect which, it seems to me, entirely vitiates the conclusion reached by him. A reference to fig. 1 of my paper in the July number, will show that for the earlier dates, from 1854·0 down to 1872·6 the graphically determined dates differ from the real dates when the record was actually lowered, by from one to two years. It will also be seen that the dates 1878·3 and 1881·0 are subject to errors which may be as great as two years.

After having made a preliminary examination, these dates might indeed have been "adjusted," so as to make them agree better with the others, and this without giving a "cooked" appearance to the reduction; but they now stand exactly as they did when first determined and before any other work had been done. I have plotted the new values of $\frac{ds}{dT}$ with the values of s, and the line representing the values so as to give most weight to the best determined values, I find to be represented by the equation

$$\frac{ds}{dT} = -1\cdot24 + 0\cdot0127\, s.$$

This line is nearly coincident with the line marked A A in the diagram in Mr. Pickering's paper.

From this equation the values of $\frac{ds}{dT}$ were calculated as given in the fourth column of the table above. The fifth column, headed E, gives the time in years by which the corresponding time intervals dT must be increased, in order to bring Mr. Pickering's values of $\frac{ds}{dT}$ of the third column, into accordance with the values calculated from the above equation. In this case the intervals were supposed to be separately adjusted. If the later dates were simultaneously adjusted by intervals ranging from a quarter to three-fourths of a year, the values which Mr. Pickering prefers to use would agree exactly with the values calculated from the last equation. Now it is perfectly clear, that these later dates, and particularly the last two, are subject to just such errors as this. If the date 1881·0 were made 1882·8, the value of $\frac{ds}{dT}$ instead of being 0·75 would be 0·44.

Whatever these values of $\frac{ds}{dT}$ may be said to prove, therefore, they do not prove that my results as before published were absurd, and they do not indicate a limiting speed of one mile in 25 seconds less than no time, but when $\frac{ds}{dT}=0$ the value of s from the last equation is 98 seconds.

I desire to express my thanks to Mr. Pickering for his suggestion and his friendly criticism, as he has corrected a tendency which I had begun to feel, to attach too much importance to the numerical results reached ; but I maintain that his method, correctly applied, gives in general, substantially the same result as my own. It is not necessary to assert that this result is really correct, if any person feels inclined to doubt it. I only insist that the conclusion that the trotting horse will finally trot his mile in about the same time that the running horse will run, is not unwarranted by the facts which we now know.

Most horsemen seem to think that the limiting speed of the trotting horse will be somewhere near a mile in 120 seconds. If this were true, the differential equation could hardly be a linear one. The equation

$$\frac{ds}{dT}=K\sqrt{s-L}$$

might, however, represent the values, L being the limiting value of s. But this equation gives on integration an equation of the form,

$$\sqrt{s-L}=C-AT.$$

According to this equation the horse would absolutely reach the limiting speed in a finite time $\frac{C}{A}$. Practically this may be true, as is in fact shown by my own equation (4) in the July number, so that some such equation might really represent the results sufficiently for all practical purposes. But the relation is not a rational one, since it cannot be supposed that the horse will really attain his limiting speed in a finite time. After he had come within a thousandth of a second, it would take a mighty effort, and a great interval of time to compass the next millionth of a second.

Moreover this equation will not hold after the limiting space shall have been attained, since it is the equation of a parobola, and the value of s will then begin to increase, which is evidently absurd.

Washington University, Nov. 10, 1883.

ART. X.—*On the Origin of Jointed Structure*; by G. K. GILBERT.

IN the number of this Journal for July, 1882, the writer pointed out that existing theories of the origin of joint structure were unsatisfactory. His note appears to have excited interest and borne fruit. Mr. McGee, in the February number of the Journal, has made a suggestion on the subject, and Messrs. Walling and Crosby have elsewhere published theories.

Mr. McGee suggests "that the vertical compression and consequent lateral expansion of beds beneath areas of deposition may produce incipient slaty cleavage along certain lines perhaps determined by crystalline structure, and that the vertical expansion and consequent lateral contraction of the same beds, when lightened by denudation and subjected to cooling and desiccation, may develop such lines in the jointage planes."

It can scarcely be questioned that incipient joints are developed into actual joints and open crevices by contraction due to cooling and desiccation; but it seems hardly admissible to compare the initiatory process as conceived by Mr. McGee to slaty cleavage. In slaty cleavage division planes are normal to the direction of pressure, while under this hypothesis they are parallel to that direction.

Mr. Walling and Mr. Crosby independently propose the theory that jointed structure is produced by earthquakes. Mr.

Walling's paper appears in the proceedings of the Montreal meeting of the American Association for the Advancement of Science. Mr. Crosby's, which is the more elaborate, was read to the Boston Society of Natural History in October, 1882.

Mr. Crosby shows, first, that the earthquake vibration, by subjecting the imperfectly elastic material through which it passes to alternate stress and tension, is competent to produce fractures; second, that such fractures would be normal to the direction of wave propagation, and therefore vertical, except in the immediate vicinity of the earthquake focus, where they might be oblique; third, that such fractures, although actually curved, would have generally so great a radius of curvature as to be sensibly plane; fourth, that they would be parallel; and fifth, that the suddenness of the earthquake shock would tend to produce smooth fractures even in heterogeneous material. All these points sustain the hypothesis, and their collective effect is to give it great strength. There are, however, two features of joint structure with which the theory does not *prima facie* consist.

In the first place the angle of intersection of two co-existent systems of joints is usually high. This is recognized as a difficulty by Mr. Crosby, and he says in explanation, "that, after the rocks have been broken by one set of joints, the layers or sheets thus formed possess a strong natural tendency to break at right angles; and, under such circumstances, oblique vibrations may give rise to rectangular fractures and blocks." If I rightly understand him, he refers by the expression, "strong natural tendency," to the comparative ease with which an elongated body of amorphous material may be broken in the direction of its least diameter, a property evidently dependent on the fact that fracture through the smallest diameter involves the overcoming of cohesion through a surface of minimum area. If this were the true explanation of the high angle assumed by secondary joints, each of the layers between primary joints would be affected independently and the planes of cross-jointing would be discontinuous. With continuous planes of cross-jointing, the total cohesion overcome is not diminished by any modification of attitude.

A somewhat different explanation has occurred to me as possible. It is, that after one set of joints has been established normal to an original direction of earthquake impulse, a second impulse, somewhat oblique to the first, may have its tensions relieved by the existing joints, and for this reason fail to produce a new set. An impulse at right angles to the original direction would produce tensions not at all relieved by the existing joints, and would initiate a series dividing the terrane into rectangular blocks. The defect of this explanation is that in diminishing one difficulty it increases another, as will presently appear.

The second feature of joint structure which occasions difficulty with the earthquake theory is that the angle of intersection of coexistent systems is *sometimes* very small. Mr. Jukes, in his Manual, mentions 5° as a measured angle; and, without being able to cite measurements, the writer believes he has observed angles as small as that. The considerations set forth in the preceding paragraph sufficiently explain how this phenomenon constitutes a difficulty.

If these two features can be satisfactorily explained, there seems no bar to the substitution of the earthquake theory for those previously entertained.

Art. XI. — *A Theory of the Earthquakes of the Great Basin, with a practical application;* by G. K. Gilbert.

[From the Salt Lake Tribune of Sept. 20, 1883.]

There are many geologists who are very wise, but even they do not understand the forces which produce mountains. And yet it must be admitted, not only that mountains have been made, but that some mountains are still rising. The mysterious forces appear to act in different ways in different places, and it is possible that their nature is not universally the same. Suffice it to say that in the Great Basin the movements they cause are vertical. It is as though something beneath each mountain was slowly, steadily, and irresistibly rising, carrying the mountain with it.

In yielding to this all-compelling upward thrust, the earth's crust sometimes bends and stretches, but more often it breaks; and when it breaks, the fracture occurs in a peculiar place. It does not run along the medial axis of the mountain, but along one margin. On one side of the fracture the crust is lifted and tilted; on the other side it either sinks or remains undisturbed. The uplifted part of the crust is the mountain, and the storms carve out its cañons; the unlifted part remains a lowland or valley, and receives the debris washed out from the cañons.

A mountain is not thrown up all at once by a great convulsive effort, but rises little by little. The subterranean upthrust is continuous and slow, and would produce a continuous upward movement of the mountain if the mountain's weight were the only resisting factor. But there is also a great friction to overcome, the friction along the surface of fracture between the rising and stationary parts of the crust; and friction gives to slow motion an uninterrupted or rhythmic character.

The disagreeable jarring of a railway car while the brake is set is due to the interruption of motion by friction, the wheels alternately sliding and stopping. The musical vibration of a violin string is due to the alternate cohesion and sliding of the bow upon it, and fails when the friction of the bow is insufficient. Attach a rope to a heavy box and drag it slowly, by means of a windlass, across a floor. As the crank is turned, the tension of the rope gradually increases until it suffices to overcome the starting friction, as it is called. Once started, the box moves easily, because sliding friction is less than starting friction. The rope shortens or sags until its tension is only sufficient for the sliding friction, and it would continue in that state but that the box, having acquired momentum, is carried a little too far. This slacks the rope still more, and the box stops, to be started only when the tension again equals the starting friction. In this way the box receives an uneven, jerky motion.

Something of this sort happens with the mountain. The upthrust produces a local strain in the crust, involving a certain amount of compression and distortion, and this strain increases until it is sufficient to overcome the starting friction along the fractured surface. Suddenly, and almost instantaneously, there is an amount of motion sufficient to relieve the strain, and this is followed by a long period of quiet, during which the strain is gradually reimposed. The motion at the instant of yielding is so swift and so abruptly terminated as to constitute a shock, and this shock vibrates through the crust with diminishing force in all directions. Movable objects are displaced, and the soil, which is movable as compared with solid rock, is cracked. In consequence of earth cracks, subterranean waters find new channels, leading to the stoppage of some springs and the starting of others. In fine, all the phenomena of an earthquake are produced.

This is not a universal theory of earthquakes—some of them are doubtless to be accounted for in a different way; but it affords a sufficient, and I do not doubt that it affords the true, explanation of the earthquakes of the Great Basin. In this region a majority of the mountain ranges have been upraised by the aid of a fracture at one side or the other, and in numerous instances there is evidence that the last increase of height was somewhat recent.

Let us look a moment at this evidence. The material eroded from a mountain by the elements is washed out through the cañons and deposited in the adjacent valleys. The coarser part of it lodges at the mountain base, and is built into a sloping mass called the foot-slope, or colloquially the "bench." When an earthquake occurs, a part of the foot-slope goes up with the mountain, and another part goes down (relatively) with the valley. It is thus divided, and a little cliff marks the line of division. A man ascending the foot-slope encounters here an abrupt hill, and finds the original grade resumed beyond. This little cliff is, in geologic parlance, a "fault-scarp," and the earth fracture which has permitted the mountain to be uplifted is a "fault." In the course of time the same slow process of erosion and deposition which originally formed the foot-slope restores its shape and obliterates the fault-scarp. When a mountain ceases to grow, its fault-scarp soon disappears; and conversely, when we find a fault-scarp at the base of a mountain, we are assured that the uplifting force has not ceased to act. Fault-scarps have now been found at the bases of so many ranges of the Great Basin, that it is safe to say that the subterranean forces are generally active in this region, and this is especially true of all the large mountain masses. The Wasatch is a conspicuous example, and residents of this city need not go far for ocular demonstration. A fault-scarp, thirty or forty feet high, divides the powder houses north of the Hot Spring, so that some of them stand above and some below it, and considerable grading was necessary to lead the road to the upper magazines. With one exception, all the lime kilns between the powder houses and the Warm Springs are built in the face of the fault-scarp, the lime rock being conveniently delivered to the kilns from the upper level, and the lime as conveniently drawn out at the lower level. At the mouth of Little Cottonwood Cañon, a smelter has been built on the edge of the upper bench for the convenience of dumping its slag over the fault-scarp. At the mouth of Spanish Fork Cañon, the D. & R. G. Railroad encounters the scarp, and the engineers have started an embankment a long way back to climb it. Similar features may be seen, with rare intervals, all along the mountain base from Nephi to Willard.

The fault-scarps of the Wasatch follow the western base. Those of the Sierra Nevada follow the eastern base; and it happens that one of them has been formed since the settlement of the country. It occurred in 1872, and produced one of the most notable earthquakes ever recorded in the United States. The height of the scarp varies from five to twenty feet, and its length is forty miles. Various tracts of land were sunk a number of feet below their previous positions, and one tract, several thousand acres in extent, was not only lowered, but carried bodily about fifteen feet northward. The ground was cracked in various directions, and several springs permanently disappeared. All houses of adobe or stone in the immediate vicinity were thrown down, and about thirty persons lost their lives. In the little town of Lone Pine, numbering some three hundred inhabitants, twenty-one were killed by falling walls.

There was only one violent shock, and the damage was all done in a few seconds, but for two months there were occasional tremors. Theoretically, the main strain of the earth's crust was relieved at once, but a complete equilibrium was brought about more slowly.

The surviving inhabitants of Lone Pine observed that the only houses that remained standing were of wood, and in rebuilding they employed that material exclusively. Such a course was natural, but I conceive that their precaution was unnecessary. They may, indeed, feel feeble shocks propagated from earthquakes centering elsewhere, but in their own locality the accumulated earthquake force is for the present spent, and many generations will probably pass before it again manifests itself. The old maxim, "Lightning never strikes the same spot twice," is unsound in theory and false in fact; but something similar might truly be said about earthquakes. The spot which is the focus of an earthquake (of the type here discussed) is thereby exempted for a long time. And conversely, any locality on the fault line of a large mountain range, which has been exempt from earthquake for a long time, is by so much nearer to the date of recurrence—and just here is the application of what I have written. Continuous as are the fault-scarps at the base of the Wasatch, there is one place where they are conspicuously absent, and that place is close to this city. From the Warm Springs to Emigration Cañon fault-scarps have not been found, and the rational explanation of their absence is that a very long time has elapsed since their last renewal. In this period the earth strain has been slowly increasing, and some day it will overcome the friction, lift the mountains a few feet, and re-enact on a more fearful scale the catastrophe of Owens Valley.

It is useless to ask when this disaster will occur. Our occupation of the country has been too brief for us to learn how fast the Wasatch grows; and, indeed, it is only by such disasters that we can learn. By the time experience has taught us this, Salt Lake City will have been shaken down, and its surviving citizens will have sorrowfully rebuilt it of wood; to use a homely figure, the horse will have escaped, and the barn door, all too late, will have been closed behind him.

When the earthquake comes, the severest shock is likely to occur along the line of the great fault at the foot of the mountain. This line follows the upper edge of the upper bench from Big Cottonwood Cañon to the rifle targets back of Fort Douglass, cutting across each creek just where it issues from between walls of bed-rock, and passing only a short distance back of the fort. At a point not far north of the targets, the fault divides; one branch continuing northward, across the spur, toward Farmington; the other turning westward, running just back of that hopeless artesian boring, and following the upper edge of the gravel bench to the vicinity of the Warm Springs. Should the earthquake follow the former of these branches, the city will not fare so badly as the fort; should it follow the latter, or follow both, city and fort will alike suffer severely.

What are the citizens going to do about it? Probably nothing. They are not likely to abandon brick and stone and adobe, and build all new houses of wood. If they did, they would put themselves at the mercy of fire; and fire, in the long run, unquestionably destroys more property than earthquakes. It is the loss of life that renders earthquakes so terrible. Possibly some combination of building materials will afford security against both dangers.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the constitution of Bleaching Powder.*—The composition of bleaching powder has long been a subject of discussion. The original formula of Gay Lussac corresponds to $Ca(OCl)_2 + CaCl_2$, while Odling gives the formula Cl–Ca–OCl and Stahlschmidt the formula HO–Ca–OCl. O'Shea has investigated the matter anew in a way which throws much light upon it. He distinguishes at the outset between bleaching powder as a whole and the special oxidizing compound contained in it which he calls the bleaching compound. That the molecule of the latter contains ClO has been placed beyond doubt by the researches of Kopfer. The question to be solved is whether the elements of water or of calcium chloride enter in any way into the molecule. Stahlschmidt represents the formation of bleaching powder thus:

$$\left(Ca\left\{\begin{matrix}OH\\OH\end{matrix}\right.\right)_3+\left(\begin{matrix}Cl\\Cl\end{matrix}\right)_2=\left(Ca\left\{\begin{matrix}OH\\OCl\end{matrix}\right.\right)_2+Ca\left\{\begin{matrix}Cl\\Cl\end{matrix}\right.+(H_2O)_2$$

Hence it must contain free calcium chloride. Odling's formula pre-supposes the non-existence of free calcium chloride. The author sought to determine therefore, (1) the proportion of $Ca(ClO)_2$, of $CaCl_2$, and of $Ca(OH)_2$ in dry bleaching powder, (2) the existence of free $CaCl_2$ and (3) the composition of the residue after removal of the $CaCl_2$. Pure lime was hydrated and analyzed. It yielded from 21·27 to 39·02 per cent of water in different samples. It was then exposed to chlorine until no further increase in weight was observed. In order to fix the ratio of molecules, the total lime was precipitated as oxalate, the total chlorine determined by boiling with ammonia and precipitation with silver nitrate, the available chlorine by Bunsen's method, the calcium hydrate by boiling with ammonia, evaporating to dryness, extracting with alcohol, and weighing the residue, and the water by igniting with lead oxide and weighing the evolved water in a calcium chloride tube. Since half the available chlorine is the actual chlorine combined with oxygen, the total chlorine less one half the available chlorine is the chlorine not combined with oxygen and the total CaO, less the free CaO, is the CaO combined with chlorine, all the needed values are obtained from the above data. Six examples of the bleaching powder were analyzed and the results show that it contains the elements of calcium hypochlorite and calcium chloride in equal molecular proportions, but that the amount of calcium hydrate is variable, contrary to the conclusion of Stahlschmidt. The calcium chloride present in the bleaching powder was extracted by alcohol, and the total lime, the free lime, and the total and available chlorine determined in the residue. The results show that in the bleaching compound the lime is to the total chlorine as 1 : 2, to the actual oxidizing chlorine as 1 : 1 and the actual oxidizing chlorine is to the total chlorine as 1 : 2; all of which conditions are fulfilled and fulfilled only by the formula of Odling. The author therefore concludes: (1) that the excess of calcium hydrate present in bleaching powder is not a constant quantity; (2) that the formula of the bleaching compound is Cl–Ca–OCl; and (3) that by the action of water this compound undergoes decomposition as follows: $(Cl\text{–}Ca\text{–}OCl)_2 = Ca(OCl)_2 + CaCl_2$.—*J. Chem. Soc.*, xliii, 410, Oct., 1883. G. F. B.

2. *On the presence of Sulphurous oxide in the air of Lille.*—LADUREAU has examined the atmosphere in Lille with a view to determine the presence of sulphurous oxide in it. His attention was first called to the matter by noticing that blue litmus paper became red when exposed to the outer air, and by the peculiar characteristic after-taste sometimes observed, on breathing it. Accordingly an aspirator of ten liters capacity was installed in a garden in the interior of the city, the air being drawn through two U tubes containing pumice moistened with pure sulphuric acid, and fragments of pure potassium hydrate, placed successively, then through Liebig's potash bulbs. The experiment continued for several months, many hundred cubic meters of air having passed through the apparatus. The potassium sulphites and sulphides were then oxidized to sulphates and the sulphuric acid determined as barium sulphate. As a result it appeared that each hectoliter of the air which passed through the apparatus contained 0·18 cubic centimeters of sulphurous oxide or 1·8 c. c. per cubic meter. The experiment was repeated, taking a time when the air was quiet, and the result showed 2·2 c. c. of sulphurous oxide to the cubic meter. On the other hand, the amount fell to 1·4 c. c. when the weather was windy. On examining the rain water of

the place, carefully collected, the sulphur products corresponded to a content of sulphuric acid of 0·022 grams per liter or 2·2 grams per hectoliter.—*Ann. Chem. Phys.*, V, xxix, 427, July, 1883.

G. F. B.

3. *On the atomic weight of Antimony.*—Bongartz has made a series of determinations of the atomic weight of antimony using for the purpose a method proposed by Classen which consists in oxidizing by means of hydrogen peroxide, the hydrogen sulphide set free from antimonous sulphide by hydrogen chloride. Pure antimony chloride, fractionated six or eight times, was digested with ammonium sulphide in excess in a platinum basin and the metal precipitated by means of electrolysis with a Siemens magneto-electric machine. It was obtained in brilliant plates from which the last traces of sulphur were removed by fusion with sodium carbonate and subsequent washing with dilute hydrogen chloride. The finely divided metal was heated with a concentrated solution of potassium sulphide, the solution was saturated with hydrogen sulphide, and precipitated with sulphuric acid. The washed antimonious sulphide was treated as described by Classen, i. e., placed in a flask with dilute hydrochloric acid, and the escaping hydrogen sulphide passed through a vertical tube filled with glass beads over which an ammoniacal solution of hydrogen peroxide trickled. The last traces of H_2S were washed out by a current of CO_2, the absorption tube was rinsed with distilled water, the solution acidulated and the sulphuric acid determined as barium sulphate. The results of twelve experiments are as follows: 120·170, 120·157, 120·091, 120·106, 120·114, 120·175, 120·390, 120·305, 120·310, 120·155, 120·206, 120·139; the mean of all being 120·193. This atomic weight confirms the values heretofore obtained by Schneider and by Cooke.—*Ber. Berl. Chem. Ges.*, xvi, 1942, Sept., 1883. G. F. B.

4. *On the constitution of Galician Petroleum.*—Lachowicz has submitted to examination the petroleum from Boryslaw in Galicia, using for the purpose first the commercial fraction having a boiling point from 30° to 125°. This was separated into three portions, of which the first boiled below 50°, the second between 50° and 80° and the third between 80° and 110°. From the first, isopentane boiling at 29°–30°, and normal pentane, boiling at 37°, were obtained. From the second, a normal hexane, boiling at 60° to 61°, and a secondary hexane boiling at 70° were obtained; and from the third a heptane boiling at 98·2° to 99·4°, was separated. In examining higher commercial fractions for hydrocarbons of the marsh gas series, nonane, boiling at 147·5° to 148·5°, and decane, at 152° to 153° were separated. Careful examination failed to discover in Galician petroleum any trace of hydrocarbons of the ethylene series. Two fractions, one boiling from 30° to 125°, mentioned above, the other from 20° to 110°, as also the crude petroleum, were examined for hydrocarbons of the aromatic series, and yielded benzene, toluene, isoxylene and mesitylene. The hydrogenized aromatic hydrocarbons found by

Beilstein and Kurbatow in Caucasian petroleum, though probably present as shown by the specific gravity, were not isolated. The fraction of Caucasian petroleum boiling between 95° and 100° has a specific gravity of 0·748, while the similar Galician fraction has a specific gravity of 0·7291 and that from American petroleum one of 0·7102.—*Liebig Ann.*, ccxx, 188, Aug., 1883. G. F. B.

5. *On the preparation of Mesitylene.*—VARENNE has made a series of experiments on the preparation of mesitylene based on the fact that this hydrocarbon results from a condensation of three molecules of acetone with the elimination of three molecules of water. The process which he prefers is as follows: The acetone (3 molecules or 180 grams) is mixed with 300 grams of sulphuric acid and allowed to stand for an hour. Then it is distilled over a naked fire, the heat being made uniform over the lower surface of the vessel. Toward the end when the mass swells up, a current of steam is passed into the flask, the fire is extinguished, and the operation stopped when no more striæ of mesitylene are seen on the condenser tube. The yield is satisfactory, the 180 grams of acetone giving 40 grams of crude product. It is purified by washing with sodium carbonate, by solution in ether and by distillation from calcium chloride.—*Bull. Soc. Ch.*, II, xl, 266, Oct., 1883. G. F. B.

6. *On certain derivatives of Benzil.*—BURTON has studied a compound obtained by Zinin by acting with hydrogen cyanide upon an alcoholic solution of benzil. It is an addition product of the formula $C_{14}H_{10}O_2(CHN)_2$ and was regarded as the nitrile of diphenyltartaric acid. When saponified, it would obviously yield an acid. After several attempts, the finely pulverized nitrile was placed in a large excess of glacial acetic acid saturated with HBr at 0°, and allowed to stand for some weeks with frequent agitation. From the solution, fine brilliant monoclinic crystals separated. On adding ammonium carbonate to the mother liquor, a white precipitate was thrown down, which after crystallization from alcohol, had the formula

$$\begin{array}{l} C_6H_5C(OH)CO\,.\,NH_2 \\ \quad\quad\;| \\ C_6H_5C(OH)CO\,.\,NH_2 \end{array}$$

On account of its becoming viscous no exact determination of the fusing point could be made. It softens at 150°, but is not fully melted until the temperature reaches 230°. It is soluble in hot water and in alcohol but not in ether. From its amide character it is only weakly basic. It dissolves in hot HCl and separates unchanged on cooling. It unites with HBr to form the beautifully crystallized compound just mentioned. This compound fuses at 185°, evolving HBr. Alkali carbonates convert it into the amide again. The amide has no acid properties and is insoluble in alkali carbonates and hydrates. The solution in sodium hydrate becomes deep red on warming, and on addition of an acid, deposits red flocks containing nitrogen.—*Ber. Berl. Chem. Ges.*, xvi, 2232, Sept., 1883. G. F. B.

7. *Relation between the Sun's spots and the Earth's temperature.*—At a meeting of the Physical Society in Berlin, Oct. 19, Dr. Frölich made a report upon the measurements of solar heat undertaken by him. The object of his work was to discover if the change in frequency of the sun's spots was accompanied by any change in the temperature of the earth. The instrument used by Dr. Frolich consisted of a thermo-electric pile inclosed in a wide double walled pipe, opening in front in the form of a funnel, in which circulated a constant stream of water at atmospheric pressure. The exposed front of the pile was closed by a plate of rock salt. The apparatus was capable of revolving in all directions. This apparatus was preferred to Langley's bolometer, since the electrical resistance of thin plates is subject to considerable variation during long periods of time. As a standard of heat the author employed a hollow screen filled with steam, one side of which was blackened with smoke and the other whitened with chalk. Measurements were taken on perfectly clear days, with the sun at different altitudes, and were represented by curves, the abscissæ showing the thickness of the atmosphere, and the ordinates the warmth of the sun. The measurements in the neighborhood of Berlin gave, in general, a straight line. One single measurement made upon the Faulhorn at a height of 9000 feet gave a perfectly straight line. Measurements distributed over the months of June, July, August, September and October, were different for each month. These measurements were compared with the daily photographs of the sun taken by Dr. Lohse at the Potsdam Observatory, and it was found that the lower degrees of solar heat corresponded with numerous formations of spots while the higher gradations of heat were accompanied by fewer spots. More observations, however, are necessary in order to prove this conclusively.—*Nature*, Nov. 8, 1883, p. 48. J. T.

8. *Theory of the Dynamo-Electric machine.*—CLAUSIUS enters upon a theoretical discussion of this machine which is much needed at the present time. The article is too long and mathematical for a suitable abstract. The question of the working of every machine as a magneto-electric engine first and afterwards, as the strength of the current increases, as a dynamo-electric engine is touched upon. The conditions of the revolving and non-revolving core of the armature are also examined.—*Ann. der Physik und Chemie*, 1883, No. 11, pp. 353–372. J. T.

9. *Aperiodic Galvanometer.*—M. G. L. GOARANT DE TROMELIN describes a galvanometer which has three magnetic needles. The two lower ones constitute the ordinary astatic combination. The additional needle is placed above the astatic combination with its poles opposite to that of the needles immediately below it. The author states that this combination is nearly three times as sensitive as that with the astatic combination alone. In another arrangement the combination consists of horse-shoe magnets placed horizontally one above the other at a distance of $0^{m} \cdot 005$ and fixed in position. The movable part of the apparatus con-

sists of a small coil of wire surrounding the poles of the central magnet and suspended by a bifilar arrangement which conducts the current to the coil; the arrangement being similar to that adopted by Sir William Thomson in his syphon recorder. This apparatus is perfectly aperiodic and is so sensitive that a few milligrams of iron filings falling upon the pole of a magnet of a telephone—the vibrating plate having been removed—give a sensible deflection.—*Comptes Rendus*, Nov. 5, 1883, p. 995. J. T.

10. *On the Heat Produced in Iron and Steel by Reversals of Magnetization;* by JOHN TROWBRIDGE and WALTER N. HILL.—The object of our investigation was to determine whether the heat which is generally attributed to rapid magnetizing and demagnetizing is really due to this cause, or to induction currents in the mass of the iron. Our work, however, had in the beginning a more practical object. Since cylinders of iron and steel are heated when they are made the cores of electro-magnets, and are submitted to the effects of rapidly alternating currents, it was thought that they might exhibit different degrees of heating, and therefore that a process of determining the character of iron and steel might be based upon the phenomena observed, which could be called an electro-magnetic criterion of certain physical properties of these metals. It is well known that chemical analyses of steel and iron throw very little light upon their physical properties, such as tenacity and elasticity in general. There is no satisfactory test for the properties of different steels save by a testing machine, and this is not readily applicable in many cases. If a method could be devised which depended simply upon electrical and magnetic phenomena, it would be a valuable aid to the metallurgist.

The amount of sulphur, of phosphorus, and other ingredients besides iron, is very small in steel, and it could hardly be expected that their presence or absence could be detected by the difference of heat developed under the influence of alternating currents, unless this heating is really due to molecular agitation produced by magnetization and demagnetization. If the heating is due to alternating induction currents in the mass of metal, there should be very little difference in the amount of heat developed by different specimens of steel; for their electrical resistance would not differ sensibly from the presence or absence of a fraction of one per cent. of phosphorus or sulphur. If the heating is due to magnetization or demagnetization, and to an actual twisting of small magnets in their beds, then the molecular arrangements consequent upon different admixtures of various ingredients might produce more heat in one specimen than in another, and thus afford a criterion of the character of the steel. * * * *
[The description given of the experiments is here omitted.]

These results show that this method affords no criterion of the physical properties of iron and steel. The molecular structure of the various specimens employed was not sufficiently modified to enable us to determine any differences in molecular heating,—if the heat developed by magnetizing and demagnetizing is due to molecular heating. If it is due entirely to induction currents in the metals, the slight changes in electrical resistance produced by small quantities of sulphur, of phosphorus, and of carbon would be inappreciable in the masses of iron which we used, and we should expect to obtain under the same conditions the same rise in temperature for the different specimens of steel. Our previous work* on cobalt and nickel must therefore have been affected by some error.

We next determined to ascertain if the heating was confined to the surface of the metallic cores. Theory indicates this to be the case, whether we adopt the hypothesis that the heat is due to magnetization and demagnetization, or the hypothesis that it is produced by induction currents. We could not find, however, any experiments upon this point. The bars were prepared as follows: Each one was bored one-half its length. At the outer end of the hole a shoulder was turned in order that a short piece of glass tubing could be cemented in. One thermometer was placed in the mercury surrounding the bar of iron, and another was hung in the hole in the center of the bar, the hole being also filled with mercury. It was difficult to distinguish between the conduction of heat and the evolution of heat. The rise of temperature indicated by the inner thermometer, however, was probably entirely due to conduction of heat, as can be seen by comparing the amounts of mercury surrounding the two thermometers.

If the heating is due to molecular movements produced by magnetizing and demagnetizing,—and the musical note is adduced as an evidence of this,—the bar would vibrate as a whole, and would become heated throughout on account of this vibration. It is difficult to conceive how the surface action of magnetism can communicate vibrations to a solid bar of iron one inch and a half in diameter. If the bar vibrates as a whole, a certain amount of heating of the bar takes place throughout its interior. The heat in the interior of the bar, however, must be less than that at the exterior, where the magnetization exists in full strength. We believe, however, that the musical note is due to a forced vibration in the coil of the electro-magnet,—possibly due to electro-magnetic attractions; for the note can be heard when the iron core is removed, and is stronger when the core is in place simply because the magnetic field is strengthened.

The appearance presented by iron filings strewn upon the pole of a straight electro-magnet, which is submitted to the action of an alternating current, shows very strikingly the fact that it takes time to magnetize, and that magnetism resides upon the exterior of electro-magnets. Under the influence of strong currents alternating six thousand times a minute, the electro-magnet is still capable of attracting an armature with great force. The filings arrange themselves as a narrow fringe or ring upon the circumference of the end of the cylindrical bar constituting the

* Proceedings of the American Academy, 1878–79, p. 114.

core of the electro-magnet, leaving the surface of the end of the cylinder entirely free from filings. If filings are scattered upon this free portion of the surface, they waltz to the circumference. The fringe of iron filings vibrates in unison with the alternating currents. In connection with this investigation, it may be interesting to refer to some experiments made by Lt.-Comm. A. G. Caldwell, U. S. N., and ourselves, on demagnetization. These experiments were made in 1880, but have not been published.

Perfect demagnetization, or entire absence of magnetism in a mass capable of magnetism, is a condition of great rarity. Approximate demagnetization has been brought about with some difficulty, but delicate tests would show traces of polarity.

We have, however, discovered a method by which complete demagnetization may be rapidly and easily produced. The principle involved is the setting up of a state of powerful magnetic vibration, by which all previous magnetic conditions are obliterated, and on the subsidence of which no polarity remains. This state of vibration is induced by an alternating current of *sufficient strength.* By this an effect is induced in the magnetized mass which can only be compared to a vibration or wave. The reversals of the inducing current cause corresponding reversals of polarity in the body acted on, and as these reversals are continuous and very rapid (5,000 to 6,000 a minute, for example), a molecular vibration probably arises. It is probable that a condition of strain or set is one of the phenomena of magnetism.

The particles have been made to assume a certain definite or polar relation or position. When, however, a powerful movement or vibration is caused, it is evident that when this vibration has become complete,—that is, involving the whole mass,—all previous conditions of strain or "permanent set" will be overcome. It must be remarked that, in order to perfectly attain this result in all cases, the exciting force must be sufficient.

When the alternating current ceases, the body acted on is left perfectly free from polarity. It is, however, in a state of extreme sensitiveness, and must be allowed to remain at rest for a short time. If it is placed north and south, it will assume polarity, and very strongly if struck with a hammer when held in the position of the dip.

Demagnetization requires but a short time in most cases,—from one to three minutes if the current is properly adjusted. There are several ways of performing the experiment, but it will be sufficient at this time to refer to a few of them. The most effective method is to enclose the mass to be demagnetized in a coil of such a length that the whole body will occupy an approximately central position. The coil may be a simple one, in which case it must stand east and west, and before removing the object the electric machine must be stopped, and the current allowed to die away. Also, when the object is taken out of the coil, it must be carefully shielded from the earth's induction; or the coil may be so constructed that it can be opened or divided at the center without breaking circuit, and then the object can be taken out without stopping the alternating current. One of the coils we used was made of No. 12 copper wire, wound as one coil, but in halves, with an elastic connection. It is well known that, with an alternating current, self-induction in the coil materially reduces the current, and therefore the coil should be one of a comparatively small number of turns.

Demagnetization of small masses, not too retentive of magnetism, may be performed by placing them on the end of a bar contained in the coil, which is a part of the alternating circuit. A bar of low steel, somewhat longer than the coil, was used, and the small objects placed on its projecting end.

Perfect demagnetization is attained with varying difficulty. Ordinarily, it is rapidly and easily accomplished. Sometimes a longer time is required, or a more intense action. In numerous experiments we derived the alternating current from a Wilde machine which gave about 6,000 reversals per minute. This rate is probably greater than is required or desirable, except in extreme cases. About 3,000 or 4,000 reversals would be a better general rate, although of course the operator should arrange his apparatus so that he could get more reversals if necessary. Failure will result if the speed is too great, as might be expected if the view here taken is correct. Usually it will be more convenient to employ, instead of an alternating machine, a battery with a reverser arranged for varying speeds.

One application to this method is to the demagnetization of watches. Watches strongly magnetized are completely demagnetized by one to three minutes' exposure in the coil. Frequently unsuspected traces of magnetism cause annoying irregularity of action of a watch. This method enables us entirely to remove this difficulty.

Some very curious and interesting results were obtained by experimenting with magnetite.

A specimen of very pure magnetite from North Carolina, showing marked magnetic properties, was completely demagnetized by a somewhat long exposure to the action of an alternating current applied as described above. Before demagnetization the piece had shown consequent points, although in general it possessed polarity. After treatment it attracted either end of a very light suspended needle indifferently, and when any part of the mineral was presented, just as a piece of soft iron would do. The demagnetized specimen was then placed across the poles of an electro-magnet excited by a strong current from a Gramme machine. It became strongly magnetic, with distinct poles, and without the consequent points it at first had. After this it was treated like an ordinary bar magnet, and magnetized or demagnetized at will.

Another more impure piece was originally less strongly magnetic, and was demagnetized with great difficulty. At first it displayed no general polarity, having consequent points irregularly distributed. After demagnetization it received induced magnetism and became polar, but it was a much feebler magnet than the previous specimen. Demagnetization was afterward performed more easily than at first.

A still more impure specimen was treated, but with the means at hand it was not *perfectly* demagnetized, although so nearly was this done that only traces of magnetism were noticeable.

The result of our work can be stated as follows:

(1) The heat developed by reversals of magnetization is probably due to induction currents, and not to molecular vibrations; for considerable changes in the molecular structure of different specimens of iron and steel fail to show differences in the amount of heat developed.

(2) The heating of iron cores o electro-magnets, which are submitted to alternating currents, is confined to the surface until conduction equalizes the heat of the cores.

(3) The musical note emitted by the core is the note of the coil, due to the number of reversals of the machine, and is merely strengthened by the metallic core of the electro-magnet. This note should not, therefore, be used as an argument in favor of molecular vibrations of magnetic particles.

(4) Experiments on demagnetization confirm what has long been known in regard to the effect of vibrations and shocks upon the magnetic condition of iron and steel. They do not invalidate our results upon the heat produced by reversals of magnetization; for a very slight change in position of the molecules might affect the magnetism of a bar, and yet be insufficient to produce the great heating observed in the armatures of dynamo-electric machines.—*Proceedings American Acad. Arts and Sciences, May* 29, 1883.

11. *On the properties of water and ice;* by OTTO PETTERSSON.—The above is the title of a valuable paper by Dr. Pettersson taken from volume II of the results of the Vega Expedition. It is devoted to a discussion of the physical properties of water in the liquid and solid state at the temperatures to which water and ice are exposed in the Arctic Sea, as between $-20°$ C. and $+15°$ C. The special subjects investigated were the change of heat and volume of (1) pure water, (2) brackish water, and (3) ocean water of ordinary saltness, but before detailing the results of his experiments the author states briefly the results reached by others, and then in detail the instruments employed by him and his methods of observation. In regard to the experiments with pure water, a series of tables gives the results of the experiments on the expansibility of pure water (ice) at the different temperatures employed. The most important point brought out in them is this: that the volume of ice, even the purest which can be tested, decreases with a rise in temperature when near the melting point and this is the more marked as the amount of salt contained in the water increases. In regard to this the author remarks that, "It is impossible to decide if absolutely pure water would be entirely free from this weakness or not, since we cannot assume that water, which has boiled for a quarter of an hour or more in a

glass vessel, is absolutely free from minimal quantities of foreign substances, as e. g. sodium salts, silica, etc. For my own part I am rather inclined to think that absolutely pure water, if it could be tested, would show an absolutely fixed melting point . . . ." In connection with this point the author remarks upon the plasticity of ice, which has been observed near the melting point, while at lower temperature it is brittle. The author shows that the irregularity in expansion is connected with the degree of rigidity of the ice: at a sufficiently low temperature every kind of ice is hard and brittle, and in this state it expands regularly with increase of temperature; the commencement of the thawing is entirely dependent upon the amount of salt, etc., present, and the softening before melting is connected finally with a contraction in volume: thus ice from ordinary distilled water begins to contract at $-0{\cdot}25^\circ$ C.; a sample containing 0·015 p. c. chlorine at -4° C.; and ice formed by the sudden freezing of ocean water begins to contract at -20° C. or below. As a consequence of this it is added that it must be acknowledged "that the ice masses of the glaciers are liable to contraction at temperatures below their melting point."

In the investigation of the chemical changes in the composition of sea water caused by freezing, the author reaches the conclusion that ice formed from sea-water is not, as has generally been supposed, essentially pure, owing its saltness to mechanically enclosed brine; the result reached is the same as that obtained in a different way by Dr. Buchanan of the Challenger. Dr. Pettersson concludes that ocean-water is divided by freezing, not into pure water and a more or less concentrated solution of ordinary sea salt, as was formerly believed, but into two saliniferous parts, one liquid and one solid, which are of different composition. Thus the formation of sea-ice is chemically a selective process, some of the elements of salt water are more fit than others to enter into the solid state by freezing, those which are rejected by the ice will preponderate in the brine, and vice versa; for example as regards the relation of $Cl:SO_3$, the ice is richer in sulphates, the brine in chlorides. The extraordinary variation both in saltness and in chemical composition of every individual specimen of sea ice and sea-brine depends upon a secondary process or the metamorphosis of the ice, due to the combined influences of time and variation of temperature. The concluding chapter is devoted to a discussion of the latent heat of fresh and salt water; the important point brought out in it is this, that the latent heat developed by the freezing of sea-water is "extraordinarily inferior to that of pure water." The author adds, that the freezing process, however, from a thermic point of view, is not entirely concluded with the solidification of the sea-water, by which it is divided into ice, solid cryohydrates, and liquid brine containing dissolved salts; for on further sinking of the temperature, still unfrozen cryohydrates will be solidified and develop heat until the whole mass, at a sufficiently low temperature is a solid rock of crystallized matter. At the rise of temperature these substances will melt one by one, and absorb heat in so doing.

12. *Contributions to the Hydrography of the Siberian Sea;* by OTTO PETTERSSON.—This is a second paper by the same author as that above noticed, it contains a long and valuable series of observations made in connection with the Vega expedition, of the temperature of the sea-water at different depths, specific gravity and the percentage of chlorine, as also that of salt deduced from the observed specific gravity. These observations were taken mostly in the Kara Sea, an admirable hydrographic chart of which accompanies the memoir.

II. GEOLOGY AND MINERALOGY.

1. *Second Annual Report of the U. S. Geological Survey to the Secretary of the Interior, for the year* 1880–81; by J. W. POWELL, Director. Washington, 1882; pp. iv and 588, 4to, with LXI Plates, Figs. 1–32, and a Map, in pocket, showing distribution of the strata and eruptive rocks in the Western part of the Plateau Province.—This volume is the first annual report of the Geological Survey issued under the directorship of Mr. Powell, who, at the close of the fiscal year for which it is issued, had held the position for less than three and a half months. The work reported upon was begun under the direction of his predecessor, Mr. Clarence King, and no change was made in his plans and methods. The volume opens with the Report of the Director, which is followed by the administrative reports of the heads of divisions and by abstracts of the several monographs which are in preparation by the Survey. The monographs are especially designed for the use of specialists, but the summaries given here present the facts and conclusions in a manner adapted to the general reading public. These papers are as follows: The Physical Geology of the Grand Cañon District, by Capt. C. E. Dutton; Contributions to the History of Lake Bonneville, by G. K. Gilbert; Abstract of Report on Geology and Mining Industry of Leadville, Lake County, Colorado, by S. F. Emmons; A Summary of the Geology of the Comstock Lode and the Washoe District, by George F. Becker; Production of the Precious Metals of the United States, by Clarence King. The volume ends with a paper by Mr. G. K. Gilbert on "A New Method of Measuring Heights by Means of the Barometer." Both of Mr. Gilbert's papers, and also the one by Mr. Emmons, have already been noticed in this Journal, as have also two of the monographs which have been issued since the publication of this annual report, viz: those by Capt. Dutton and Mr. Becker.

The Report of the Director is introductory to the volume. It epitomizes the various papers included and details the plan of publication. Reference is made to a report, in preparation by Eliot Lord, on the history of the Comstock Lode, and an account is given of Dr. R. D. Irving's investigation of the copper-bearing rocks of Lake Superior. A statement is also made of a few rules adopted by the Survey, in relation to general geologic nomenclature, cartography and diagrams. The scheme of geologic nomenclature, as laid down in Dana's Manual and subsequently adopted by LeConte in his Elements of Geology, will be followed without material change. In the opinion of the Director, it is unwise for the exploring geologist to commit himself in early stages of investigation to refined and exact correlations, and in the scheme adopted by the Survey the column of epochs or formations is left to be formulated in the various districts as the facts demand. A scheme of colors for geologic charts and of conventional characters for diagrams is presented with illustrations, and the report concludes with a financial statement for the fiscal year ending June 30th, 1881.

Among the administrative reports, that of Mr. Arnold Hague is of some length and considerable interest. It is accompanied by a double page geologic map (in colors) of Ruby Hill Eureka Mining District, Nevada. Mr. Hague reports on the field work in this district, which ranks so high as a mining center, that for economic purposes its elaborate study is important. Its general geological structure has been investigated, and is to be supplemented by a study of its mining geology. As the Director says in another place, mining geology is superficial and almost valueless unless it has a solid foundation in structural geology, and for this reason it is the policy of the Survey to conduct both lines of research in every special district that is taken up for examination. Mr. Hague's field work is completed, and he states that the main features of his monograph on the district will be as follows:

1st. A description of each mountain block, with a detailed account of the formations and their relations to each other.

2d. A detailed description of the great series of Paleozoic sediments, embracing 20,000 feet of strata, extending from the base of the Middle Cambrian up into the upper Coal-measure limestone.

3d. An account of some of the more important dynamical events that have produced the present physical features of the country.

4th. A history of Tertiary volcanic activity, during which all the principal types of volcanic rocks except trachyte found their way to the surface. The relation of the sedimentary beds to the volcanic rocks will also be discussed.

5th. A statement of the position and geologic horizon of the several mining districts and some of the more important mining properties, and some observations on the relations of the ore deposits to both Tertiary and Pre-Tertiary crystalline rocks.

Mr. Hague's monograph is to be accompanied by an atlas of twelve sheets, on which twenty-five colors will be required to represent the Paleozoic system of the district and nine colors will be needed for the igneous rocks. A special monograph on the microscopic petrography of the district by Mr. Joseph P. Iddings is to accompany it; also a report by Mr. Charles D. Walcott. The latter will undoubtedly be one of the most valuable contributions ever made to the paleontological history of the Great Basin. Heretofore this district has been considered a poor one for organic remains, but the present survey of it has secured a collection of nearly 5,000 specimens, which is probably the largest collection of Paleozoic fossils ever obtained from so limited an area in the far West. It is, however, not the number of specimens nor the number of species represented, which Mr. Walcott has determined to be 359 (more than a third of them new), that gives greatest value to this collection, but the fact that it is a systematic collection in one district, extending through one series of 20,000 feet of Paleozoic sediments, included between the base of the Middle Cambrian and the upper Coal-measure limestone. The Cambrian fauna embraces 119 species; the Devonian, 144, and the Carboniferous, 83. In the Silurian the fauna is but slightly developed, the material being derived mainly from the Trenton formation. Thirteen species which suffice to determine the horizon were found, but they are too fragmentary for detailed study.

In an administrative report by Prof. R. Pumpelly, statistics are given of the production of coal, copper, iron, lead and zinc. The collection of these statistics was made in connection with the Census Bureau, and they embody the information obtained from the canvass of 10,440 mining establishments.

The paper by Mr. Clarence King on the Production of the Precious Metals was also prepared in coöperation with the Tenth Census, and is preliminary to a monograph to be published by the Survey. The present paper is practically the same as the one on the same subject published by the Census Bureau, and which has already been noticed in this Journal.

The work is handsomely illustrated, especially in Capt. Dutton's paper, many of the plates and figures being made from sketches by Mr. W. H. Holmes, whose hand has lost none of its cunning.

A double column index of twenty pages effectively concludes this valuable report.

2. *Third Annual Report of the U. S. Geological Survey to the Secretary of the Interior*, 1881–82. By J. W. POWELL, Director. Washington, 1883. 4to, pp. XVIII and 564, with XXXV Plates and Figs. 1 to 56.—A few advance copies of this report have been issued without the complete set of illustrations. The volume opens with the Report of the Director, which gives a résumé of the work accomplished during the year and presents a financial statement. Following this are administrative reports by Messrs. Clarence King, Arnold Hague, G. K. Gilbert, T. C. Chamberlin, S. F. Emmons, G. F. Becker, L. F. Ward, J. Howard Gore and Gilbert Thompson.

Mr. Hague in his report states that he, in connection with Mr. J. P. Iddings, has undertaken an investigation of the acidic volcanic rocks collected by the geologists of the Geological Exploration of the 40th Parallel, including not only the rocks reported upon by Prof. Zirkel in his Microscopical Petrography, but also a large amount of material not prepared at the time his report was published. The result of this investigation has been to correct a grave mistake in Prof. Zirkel's work where he frequently calls the feldspars in certain rocks, sanidin, when they are really determinable as belonging to triclinic species. Messrs. Hague and Iddings find that, in the area covered by the explorations of the 40th Parallel Survey, there are, so far as represented by the collections, no normal trachytes, and that the rocks which have been so classed are andesites. Mr. Hague says that this result is the more remarkable, as rhyolite is by far the most abundant of all the acidic volcanic rocks of the Great Basin. The study of these results leads them to make the broad general statement that among the products of volcanic action in the Great Basin (at least so far as the area indicated above is concerned), the occurrence of orthoclase rocks is dependent upon the percentage of silica in the rock. A preliminary examination has also been made of the rocks from the great cones of Mt. Rainier, Mt. Hood, Mt. Shasta and Lassen's Peak, and the announcement is made that they are andesitic volcanoes, not a single trachyte being included in the collections from the four volcanoes.

After the administrative reports, which space does not allow us to notice further, is a series of "Accompanying Papers" as follows: Birds with Teeth, by O. C. Marsh; the Copper-bearing Rocks of Lake Superior, by Roland D. Irving; Sketch of the Geological History of Lake Lahontan, by Israel C. Russell; Abstract of the Report on the Geology of the Eureka District, Nevada, by Arnold Hague; Preliminary paper on the Terminal Moraine of the second Glacial Epoch, by Thomas C. Chamberlin; and A Review of the Non-marine fossil Mollusca of North America, by C. A. White.

Prof. Marsh in his paper gives a résumé of his investigations of all the known forms of the oldest birds, which differ from recent birds, in having well developed teeth. Prof. Irving's paper, of 102 pages, is an abstract of Vol. V, of the Monographic Series of Reports of the Survey, which is in an advanced stage of preparation. Mr. Russell's paper is also an abstract of one of the monographs. The basin of Lake Lahontan, a Quarternary lake of Northwestern Nevada, according to Mr. Russell, exhibits a vast amount of calcareous tufa, of which there are three varieties, characterizing three distinct deposits in the basin. They are designated, in the order of their age, as *lithoid*, *thinolitic*, and *dendritic*. The first of these reaches the level of the lithoid terrace about 500 feet above the present level of Pyramid Lake and was the first formed. At the top it is only a few inches thick, but increases as the slopes are followed downward. The *thinolitic* tufa layer was deposited at a lower water-stage and reaches only 100 feet above the present lake-level. It differs from the other tufas of the basin and from calcareous tufas in general, in the fact that it is composed of crystals. It has a thickness of six to eight feet. The third and most abundant of all the chemically formed rocks of the basin, is the dendritic tufa, which is locally twenty feet and possibly fifty feet thick, and extends about 300 feet above the present lake-level. These deposits show at least three well-defined periods in the history of Lake Lahontan. When the first was formed, the lake, then a fresh-water body, as shown by the fossils, filled the basin to within thirty feet of the highest water-line now scoring its sides. Later the water was 400 feet lower and it was highly charged with soda. Then the thinolite terrace was carved. Later still the water rose 200 to 250 feet above this terrace and the heaviest tufa deposit was precipitated. There were, therefore, two moist periods, when the lake was deep, separated by a time of dessication and followed by the present period of aridity.

Mr. Hague, in his abstract on the geology of the Eureka District, gives the Eureka section a thickness of 30,000 feet, divided as follows: Cambrian, 7,700 feet; Silurian, 5,000 feet; Devonian, 8,000 feet, and Carboniferous 9,300 feet. The mingling of Coal-Measure and Lower Carboniferous types is more clearly shown in the Carboniferous rocks of the Eureka Basin than in any other western locality.

In the paper on the terminal moraine of the second glacial epoch, Prof. Chamberlin not only abstracts the results of recent investigations by himself and assistants, but combines therewith the observations of others; he gives a description of a compound moraine traced continuously from the Atlantic coast in New England, through New Jersey, Pennsylvania, Ohio, Indiana, Illinois, Wisconsin, Minnesota, Iowa, and finally Dakota, where, at the 103d meridian, it passes into British America. His contribution to glacial geology is too important to be thus briefly characterized, but space will not permit of more at present.

Dr. C. A. White's paper on the non-marine fossil Mollusca of North America, which concludes the volume, is one of the most interesting in it, especially to those who have followed the controversy as to the age of the Laramie group. The paper is accompanied by thirty-two plates, one of which is devoted to Devonian forms, one to Jurassic and Triassic, two to Cretaceous, three to the Bear River Laramie, and the remainder to the Laramie group proper. These plates illustrate an annotated catalogue which is a résumé of the subject by zoological families. A tabular view is also presented. There is besides, an introduction which states the object and method of the work, and a general discussion which ends the paper. The space at command here will not permit of reference to more than one or two points. Three categories of non-marine mollusks are embraced by those of brackish-water, those of fresh water, and those of land habitat. Dr. White points out the analogy between the ancient Laramie Sea and the Black Sea, which in his opinion, the Laramie hydrographic system more nearly resembled. He also states the conclusion that the molluscan fauna of the present Mississippi system is lineally descended from the faunæ of the ancient lakes and seas of the Tertiary and Laramie periods and the river systems of which they constituted lacustrine portions. Dr. White is the first to emphasize this fact.

Heretofore the commingling of brackish-water and fresh-water fossils has been explained on the supposition that the beds in which they were found were estuary deposits. Dr. White says that there is evidence "that the fresh-water fauna proper of the Laramie system not only inhabited the streams which emptied into its sea, but that in great and shifting areas of the sea itself, the waters were sufficiently fresh to allow the existence in them of such Mollusca as *Unio*, *Goniobasis*, *Viviparus*, *Campeloma*, etc., and saline enough in other parts for the existence of *Ostrea*, *Anomia*, *Corbula*, etc." The volume is handsomely illustrated and has a full table of contents and index.

3. *Geology of Lehigh and Northampton Counties, making Report of Progress D3, Vol. I, of the Second Geological Survey of Pennsylvania.* 284 pp. 8vo, with illustrations in the text and a thick atlas in 8vo of over 30 folded sheets. Harrisburg, 1883. —This volume contains the following reports: on the slate-belt and quarries, by R. N. SANDERS; water-gaps, by H. M. CHANCE; on the limestone belt and the Potsdam rocks, by F. PRIME; an itinerary survey of the South Mountain gneiss, etc., by C. E. HALL; and a "Prefatory Letter" and "General Introduction," reviewing many points in the geology of eastern Pennsylvania, by Professor Lesley, the director of the survey.

Mr. Sanders gives, in addition to his descriptions of the slate-quarries, several figures illustrating well the transverse relations of the cleavage and bedding. The dip of the cleavage planes is stated to be in general parallel to that of the axial plane of the flexures in the stratification; the strike is usually the same for bedding and slates; and the exceptions in general occur where the beds bend around in the head of the flexure.

Mr. H. M. Chance describes and figures sections of the slate-belt at the Schuylkill, Lehigh and Delaware water-gaps.

Mr. Prime's report is on the limestone region of Northampton County—the county which lies against the middle of the eastern boundary of the State, and on the Potsdam sandstone in the same region. It covers a little over fifty pages of the volume.*

The limestone is the metamorphic limestone of the Great or Kittatiny valley, which extends southwestward from Northampton County into Lehigh and Berks counties, and beyond. In a former report (DD) the author proved, by the discovery of fossils, that this limestone in Lehigh County (the next county to the southwest) was Lower Silurian, of the age of the Chazy and Trenton. In this volume he announces the discovery in it of similar fossils in Northampton County. The following are some of the facts: 1¼ m. S.W. of Bath, occur species of the genus *Maclurea* or *Euomphalus* (not determinable, because poorly preserved) which are probably of Chazy age; a short distance N.E. of this locality and also at Christian Springs are *Crinoidal stems*, which are abundant and of Trenton age; just outside of Nazareth,

* For some unexplained reason, Mr. Prime's name is in the running title of the whole volume.

besides crinoidal remains, a few specimens of *Orthis testudinaria*; nearly ¼ m. S.W. of Stockertown, similar *crinoidal stems*, *Chætetes lycoperdon* and *Orthis testudinaria*; at Churchville, along with the same crinoidal stems, *Leptæna sericea*, *Orthis testudinaria*, *O. pectinella*; on the Delaware, south of and close to Howell's cotton-mill, besides the species of *Leptæna* and *Orthis* just mentioned, also *Strophomena alternata* and *Chætetes lycoperdon*, the specimens in some spots crowded. Mr. Prime concludes from this best of evidence that the limestone formation is in part *Trenton*, in part *Chazy*, and infers doubtingly, on lithological evidence, that the limestone on the north flank of the South Mountain range is *Calciferous*; and since the Trenton limestone—in many places holding its characteristic fossils—lies conformably beneath the adjoining slates and shales, these slates and shales must be of *Utica* and *Hudson River* age; and he adds "there is not a particle of evidence that any of these limestones belong to Huronian or older periods." At one locality graphite scales occur, with traces of brachiopod shells. The limestone has in some parts intercalated layers of hydromica slate, and others of quartzyte. These and various other points connected with the limestone formation are discussed at length in the report. The facts as to fossils, geological age, metamorphic character of the limestone, and association conformably with hydromica slates, are precisely in accord with those connected with the great metamorphic limestone on the west part of the Green Mountain region in Vermont, where the slates are those of the Taconic range.

Professor Lesley reviews the topography of Northampton County and the associated region to the east, south and southwest; describes the sink-holes, and the underground drainage connected therewith, in the limestone region; and states in brief the geological constitution of the ridges and valleys. The question as to unconformability in Pennsylvania between the Lower Silurian and the overlying beds—the Oneida Conglomerate—is decided by him adversely. Professor Lesley continues with a discussion of the general question whether unconformability—as a result of an epoch of mountain-making—exists in the region of the Hudson River valley to the north, where such evidence has been thought to indicate a disturbance after the Lower Silurian era. He commences by saying that out of the alleged facts "an hypothesis has been framed and made to apply to a thousand miles of the continent;" but by whom, he does not state, or in what publication; the published conclusions, as far as the writer knows, confining the supposed upturning to the regions east of the Hudson, with a narrow strip west of part of it, and the extension of the unconformability southwestward being treated simply as a proper subject for investigation. His arguments against the unconformability in the Hudson River valley are based on general considerations, not on facts derived from personal observations in the region, such as seem necessary to settle a question in stratification. The fact that there is a great gap in the series of formations above the Lower Silurian, including all of the Oneida, Medina, Clinton and Niagara formations, except a few yards of the latter, which all New York geological observers have described, is set aside by arguing the case. Mr. Davis's statement with regard to the conformability of Lower and Upper Silurian strata at the eastern base of the Catskills, that gap in the series excepted, is cited as in opposition; while in fact the region is outside (west) of the supposed area of upturning. Other arguments are based on facts derived from localities "far south of the Hudson River belts" in New Jersey and Pennsylvania, which also are outside of the area of Green Mountain disturbance, and affect only the question that future geologists will discuss with new facts—as to the southwestern extension or limit of the Green Mountain disturbance. The facts in Mr. Davis's excellent papers on Becraft's Mountain and the Rondout region, published in this Journal since Professor Lesley's report appeared, are to the point, and of the kind needed to settle the question. His observations about Becraft's Mountain put the question in just the state in which it was left, in the writer's hearing, by the New York geologists, at a meeting of the American Association of Geologists and Naturalists over thirty-five years since; they afford some reason for doubting the unconformability, but stronger for sustaining it. The Rondout facts are of the positive kind, too positive to be disturbed by imagined or not proven overturns. The facts favor strongly the view that the close of the Lower Silurian was an epoch of mountain-making, along the Green Mountain region. That an epoch of some degree of disturbance in Eastern North America intervened directly after the Lower Silurian—is shown also by the Lower Silurian uplift about the Cincinnati region, well proved by Newberry, and that on the same southwest and northeast line (parallel to the general course of the Appalachians) in Tennessee, made known by Safford's investigations.

Professor Lesley reviews also facts connected with the stratification of the limestone, the Archæan rocks of South Mountain, and the Ice-age. J. D. D.

4. *Pennsylvania Geological Survey.*—Besides the volume above noticed, the survey has recently issued the following reports. No. AA, of plates, The Southern Anthracite Field, vol. I.—No. AC, with an atlas, On the Mining Methods and Appliances used in the Anthracite Coal Fields, by H. M. Chance.—No. C4, The Geology of Chester County after the surveys of H. D. Rogers, P. Frazer and C. E. Hall, edited by J. P. Lesley.—No. D3, Berks County, by E. V. D'Invilliers.—No. D5, Adams, Franklin and Cumberland, maps.—No. I4, On Warren County and the neighboring Oil Regions, by John F. Carll.

5. *The Contents of a Bone Cave in the Island of Anguilla;* by E. D. Cope. Smithsonian Contributions to Knowledge, No. 489. Washington, 1883. 30 pp. 4to, with 5 plates.—This paper is a full description of the bones from the Anguilla Cave—partially described by Professor Cope in 1868. The extinct species

are large Rodents of the genus *Amblyrhiza* and a small Ruminant, probably of the Bovidæ, besides others not determinable; and in the same cave were obtained a scraper or chisel made by man from the large shell *Strombus gigas*. Whether the Amblyrhiza and the Ruminant are of the same era, or man and either of these species, is not ascertained. Professor Cope remarks that the deposit containing the Amblyrhiza is not in his view "earlier than the Pliocene." The paper closes with the following inference. "The island of Anguilla, now embracing but 30 square miles could not readily have supported a fauna of which these huge Rodents formed a part." "This, and other facts mentioned by Pomel, lend probability to the hypothesis of the latter author, that the submergence of the ranges connecting many of the islands of the Antilles has taken place subsequent to Pliocene times." Such facts bear also on the question of a coral reef subsidence in those seas since the Pliocene.

6. *On the Chrysolitic beds or Dunyte of North Carolina;* by A. A. JULIEN. (Proc. Bost. Soc. Nat. Hist., xxii, 141, December, 1882.)—In this important paper, Professor Julien shows that the well known dunyte of North Carolina, which occupies "mainly a zone in the mountain plateau between the Blue Ridge and the Great Smoky Range 250 km. long and 15–30 km. wide" is distinctly bedded, and is enclosed in a stratum of black and slaty hornblende-gneiss, in a region of gneisses and other schists. The rock has a slaty lamination due to bedding, like that of the hornblende gneisses, and it is conformable to the latter in strike and dip with only local exceptions. At a few localities it is interbedded with the latter in layers 1 to 6 yards thick. Professor Julien thus proves, as he urges, that the chrysolite rock was originally of sedimentary origin like the associated schists. He also treats of the alterations of the dunyte, under the heads of Chalcedonic, Hornblendic, Talcose, Ophiolitic and Dioritic. All the hornblende within the chrysolite rock is attributed to alteration, like the serpentine, talc, chalcedony, and this rock is supposed to have originated in sedimentary deposits of chrysolite sand. But the occurrence of the chrysolite stratum in and among hornblende schists suggests that the hornblende of these schists and of the chrysolite was alike in metamorphic origin and source, and it seems to be hardly probable that the material so changed was throughout chrysolite.

7. "*Lenticular Hills.*"—Note by Prof. C. H. HITCHCOCK. (Letter to J. D. Dana, dated Hanover, N. H., Nov. 27th.)—It is not common for me to find some of my views or descriptions ascribed to my father; but in your remarks about the "lenticular hills" (this Journal, III, xxvi, p. 358), you speak of them as having been described by him. I am glad to say that he would have invented a better expression than "lenticular" hills, if he had described them. I suppose we may call them "drumlins," as that term has been applied to them in Scotland.

8. *On the probable occurrence of Herderite in Maine;* by Wm. Earl Hidden. (Communicated in a letter dated Newark, New Jersey, December 11, 1883.)—To Mr. Nathan H. Perry, of South Paris, Maine, an earnest and successful collector of Maine minerals, and the discoverer of many new mineral localities in his State, I am indebted for a few specimens of a dark, oil-green mica, having implanted on it clear crystals of a mineral resembling some varieties of apatite. The preliminary examination which I have made makes it probable that the mineral is the rare species *Herderite.** The crystals are short, terminated prisms, of from 1^{mm} to 1^{cm} in length and diameter, transparent to translucent. Surfaces smooth and not highly polished, but bright. Luster greasy-vitreous. Streak white. Colorless to faintly yellowish. Hardness 5. Sp. Grav. 3. Crystals orthorhombic, with $I \wedge I = 116°$ (hand goniometer). Among the planes already observed are I, $i\text{-}\bar{\imath}$, O, three macrodomes, one brachydome and three octahedral pyramids. A partial qualitative examination has shown the presence of phosphorus in large quantities. A careful analysis is now under-way by Mr. J. B. Mackintosh, E.M., of the School of Mines, New York City, and will shortly be published, with a full account of the method of occurrence and the general physical characters of the mineral.

This mineral had been previously called topaz, from its resemblance to that species in form and color, and also from the fact of its being found at Stoneham, Maine, in the pockets that yielded the fine crystals of topaz noticed in this Journal by G. F. Kunz (III, xxv, p. 161), but the absence of the characteristic basal cleavage and of the hardness of that mineral led me to make the observations whose results have been given.

[*Note.*—Since the above notice was received from Mr. Hidden, the writer has had placed in his hands, by Professor Brush, a few crystals of the supposed herderite from Maine; these specimens were sent by Mr. Perry. A partial examination of these crystals shows that they approximate closely in form to that given for herderite, so that there can be but little doubt of the correctness of Mr. Hidden's determination. The crystals are prismatically developed in the direction of the brachydiagonal axis (see fig. 454, p. 546, Dana's Syst. Min.) The planes observed are: O(001), $i\text{-}\breve{\imath}$ (010), I (110), $\frac{3}{2}\text{-}\bar{\imath}$ (302), $1\text{-}\breve{\imath}$ (011), $3\text{-}\breve{\imath}$ (031), $6\text{-}\breve{\imath}$ (061), $\frac{3}{2}$ (322), 3 (311). Of these planes all occur on herderite except $\frac{3}{2}\text{-}\bar{\imath}$, $3\text{-}\breve{\imath}$, $\frac{3}{2}$. The angles thus far obtained are only approximations, but they serve to show a close correspondence between the Maine phosphate and herderite, for example:—$I \wedge I = 116\frac{1}{2}°$, for herderite $= 115°\ 53'$; $O \wedge 1\text{-}\breve{\imath} = 156°\ 40'$ for herderite $= 156°\ 59'$; $O \wedge 3 = 112°\ 40'$ for herderite $= 112°\ 35'$.—E. S. Dana.]

9. *Analyses of Brazilian Minerals.* (Communicated by Orville A. Derby in a letter dated Rio Janeiro, October 30, 1883).—

* Probably, according to trials by Plattner and Turner, an anhydrous phosphate of alumina and lime with fluorine, orthorhombic with $I \wedge I = 115°\ 53'$, G. $= 2{\cdot}985$. Haidinger, Phil. Mag., IV, i, 1828. J. D. Dana's System Min., p. 546.

Gorceix gives the following analyses of minerals from Ouro Preto (formerly Villa Rica), in the province of Minas Geraes, Brazil.

Green mica (fuchsite); specific gravity 3·1.

SiO_2	Al_2O_3,Fe_2O_3	Cr_2O_3	MgO	K_2O	Na_2O	Volatile matter.	
46·5	37·2	0·9	0·8	7·9	1·3	4·7	= 99·3

Hydrargillite; specific gravity 2·3.

Al_2O_3	H_2O
65·2	34·8 = 100·00

Wavellite; specific gravity 2·34.

P_2O_5	F	Al_2O_3	CaO	MgO	H_2O
33·0	3·6	36·1	0·3	0·2	26·2 = 99·4

Gorceix calls attention to the large amount of fluorine present in this mineral; it was determined by the St. Claire Deville process.

Pyrophyllite; in greenish white acicular crystals; specific gravity 2·76.

SiO_2	Al_2O_3	FeO	CaO	H_2O
65·3	28·0	1·7	0·4	5·5 = 100·9

In the same article the occurrence of rolled crystals of monazite in the diamond sands of the Jequetinhonha near Diamantina is noted. A similar mineral, found abundantly in sands from Caravellas in the province of Bahia, consists essentially of phosphate of cerium and other rare earths, but differs from the Jequetinhonha specimens in specific gravity (5·01) and in aspect. Its crystalline form could not be determined. By error it is stated to be from the Serra de Quebra Cangalha in the province of Sao Paulo.

10. *Groddeckite: a new mineral of the Chabazite group.*—A new zeolite, to be regarded as a variety of gmelinite, has been recently described by Arzruni. It was discovered by him on a single specimen in the museum of the Clausthal Bergakadamie, which was obtained in 1867 from the Franz-August vein at Andreasberg in the Harz. The mineral occurs in small transparent crystals, with vitreous luster, covering calcite crystals. The crystals form combinations of a rhombohedron, a scalenohedron nearly coincident with it, and a hexagonal prism; in habit and angles it is hardly to be distinguished from gmelinite. The hardness is between 3 and 4. An analysis by Broockmann upon 0·0559 gr. gave the following results:

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	H_2O
51·2	12·0	7·7	1·1	3·3	[4·5]	20·2 = 100·

A comparison of the above with the percentage composition of gmelinite shows that the new species, or more properly new variety, differs in the substitution of iron sesquioxide for part of the alumina, and of magnesia for part of the lime. The high percentage amount of silica is ascribed to an admixture of quartz, but the material at hand was too scanty to allow of direct proof of this point, or indeed of another and more complete analysis;

the composition consequently must be considered somewhat doubtful. The mineral is named from Dr. A. von Groddeck, Director of the Bergakadamie at Clausthal.—*Z. Kryst.*, viii, 343, 1883.

11. *Mineral Resources of the United States;* by ALBERT WILLIAMS, Jr., Chief of Division of Mining Statistics and Technology. 813 pp. 8vo. Washington, 1883. (U. S. Geological Survey, J. W. Powell, Director).—Mr. Williams has performed a work of much importance in bringing together the extended series of statistics contained in this volume. The magnitude of the results accomplished is especially remarkable in view of the short time taken for the preparation of the volume. The subject is treated in two parts: the first contains statements and statistics in regard to the occurrence and production of the individual mineral products, as coal, petroleum, also iron, copper, lead, zinc, etc.; and, after the metallic products, others as building stones, bricks, clays, fertilizers, salt, borax, sulphur, etc. To the more important of these products chapters of considerable length are given; thus to the subject of coal about one hundred pages are devoted, and similarly of iron, copper, lead, and so on. These larger chapters have been prepared in whole or in part by different contributors, whose past work has given them especial opportunities for acquiring a knowledge of the facts, and they contain a vast amount of valuable information in regard to the amount of each material mined, the cost of production and allied details.

The second part of the volume contains statistics in tabular form, arranged according to States, giving the scientific and popular names of the various ores, minerals, etc., which are now mined, and in a second table those which are known to occur, but which are not at present mined, with a general statement of the localities. These tables do not profess to be complete in their present form, but they form a nucleus which may be expanded and revised as additional facts are collected.

12. *Lehrbuch der Mineralogie;* von DR. GUSTAV TSCHERMAK. III Lieferung, pp. 369-589. Vienna, 1884 (Alfred Hölder).—The two preceding parts of Professor Tschermak's Mineralogy have already been noticed in this Journal (III, xxiii, p. 68; xxiv, p. 232); this third part concludes the work. It contains the description of species, with an appendix devoted to a brief statement of the mineral constituents of meteorites. This portion of the Text Book is very much condensed, too much so to be entirely satisfactory, but it contains much that is fresh, particularly in the way of figures. The work as a whole is an excellent one for the class of students for whom it has been prepared.

III. Astronomy.

1. *Observations upon the Comet Pons-Brooks made at the Observatory of Yale College;* by O. T. Sherman.—The comet Pons-Brooks has been followed, at the Observatory, by the equatorial of 8 inches aperture (presented by E. M. Reed, Esq.) as steadily as circumstances permitted. Up to date (Dec. 10th) thirty-four observations of position have been obtained; six observations yielding the position of the plane of polarization, and six the percentage.

When first seen, Sept. 6, the nebulosity was very faint globular, about 60″ in extent, without definite nucleus; Sept. 25 the comet had suddenly increased in brightness, presenting an oval 95″ by 64″ in extent, light almost equally diffused. No sharp nucleus. The direction of the elongation was about N. 15° W. Sept. 27–Oct. 3, the nucleus continued to grow brighter while the nebulosity remained indistinct. Oct. 16, the coma or condensation around the nucleus became distinct from the outer nebulosity, the direction of elongation being about S. 20° E. Oct. 24–27, there was a suspected tail about 10′ in extent, which had again disappeared by the 30th. Nov. 2d it appeared again as a globular body presenting a sharp nucleus with a coma of about 50″ surrounding it and a nebulosity of about 3′. Nov. 17–19 there was again a suspected development of the tail. Nov. 24 it again presented a form similar to Nov. 2d, but with a fourth distinction in brightness, the dimensions being (approximately), for coma 50″; inner nebulosity 8′; outer nebulosity 10′. On the days immediately following, the distinctness of the third outline was lost and the coma became somewhat radiated. Dec. 3d, the coma appeared somewhat lens-shaped, extending crosswise of the nebulosity about 5′ by 1′. The nebulosity was oblong, about 12′ by 7′.

When examined by a Nicol's prism there appear two positions of maximum intensity, two of minimum but no disappearance. At the time of least intensity the nucleus and a portion of the coma appear deprived of the nebulosity. Under a double image prism the position of equal intensity is 24°·5 removed from the nearer position of maximum-minimum intensity.

2. *Spectroscopic Observations of Comet Pons-Brooks;* by Dr. N. de Konkoly.—The spectrum was very faint and appeared as a diffused nebulous spot of light. After looking in the spectroscope for a long time I saw three bright bands in the spectrum. The bands were all extremely faint and diffused on both sides, the slit being opened rather wide. The second band from the red end was the brightest, the third band was the next brightest, and the least refrangible band near the red portion of the spectrum was the faintest. All three bands ended in a faint point. They were of unequal lengths; the brightest being the longest, the least refrangible next, and the band toward the more refrangible end of the spectrum the shortest.

There were moments in which for one or two seconds at a time the bands were very clear and bright, and at these times they seemed to be much shorter than ordinarily. I should say but one-third the length,—a singular phenomenon which I have never seen on any other occasion.—*Observatory, and Astr. Nachrichten.*

3. *Observations of the Great Comet of* 1882 *made at the U. S. N. Observatory.*—This appendix to the volume of Observations for 1880 is prepared by W. C. Winlock, by whom the larger part of the observations were made. The comet was observed first on the 19th of September by daylight, two days after the perihelion passage. It was last seen on the 4th of April. Eight diagrams are given of the appearance of the head, seven of them as seen in the 26-inch equatorial, showing the disintegration of nucleus, and the gradual separation of the several parts. Observations for the comet's position, differential measurements of the points of light of the nuclei, descriptions of the shape and appearance of the tail, and also of the curious "outer-envelope" or "veil" that extended back toward the sun are all given in detail. H. A. N.

IV. Miscellaneous Scientific Intelligence.

1. *Report of the Superintendent of the U. S. Coast and Geodetic Survey for* 1882. Washington: Government Printing Office. 1883. 4to, 565 pages and 52 plates.—This report has just been received from the Public Printer and is now ready for distribution. As usual the first part of the volume is devoted to a statement of the progress made by the various branches of the Survey in all parts of the country and shows that the work is being prosecuted with vigor and a discriminating regard for the requirements of the country at large, and the necessities of those portions of our extensive coast line which are as yet unsurveyed. This portion closes with detailed statements by the Chiefs of Divisions of the Coast and Geodetic Survey Office of the work done under their direction. Following the report proper of the Superintendent, and the statistical reports from Divisions, are a number of monographs relative to the work. As a collection this is the most important series of papers yet published by the Survey.

The principal geodetic work executed during the year was the measurement of the Yolo Base in California. This primary base line is situated in the Sacramento Valley, about twenty miles west of the city of Sacramento and parallel to the general direction of the Coast Range. As the primary triangulation in California has furnished the largest triangles known to geodesy, so also in this base line we have one of the longest primary bases ever measured. It is 17·49 kilometers in length. Preparations for its measurement had been in progress for several years and for this purpose a new compensating base apparatus was constructed on a principle not new in itself but new as applied to base apparatus. It was made from the designs and under the supervision of Mr. C. A. Schott, Assistant C. and G. Survey. The standard of reference is the iron "Committee Meter" of the United States, one of the original meters used by the French Committee in 1795. In connection with the construction of the base apparatus the coefficient of expansion of the Committee meter was elaborately redetermined. A detailed account of the steps followed in the determination of the coefficients of expansion and lengths of the various bars used, of the primary and secondary compensation, and of the resulting length's of the 5-meter standards and measuring bars, is given in Appendix No. 7, by C. A. Schott.

Following this is a paper by Professor Geo. Davidson, Assistant Coast and Geodetic Survey, giving an account of the measurement of the Yolo Base, of which work he had charge. He gives a short history of the base, its selection and survey, and method of marking the ends, and then goes into a more detailed account of the operations immediately connected with the measurement. The working force was twenty-one persons, seven officers and fourteen men. All the operations of measurement were conducted under a large canvas screen moving on wheels and pushed forward by hand. The party, as well as the apparatus, was thus protected from the direct rays of the sun. Daily comparisons were made between the measuring bars and the standard. On the first measurement heavy "kilometer stones" were put down at the end of every 200th bar and on the second measurement comparisons were made. Whenever the field reductions indicated a difference between the two exceeding four millimeters the kilometer was again re-measured. This was, however, not done until the completion of the second measure. Seven kilometers were thus re-measured, but the office reduction showed that the introduction of certain small quantities of which no note could be taken in the hurried work of a field reduction made such corrections to the field differences that the third measurement would nowhere have been necessary. The probable error from all sources combined is 0·0096 meter. Expressed as a vulgar fraction this is $\frac{1}{1826000}$ of the length.

The next paper is a reprint, with additions, of the manual on the "Field work of the Triangulation," by R. D. Cutts, Assistant Coast and Geodetic Survey. This paper was originally printed in the Coast Survey Report for 1868, and again printed, with additions, as a separate publication in 1877. In its present form it is still further enlarged and is fully adapted to the needs and requirements of geodetic practice at the present day. The portion of the manual devoted to signals is elaborated in a separate paper on the subject by C. O. Boutelle, Assistant Coast and Geodetic Survey. In this are given a number of tables which will be of value and assistance to those having such signals to erect.

In addition to the one already mentioned there are three other papers from the fertile pen of Mr. Schott. One is a discussion of the results of the line of transcontinental spirit levelling now conducting in connection with the triangulation of the 39th parallel. Beginning with the mean tide level at Sandy Hook, N. J., the line of levels passes Hagerstown, Md., Grafton, W. Va., Mitchell, Ind., and has now progressed seventy miles beyond St. Louis. The levels were executed by the use of the "geodesic level," a double line being run, not simultaneously but forward and back over short spaces. The small difference between the two and the very slow accumulation of error shows the great accuracy attainable with this instrument. A discussion of the results shows a probable error of only 47 millimeters for the height of the bench mark on the bridge at St. Louis, the linear distance from Sandy Hook being 1784·6 kilometers = 1191·4 statute miles.

The other two papers by Mr. Schott relate to terrestrial magnetism. One is a fifth, and considerably enlarged, edition of his previously published work on the "Secular Variation of the Magnetic Declination in the United States and at some foreign stations." The constant demand for this paper renders necessary its frequent republication and it is so well known that more detailed mention of it need not here be made. Following this is a paper giving magnetic declination for the epoch 1885·0 at more than 2300 stations in and on the confines of the United States and Alaska. It is accompanied by isogonic charts for the U. S. and Alaska. The last chart of this character published by the Survey appears in the report for 1876 and represents the distribution of terrestrial magnetism in the United States for the epoch of 1875·0.

Following the last named paper is one by Professor J. E. Hilgard giving the results for magnetic declination, dip and intensity as obtained between 1871 and 1876, through aid of a portion of the Bache Fund for scientific research, so applied by the National Academy of Sciences, and of which work Professor Hilgard had the direction. One hundred and forty stations were occupied. They represent twenty-six States and Territories, from Vermont to Florida and Wyoming, and also Canada and New Brunswick. Observations for declination were made at 141, for dip at 94, and for intensity at 93 stations. Full abstracts of the results are given and the values were used in the preparation of the isogonic charts of 1875·0 and of 1885·0.

Five papers devoted to the consideration of hydrographic questions come next. Of these the most important is a "Discussion of the tides of the Pacific Coast of the United States," by Wm. Ferrell, whose contributions to meteorology and tidal researches have become everywhere known. In this paper Mr. Ferrell discusses the hourly results for a period of three years at the stations Port Townsend, Astoria and San Diego, and his deductions form a valuable addition to the data previously in hand for predicting the tides on that coast. The other papers are a "Comparison of the Survey of Delaware River of 1819, between Pettys and Tinicum Islands, with more recent surveys," by H. L. Marindin, Assistant Coast and Geodetic Survey; a "Study of the effect of river bends on the lower Mississippi," by Henry Mitchell, Assistant Coast and Geodetic Survey; a "Report on the Siemens' Electrical Deep Sea Thermometer," by Commander J. R. Bartlett, U.S.N., Assistant C. and G. Survey, commanding C. and G. Survey Steamer Blake, and on "Recent Deep Soundings off the Atlantic Coast of the United States," by Lieut. J. E. Pillsbury, U.S.N., Assistant C. and G. Survey, Acting Hydrographic Inspector.

Succeeding these are a paper by Professor Geo. Davidson giving an account of the total solar eclipse of January 11, 1880, as observed by him at Mt. Santa Lucia, California, and a "New Reduction of Lacaille's Observations of Fundamental Stars in the Southern Heavens" (between 1749 and 1757), the computations of which were made by Dr. C. R. Powalky, under direction of the National Academy and at the expense of the Bache Fund. This paper will find publication in the Bache Fund Memoirs, but is here published to give earlier appearance to so important a work. This re-computation, taking account of and correcting the many imperfections of Lacaille's instruments, will give the most valuable data for the determination of the proper motions of many of the southern stars.

This paper is followed by a report on a "Conference on Gravity Determinations, held at Washington, D. C., in May, 1882," in which Hilgard, Herschell, Peirce, Newcomb, Davidson and Schott participated. The present state of the science was discussed and opinions expressed as to the method of conducting gravity observations and the sense of the conference was formulated in distinct categorical statements and conclusions which are now published.

Finally, the Report closes with a tribute to the memory of the late Carlile P. Patterson, LL.D., fourth Superintendent of the Survey.

2. *Annals of Mathematics, pure and applied;* edited by Ormond Stone, Professor of Astronomy, and William M. Thornton, Professor of Engineering, both of the University of Virginia.—This new Journal has its office of publication at the University of Virginia. It is announced as "the successor of the Analyst, which has been edited for the past ten years by Mr. J. E. Hendricks, and which is now discontinued by him on account of impaired health."

The Annals of Mathematics will appear every other month, commencing with February 1st, in a small quarto form, and each number will contain at least twenty-four pages. It is designed to be a medium of communication and publication for teachers and students of mathematics. The purpose of the editors will be to guide and encourage the study of mathematics, pure and applied, in all its branches; to stimulate independent mathematical investigation by offering prompt publication of its results; to report the more important advances in mathematical discovery; and, to register the more valuable additions to mathematical literature. The subscription price is two dollars per annum. The Journal should have the support of all who are interested in the advance of mathematical studies and in methods of instruction.

Chemistry: Inorganic and Organic, with experiments, by Charles Loudon Bloxam. From the fifth and revised English edition. 738 pp. 8vo. Philadelphia, 1883 (Henry C. Leas' Son & Co.) This well known and standard work has now passed to its fifth edition.

A Manual of Chemistry, Physical and Inorganic, by Henry Watts, B.A., F.R.S., 595 pp. 8vo. Philadelphia, 1884 (P. Blakiston, Son & Co.) A new work by the author of the Dictionary of Chemistry; it differs from most recent elementary works in that it gives so much space to Physics.

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ART. XII.—*Examination of Mr. Alfred R. Wallace's Modification of the Physical Theory of Secular Changes of Climate;* by JAMES CROLL, LL.D., F.R.S.*

ON the publication of 'Island Life,' upwards of three years ago, the author kindly favored me with a copy. He at the same time wrote to me stating that the volume contained some modifications of my theory of secular changes of climate, to which he had been led by a careful consideration of the subject, and that he would be glad to have an expression of my opinion in regard to his results. Deeply interested as I, of course, felt in the matter, I was however compelled, owing to the state of my health, to leave the volume unread till within the last few months. This fact will account for the appearance of the following remarks at this somewhat late date.

I have read the chapters relating to Geological Climate with the greatest amount of interest and pleasure, and have to thank the author for his very clear and able exposition and defence of the main points of my theory. It appears to me, however, that what Mr. Wallace regards as modifications are in some cases really necessary parts of the theory. These may not, it is true, have been in all cases expressed by me, but they are nevertheless implied in the theory. Other points, again, regarded as modifications are simply facts lying altogether outside of the theory, which can in no way affect it. With much

*From advance sheets of the Philosophical Magazine for February, 1884.

that Mr. Wallace has advanced in explanation of geological climate I fully agree, but I am, nevertheless, wholly unable to perceive that any of his arguments or considerations do in reality materially affect the theory advocated in 'Climate and Time.' This I hope presently to show.

Before proceeding, however, to examine in detail Mr. Wallace's modifications of the theory, it may be as well to consider one or two minor points on which I differ from him, as this will save the necessity of referring to them when we come to discuss his main argument.

Effect of Winter Solstice in Aphelion.—At page 126 ('Island Life') he says :—"We may therefore say generally, that during our northern winter, at the time of the Glacial epoch, the northern hemisphere was receiving so much less heat from the sun as to lower its surface-temperature on an average about 35° F., while during the height of summer of the same period it would be receiving so much more heat as would suffice to raise its mean temperature about 60° F. above what it is now." In a foot-note he adds that "the reason of the increase of summer heat being 60° while the decrease of winter cold is only 35°, is because our summer is now *below* and our winter *above* the average."

There is surely a confusion of ideas here. It is of course true that, as our summer at present occurs in aphelion and our winter in perihelion, the temperature of the former is below and that of the latter above the average; but this can afford no grounds for the result Mr. Wallace attributes to it unless it be assumed (for which there are no astronomical grounds) that our summer is 25° *further* below the average than our winter is above it.

On the Storage of Cold.—In a section on the Effects of Snow on Climate, Mr. Wallace points out the different effects produced by water falling as a liquid in the form of rain and as a solid in the form of snow. The rain, however much of it may fall, runs off rapidly, he states, without producing any permanent effect on temperature. But if snow falls, it lies where it fell, and becomes compacted into a mass which keeps the earth below and the air above, at or near the freezing-point When the snow becomes perpetual, as on the summits of high mountains, permanent cold is the result; and however strong the sun's rays may be, the temperature of both the air and the earth cannot possibly rise much above the freezing-point. "This," he says, "is illustrated by the often-quoted fact that at 80° N. lat. Captain Scoresby had the pitch melted on the one side of his ship by the heat of the sun, while water was freezing on the other side owing to the coldness of the air." Doubtless this is perfectly correct; but on page 502 he states that he has pointed out with more precision than has, he believes, hitherto been done, the different effects on climate of water in the liquid and solid states. This is a somewhat doubtful statement; for in chapter iv, 'Climate and Time,' in Phil. Mag., March, 1870, and in other places will, I think, be found all that this section contains. In fact the influence of snow and ice as a *permanent source of cold* is one of the main factors of my theory. The three great factors are (1) the influence of snow and ice, (2) the influence of aqueous vapor, and (3) the influence of ocean-currents. How persistently has it been urged as an objection to my theory that, during the Glacial epoch, the great heat of the perihelion summer would more than counterbalance the effect of the aphelion winter. But I have maintained that, the summers, notwithstanding the intensity of the sun's rays, instead of being warmer than at present, would in reality be far colder; for this reason, that the temperature of a snow-and-ice covered country can never rise much above the freezing-point. As an example of this I pointed out that, 'were it not for ice, the summers of North Greenland would be as warm as those of England (whereas in point of fact they are colder than our winters); and that were India covered with an ice-sheet, its summers would be colder than those of England.'

"Another point," he says, "of great importance in connexion with this subject is the fact, that this permanent storing-up of cold depends *entirely* on the annual amount of snowfall in proportion to that of the sun- and air-heat, and not on the actual cold of winter, or even on the average cold of the year." This, I have shown (American Journal of Science, Oct., 1883; Phil. Mag., Oct., 1883) at considerable length, is one of the most widespread and fundamental errors within the whole range of geological climatology. Perpetual snow, instead of being due "entirely" to the annual amount of snowfall in proportion to the quantity of heat received by the snow, is in most cases not even *mainly* due to this cause. Overlooking the fact, that in the conservation of snow the temperature of the snow is one of the main factors, has been a fruitful source of error.

High Land and Heavy Snowfall in relation to the Glacial Epoch.—According to Mr. Wallace, "high land and great moisture" are essential to the initiation of a glacial epoch. Undoubtedly high land and great moisture are the most favorable conditions for bringing about a glacial state of things; but I can hardly agree with him that they are necessary and indispensable.

As to the second of these conditions, great moisture is evidently necessary only in order to produce a great snowfall; a great snowfall is necessary only in order that the snow may become permanent; and the permanent snow in turn is necessary only in order to have permanent glaciation. But it has already been shown* that we frequently have permanent snow with a very light snowfall, even where the direct heat of the sun is excessive, as on the summits of lofty mountains. Greenland, for example, has but a very small snowfall, and yet the snow and ice are perpetual. What is necessary is, that the small amount which falls should not all melt. If this be the case, the ice will accumulate year by year, and a glacial condition will ultimately result.

Suppose that the annual precipitation of snow on a continent is equivalent to only 10 inches of ice, and that at the end of each summer one inch remains unmelted, then, in this case, the ice will continue to accumulate year by year until the quantity annually discharged by the outward motion from the center of dispersion equals that annually formed. But in the case of a continent this condition can be attained only when the sheet at the center becomes of enormous thickness. Whether high land be necessary to a glacial epoch or not, it is evident that a heavy snowfall is not an indispensable condition.

As to the second of these conditions, namely, high land, it must be borne in mind that the question is not, Could the causes which are *now* in operation bring about a glacial condition of things without high land? but, Could those physical agencies brought into operation during a high state of eccentricity produce a glacial state of things without high land? Mr. Wallace's answer is that they could not. But I am not satisfied with the grounds on which he bases this opinion. A necessary condition to a glacial epoch is, of course, the existence of perpetual snow; for without perpetual snow there could be no permanent land-ice. The question then is, Could not those physical agencies brought into operation during a high state of eccentricity cover lowlands with perpetual snow without the aid of high lands? Mr. Wallace replies, "Perpetual snow nowhere exists on low lands." Supposing this were true (I have endeavored to show it is not),† still it does not follow that perpetual snow may not have existed on lowlands, or that, when the present condition of things changes, it may not yet exist. It is not difficult to conceive how, under certain conditions, the snow-line may in some places have been brought to the sea-level. In arctic, or even in subarctic regions, an excessively heavy snowfall, followed by piercingly cold winds from the north, during the whole of the summer

* American Journal of Science, October, 1883; Philosophical Magazine, October, 1883.

† Philosophical Magazine, November, 1883.

months, would keep the snow at a low temperature and certainly prevent it from disappearing. Keep the surface of the snow at or below the freezing-point, and melting will not take place, no matter how intense the sun's rays may be. A strong wind below the freezing-point will cool the surface of the snow more rapidly than the sun can manage to heat it. Another cause which would tend to keep the snow at a low temperature would be that, along with a cold northerly wind, there is usually a great diminution of aqueous vapor, thus allowing the surface of the snow to radiate its heat more freely into stellar space. For were it not for the aqueous vapor in the atmosphere, the snow-line, even at the equator, would descend to the sea-level.*

Perhaps it is owing to the warm southerly winds of the two midsummer months that Siberia, even with its inconsiderable snowfall, is not at the present day covered with permanent snow and ice. Mr. Wallace mentions that "in Siberia, within and near the Arctic circle, about six feet of snow covers the country all the winter and spring, and is not sensibly diminished by the powerful sun so long as northerly winds keep the air below the freezing-point, and occasional snow storms occur. But early in June the wind usually changes to southerly, and under its influence the snow all disappears in a few days." But what would be the consequence were these northerly winds to continue during the whole of June and July? It would probably be that the snow of autumn would begin to fall before that of spring had disapppeared. Were this to result, the country would soon become covered with permanent ice. Matters would be still worse if these southerly winds, instead of ceasing, were simply to change from June and July to December and January, for then, in place of producing a melting effect, they would greatly add to the snowfall.

Such a condition of things may never have obtained on the plains of Siberia; but I have shown in my paper on the Ice of Greenland and the Antarctic regions† that there are certainly good grounds for concluding that during the Glacial epoch, and even at a date more recent, permanent ice must have begun to accumulate on lowlands, which could not have been the case had not the ground been previously covered with perpetual snow.

The only Continental Ice on the Globe probably on Lowlands.—The only two continents on the globe covered by permanent ice and snow are Greenland and the Antarctic. But are these continents to be regarded as high lands or as low lands? Mr.

* See American Journal of Science for October, 1883; Philosophical Magazine for October, 1883.

† Phil. Mag. for November, 1883.

Wallace maintains that they are high lands. "It is," he says, "only where there are lofty mountains or elevated plateaus, as in Greenland, etc., that glaciers accompanied by perpetual snow cover the country. The north polar area is free from any accumulation of permanent ice, excepting the high lands of Greenland and Grinnel Land." And in regard to the Antarctic continent, he says, "The much greater quantity of ice at the south pole is undoubtedly due to the presence of a large extent of high land." Were it not for these extensive high lands and lofty mountains, Greenland and the Antarctic regions, according to Mr. Wallace's theory, would be free from permanent snow and ice. He, however, nowhere, so far as I can find, offers any proof for the conclusion that those regions possess extensive highlands, elevated plateaus, and lofty mountains sufficient to account for these icy mantles. In the paper just referred to (Phil. Mag., November, 1883), I have discussed this subject at considerable length, and have arrived at conclusions diametrically the opposite of those advocated by Mr. Wallace, viz: that Greenland and likely the greater part of the Antarctic regions consist of land probably not much above sea-level, and that the mass of ice under which they are buried must be due to some other cause than elevation of the land.

Mr. Wallace's Modification of the Theory Examined. — Mr. Wallace's chief, and, I may say, only real modification of my theory is this. I give it in his own words:

"The alternate phases of precession—causing the winter of each hemisphere to be in *aphelion* and *perihelion* each 10,500 years—would produce a complete change of climate only where a country was *partially* snow-clad; while, whenever a large area became almost *wholly* buried in snow and ice, as was certainly the case with Northern Europe during the Glacial epoch, then the glacial conditions would be continued, and perhaps even intensified, when the sun approached nearest to the earth in winter, instead of their being at the time, as Mr. Croll maintains, an almost perpetual spring."—p. 503.

"When geographical conditions and eccentricity combine to produce a severe glacial epoch, the changing phases of precession have very little, if any, effect on the character of the climate, as mild or glacial, though it may modify the seasons; but when the eccentricity becomes moderate and the resulting climate less severe, then the changing phases of precession bring about a considerable alteration and even a partial reversal of the climate."—p. 153.

Again: "It follows that towards the equatorial limits of a glaciated country alternations of climate may occur during a period of high eccentricity, while near the pole, where the whole country is completely ice-clad, no amelioration may take place. Exactly the same thing will occur inversely with mild Arctic climates."—p. 154.

I have, on the contrary, maintained that the more severe the glacial condition of the one hemisphere, the warmer and the more equable would necessarily be that of the other; for the very same combination of causes which would tend to cool the one hemisphere would necessarily tend to warm the other. The process to a large extent consists of a transference of heat from one hemisphere to the other. Consequently the one hemisphere could not be heated without the other being cooled, or the one cooled without the other being heated. The hotter the one, the colder the other, and the colder the one, the hotter the other. It therefore follows that the more severe the glacial conditions, the warmer and more equable must be the inter-glacial warm periods. But, according to Mr. Wallace, there could be no warm interglacial periods, either in temperate or polar regions, except during the commencement and toward the close of the Glacial epoch.

Before, however, proceeding to examine in detail the steps by which he arrives at this modification of my theory, it will be as well that the reader should have a clear and distinct knowledge of what that theory really is, and what it professes to explain. These I shall now briefly state in the most general terms, for misapprehension in regard to the main features of the theory lie at the root of most of the objections which have been urged against it.

General Statement of the Theory.—1st. It is not professed that the theory will account for the condition of climate during *all* past geological ages. It treats mainly of the cause of glacial epochs; and one of its essential elements is that these epochs consist of alternate changes, to a greater or less extent, of cold and warm periods; or, in other words, that glacial epochs must consist of alternate glacial and interglacial periods. The chief, though not the sole, aim of the theory is to account for geological climate in so far as such epochs are concerned. Although it could be satisfactorily shown, for example, and this has certainly not yet been done, that during some past geological age, such as the Miocene, the Eocene, or the Cretaceous, the climate was throughout uniformly warm or sub-tropical, this would not prove that the theory was wrong, unless it could at the same time be shown that the necessary conditions demanded by the theory did then exist. But instead of this supposed condition of climate during Secondary and Tertiary periods being inconsistent with my theory, the fact is, as we shall see by and by, that this theory affords the only rational explanation of such a state of things which has yet been given.

2d. The theory is not that a high state of eccentricity will necessarily produce a glacial epoch. No misapprehension has been more widespread or more difficult to remove than this. From the very commencement I have maintained that no amount of eccentricity, however great, could produce a glacial condition of things; that the Glacial epoch was the result, not of a high state of eccentricity, but of a combination of *physical* agencies, brought into operation by means of this high state.* As an example of this misapprehension, how frequently has the present condition of the planet Mars been adduced as evidence against the theory. The eccentricity of Mars' orbit is at present greater than that of the Earth's even when at its superior limit; and its southern winter solstice is not far removed from aphelion. It is therefore maintained that, if my theory of the cause of the Glacial epoch be correct, the southern hemisphere of Mars ought to be under a glacial condition, and the northern enjoying a perpetual spring—and this, as is well known, is not the case. Here it is assumed that, according to the theory, eccentricity alone ought to produce a glacial epoch, irrespective of the necessary physical conditions. We know with certainty that those physical conditions which, according to the theory, were the direct cause of the Glacial epoch on our globe, cannot possibly exist on the planet Mars.† Just take one example; either the properties of water on the planet Mars or the conditions of its atmosphere must be totally different from those of our earth; for were our earth removed to Mars's distance from the sun, our seas would soon become solid ice and we could have neither snow nor rain, ocean-currents, nor any of the necessary conditions for secular change of climate. This is doubtless not the present state of Mars; but the reason of this can only be that the physical and meteorological conditions of the planet must be wholly different from those of the earth.

When we reflect that a very slight change in the properties of aqueous vapor, or in the condition of our atmosphere, would effectually prevent the possibility of a glacial epoch occurring on our earth, notwithstanding a high state of eccentricity, we need not wonder that the planet Mars is not in a state of glaciation. But the eccentricity of Mars, though high, is still far from its superior limit, and the planet may yet, for anything which we know to the contrary, pass through a Glacial epoch.

3d. Another prevailing misapprehension is the supposition that the theory does not recognize the necessity for geographical conditions. In reading "Island Life" one might be apt to suppose that one of the chief points of difference between Mr. Wallace and myself is that he regards geographical distribution

* For this reason I prefer to term the theory the Physical Theory rather than the Eccentricity Theory, as it has been called by some writers.

† See 'Climate and Time,' p. 79.

of sea and land as an important factor in a theory of geological climate, whereas I entirely ignore this condition. Nothing could be further from the truth than such a supposition. I can boldly affirm that the necessity for geographical conditions is as truly a part of my theory as of Mr. Wallace's modification thereof.

One of the most important agencies, according to my view, is the enormous amount of heat conveyed from equatorial to temperate and polar regions by means of ocean-currents, and the deflection of this heat, during a high state of eccentricity, from the one hemisphere to the other. But all this depends on ocean-currents flowing from equatorial to polar regions; and the existence of these currents in turn depends, to a large extent, on the contour of the continents and the particular distribution of sea and land. Take, as one example, the Gulf-stream, a current which played so important a part in the phenomena of the Glacial epoch. A very slight change in geographical conditions, such as the opening of communication between the Gulf of Mexico and the Pacific, would have greatly diminished, if not entirely destroyed, that stream. Or, as I showed on a former occasion, a change in the form or contour of the northeast corner of the South American continent would have deflected the great equatorial current, the feeder of the Gulf Stream, into the Southern Ocean and away from the Carribean Sea. One of the main causes of the extreme condition of things in Northwestern Europe, as well as in eastern parts of America, during the Glacial epoch, was a large withdrawal of the warm waters of the Gulf Stream; and this was to a great extent due, as I stated in my very first paper on this subject,* to the position of Cape St. Roque, which deflected the equatorial current into the Southern Ocean. That a geographical distribution of land and water permitting of the existence and deflection of those heat-bearing currents is one of the main factors in my theory is what must be obvious to every reader of 'Climate and Time.'

The difference between Mr. Wallace and myself is this:—I maintain that with the *present* distribution of land and water, without calling in the aid of any other geographical conditions than now obtain, those physical agencies detailed in 'Climate and Time' are perfectly sufficient to account for all the phenomena of the Glacial epoch, including those intercalated warm periods, during which Greenland would probably be free from ice and the Arctic regions enjoying a mild climate; while Mr. Wallace, on the other hand, maintains that without assuming some *change* in the geographical conditions of our globe those physical agencies will not account for that state of things,

* Phil. Mag. for August, 1864.

at least in so far as the disappearance of the ice in Arctic regions is concerned.

To narrow the field of inquiry, and bring more prominently before the mind the real question at issue, I shall state the main points on which Mr. Wallace and I appear to agree.

Points of agreement.—1. Mr. Wallace agrees with me that a high state of eccentricity could never directly produce a glacial condition of climate; that the Glacial epoch was the result, not of a high state of eccentricity, but of a combination of physical agencies brought into operation by means of this high state.

2. He agrees with me also in regard to what these physical agencies really were; for the agencies to which he refers in his 'Island Life' are almost identically those which I have advanced in 'Climate and Time' and elsewhere.

3. Mr. Wallace agrees with me in regard to the mutual reactions of the physical agents. He maintains with me that these physical agencies not only all lead to one result—the accumulation of snow and ice, but that their efficiency in bringing about this result is strengthened by their interaction. At pp. 137–139 he gives a variety of examples of these interactions, and says that they "produce a maximum of effect which, without their aid, would be altogether unattainable."

4. As has already been shown, we agree as to the necessity of certain geographical conditions for the production of the Glacial epoch. For although that epoch was mainly brought about by the physical agencies, yet these agencies could not have produced the required effect unless the necessary geographical conditions had been supplied, these being necessary for their effective operation.

5. Mr. Wallace admits, of course, that the necessary geographical conditions existed during the Glacial epoch; for, unless this had been the case, no glacial epoch could have occurred. Therefore all that was required to produce glaciation was an amount of eccentricity sufficient to set the physical agencies into operation. Be it observed, it did not require, in *addition* to the physical agencies, some changes in the geographical conditions, or some new conditions; for the geographical conditions being existent, all that was then required to bring about the Glacial epoch was the operation of the physical agencies. The overlooking of this fact has led to much confusion. For example, 210,000 years ago, with winter in aphelion, "the problem to be solved," says Mr. Wallace, "is, whether the snow that fell in winter would accumulate to such an extent that it would not be melted in summer, and so go on increasing year by year till it covered the whole of Scotland, Ireland and Wales, and much of England. Dr. Croll and Dr. Geikie answer without hesitation that it would. Sir Charles

Lyell maintained that it would only do so when geographical conditions were favorable" (p. 136). Here we have a complete misapprehension of the relation between Sir Charles Lyell's views and mine; for I would certainly maintain (and, I presume, Dr. Geikie also) as emphatically as Sir Charles could do, "that it would only do so when geographical conditions were favorable." For undoubtedly, according to the theory advocated in 'Climate and Time,' no glacial epoch could result without geographical conditions suitable for the operation of the physical agencies; and this is virtually what Sir Charles maintains. The Glacial epoch resulted during the last period of high eccentricity because the geographical conditions suitable for the effective operation of the physical causes then existed.

6. It is assumed in 'Climate and Time' that, the general distribution of sea and land, and other geographical conditions, with the exception of those resulting from oscillations of sea-level, afterwards to be considered, were the same during the Glacial epoch as they are at present.* Consequently, in accounting for the Glacial epoch I had only to consider the effects resulting from those physical agencies called into operation by an increase of eccentricity. To have speculated on hypothetical conditions different from those which now obtain, and on the influence which these may have had in bringing about the Glacial epoch, would have been on my part perfectly absurd, as I knew we had no evidence of the existence of any such conditions. Besides, my aim was to account for that epoch from known and established facts and principles without the introduction of hypothetical causes. I fear that the fact of my making little or no allusion to geographical conditions in my *explanations* may have unfortunately led Mr. Wallace and others to conclude that I altogether ignore, or, at least, undervalue their importance, which is certainly not the case.

Although Mr. Wallace so frequently alludes to the importance of geographical conditions, I am not sure if he believes that during the Glacial epoch those conditions differed materially from what they are at present, or that glaciation could have been greatly influenced by any difference which did exist.

7. Mr. Wallace alludes to one or two geographical conditions which, *if* they had existed during the Glacial epoch, would have greatly aided glaciation. As, for example, if a land-

* Professor J. Geikie, however, believes that during early Post-glacial times a considerable change in the physical geography of the North seas took place (see 'Prehistoric Europe,' chap. xxii). In order to account for the floras of Greenland, Iceland and the Faröe Islands, he thinks a land-connexion must have existed between these places and Scandinavia. For reasons to be stated on a future occasion, I am unable to agree with this conclusion. Professor Geikie, however, does not believe that the climatic condition of that period was in any way due to this change.

barrier had extended from the British Isles, across the Faröe Islands and Iceland to Greenland, cutting off from Northern Europe the warm waters of the Atlantic, including the Gulf-Stream. "The result," he says, "would almost certainly be that snow would accumulate on the high mountains of Scandinavia till they became glaciated to as great an extent as Greenland."

It would be easy to multiply cases of this kind where a distribution of land and water different from the present might have been more favorable to glaciation than the present; but the question is, Did any such difference favoring glaciation *actually exist* during the Glacial epoch? I have never been able to find any evidence that it did. Many a change in geographical conditions has taken place during Tertiary times, some of which were doubtless favorable to glaciation; but have we any evidence that during the Glacial epoch the geographical conditions were more favorable than they are at present? Unless this can be shown to be the case, there is no necessity for referring to a difference in geographical conditions during that epoch as a cause of glaciation. This being so, it does not follow, because in my explanation of the cause of the Glacial epoch I may not, like Sir Charles Lyell and others, have speculated on the effects which might have resulted had the distribution of land and water been different from what it is now, that I ought on this account to be charged with undervaluing the importance of geographical conditions.

Mr. Wallace refers to one case of a difference in geographical conditions which he thinks might have aided glaciation. Professor Dana has expressed the opinion that, during the height of the Glacial epoch, Northeastern America was considerably elevated, bringing the wide area of the banks of Newfoundland far above water. This, Mr. Wallace thinks, would reduce the southward-flowing Arctic currents, causing the icebergs to hang about the American shores, chilling the air so as to produce constant fogs and clouds with almost perpetual snow-showers, even at midsummer. But Professor Dana has also shown that during the Glacial epoch Northeastern America was depressed as well as elevated. Now the point is: whether the elevation was contemporaneous with the cold, or with the warm periods of the Glacial epoch? Mr. Wallace himself admits that depression, not elevation, of the land accompanied the increased cold; and he quotes Mr. Searles V. Wood, Jun., approvingly as holding the same opinion (p. 115). It was quite natural for Professor Dana to suppose that the elevation to which he refers occurred at the time the country was buried under ice; for when he wrote he believed the Glacial epoch was chiefly due to elevation of the land caused by the lateral pressure resulting from the shrinking of the earth's crust. It is now, however, pretty well established that the continental or elevated periods of the Glacial epoch, when our island was united to the mainland, were warm periods; for it was then that this country was invaded by tropical and subtropical mammals. Had the climate at that time been cold, and the country even partially covered with snow and ice, these animals would not have made their appearance. It is therefore probable that the elevation to which Professor Dana refers may have taken place during some of those warm periods.* But be this as it may, even were it proved that during the Glacial epoch geographical conditions were more favorable for the formation of ice than the present, this would not affect the general conclusion at which I wish to arrive.

Trusting that these preliminary considerations may tend to remove the partial confusion in which this somewhat complex subject has been involved, I shall now proceed to examine Mr. Wallace's main argument.

[To be continued]

[* The opinion advocated formerly, and now, by Mr. Dana, is that the more northern lands (or, in later papers, portions of northern lands), were more elevated than now during the era of increasing and maximum ice, or the era distinguished by him as the *Glacial* period; that this era was followed both in America and Europe, by a subsidence of the same land initiating the Champlain period, and that this was the era of melting, and of the spreading of mammals northward, an impossible occurrence in America during the Glacial era; that another era of ice of much less extent occurred subsequently in Europe, if not also in North America, probably commencing with the epoch of the change in the land to its present level, and that this was the occasion of the destruction of the mammals of North Siberia, and other faunal changes. The evidences believed to favor these conclusions are stated in his various papers and his Manual of Geology, and need not be here repeated. The latest discussion by him of the facts from Eastern North America as to the Champlain subsidence is contained in this Journal for 1882.

Mr. Dana's opinion as to the fact of an elevation of northern lands in the Glacial era (that is, the era as he defines it) was a conclusion from facts that had been observed in Europe and America, and not a supposition suggested by, or thought to be sustained by, any theory as to the cause of the elevation. The era of maximum ice he has always supposed to be that of maximum or nearly maximum cold; and the Champlain era, following, an interglacial era (for Europe at least) of milder climate, in which the Mammoth and the associated mammals and other species of life, animal and vegetable, of the colder temperate and temperate latitudes, reached their farthest northern limit.—J. D. D.]

ART. XIII.—*Communications from the U. S. Geological Survey, Rocky Mountain division.*—V. *On Sanidine and Topaz, etc., in the Nevadite of Chalk Mountain, Colorado;* by WHITMAN CROSS.

CHALK MOUNTAIN is situated where Lake, Eagle and Summit Counties join, and is also upon the boundary of the maps of the Mosquito Range and of the Ten-Mile mining district, which are soon to be published with monographic reports by the U. S. Geological Survey. The description of the nevadite, which forms the mass of the mountain, will therefore be brief, and all references to manner of occurrence, etc., omitted. It is, however, thought desirable to describe at once the following interesting minerals occurring in the rock.

The nevadite, while showing local variations in structure, may be characterized as a porphyritic rock, showing large glassy sanidine and many smoky quartz crystals imbedded in a grayish ground-mass, which appears under the lens to be evenly granular, and is really so, with the exception of isolated glass particles revealed by the microscope. Biotite is but sparingly present. This nevadite is one of the most beautiful of rocks, owing to its abundant, smoky quartz crystals and to a very delicate but brilliant, satin-like luster exhibited by the sanidines. This luster, or rather its cause, is the chief subject of these notes.

The lustrous surface is in the ortho-diagonal zone and inclined a few degrees to the ortho-pinacoid, as is evident, in the Carlsbad twins, usually polysynthetic, the luster reaching its maximum of brightness simultaneously in alternate plates. Microscopic investigation shows a most perfect parting parallel to the surface of luster and with a knife blade flakes can be split off in this direction even more readily than parallel to the basal cleavage plane. Thin plates parallel to the base (O) show a very fine striation at right angles to the line of i-$\bar{i}$ and $\pm$ to the directions of extinction. Thin flakes split off parallel to the lustrous surface show, under the microscope, that the luster is due to interference of light in passing the films of air between the extremely thin plates produced by the parting. The thinnest flakes, composed of a few plates, are transparent and exhibit delicate colors of interference, while those composed of more plates are dull translucent, or opaque, the light having been completely extinguished by the repeated interference. The luster is, then, due to reflected light from the air films near the surface, and to its interference. By examination with a good hand lens a delicate play of colors may be seen upon the lustrous surface of the crystals.

At one point in the mountain, the nevadite, here unusually coarse-grained, was found to contain many small, round or irregular druses lined by minute but perfect transparent crystals, chiefly of sanidine and quartz. The quartz crystals are, for the most part, simple dihexahedrons; the sanidines thin tablets which are almost invariably Carlsbad twins with prominent development of the clino-pinacoid. Such crystals examined under the microscope, as they lie upon the predominant pinacoidal face, afford a means of determining approximately the position of the plane parallel to which the parting referred to takes place. The adjoining cut represents one of these crystals, a normal Carlsbad twin with a third and smaller plate, also in twin position. The faces shown are: I (110), i-$\grave{\imath}$ (010), O(001), 1-$\bar{\imath}$ ($\bar{1}$01) and 2-$\bar{\imath}$ ($\bar{2}$01) as indicated. From all the outlines and from basal cleavage or irregular fissures run dark lines, in uniform direction for each individual of the twin, and penetrating varying distances into the crystal. This undoubtedly represents an incipient stage of that parting, which, in the large crystals of the rock, occasions the brilliant luster, for these dark lines do not represent needles of any mineral substance, but the air films filling the fissures.

$\frac{57}{1}$

This parting may be seen upon all microscopic sanidine crystals of the rock, and even the irregular grains of that mineral in the ground-mass, when cut in the right direction, show a very fine delicate striation which is undoubtedly due to the same cause. As seen from the figure, the position of the surface is that of a positive hemi-orthodome, for the cleavage plates of large crystals show the plane to be at right angles to the clino-pinacoid. Assuming the axial ratio

$$\bar{a} : \bar{b} : \grave{c} = 0{\cdot}653 : 1 : 0{\cdot}552 \text{ and } \beta = 64^\circ$$

as determined by Strüver* for free crystals of sanidine, the face corresponds closely to $\frac{15}{2}$-$\bar{\imath}$ ($\overline{15}{\cdot}0{\cdot}2$). This would require an angle of 72° 40′ with the basal plane, while that measured in the crystal figured was 72° 53′. Of course this can not be regarded under the circumstances as anything more than an approximate determination.

I am indebted to Professor G. vom Rath for the information given during a recent visit in Denver, that a similar but much fainter luster frequently observed in crystals of adularia, has been proven by Reusch to be parallel to a surface in the orthodiagonal zone inclined but a few degrees to the pinacoid, and

* Cited by Tschermak, Lehrbuch der Mineralogie, 1883, p. 455.

probably identical with that above described. Unfortunately, neither the original nor any references to it are accessible to me, hence I cannot draw any further parallel between the two cases.

Accompanying the quartz and sanidine in the cavities are minute leaflets of biotite, a few ore grains, and in a few druses only, very perfect crystals of colorless, transparent *topaz*. Usually but a single crystal of topaz is present in one of the druses and that is larger and more perfect in development than any other. The topaz is attached directly to the walls of the cavity and often bears small tablets of sanidine upon it. The crystals which can be recognized as topaz vary from 0·5^{mm} to 3^{mm} in length, but it seems quite probable that there are some smaller ones indistinguishable from quartz.

The determination as topaz rests upon the crystalline form, which is very distinct, and is that of common topaz. One crystal measuring 3^{mm} in length and 1^{mm} in thickness was removed from the rock and its angles measured with a Fuess reflection goniometer. This crystal presents *I* (110), $i\text{-}\breve{2}$ (120) and 2-ĭ (021) as the dominant forms; *O* (001) is a narrow face and 4-ĭ (041) 2-ī (201), 2 (221) and 1 (111) are minute but very distinct. The angles measured are as follows:

$I \wedge I$	124° 16′
$i\text{-}\breve{2} \wedge i\text{-}\breve{2}$ over $i\text{-}\breve{i}$	93° 7′
$O \wedge$ 2-ĭ	136° 30′
$O \wedge 1$	134° 11′
$O \wedge 2$	115° 55′

2-ī appears as a very narrow face in the zone of 2 to 2. This is the usual habitus with occasional addition of *i*-ĭ and a more prominent development of *O*. This crystal is also imperfectly terminated at the attached end showing 2-ĭ most prominently, with 4-ĭ and 2 also recognizable and there are no signs of hemimorphism.

In some druses all crystals are thinly coated by a black incrustation which seems to be pyrolusite.

So far as I can ascertain, all previously known and described occurrences of topaz are in granite, gneiss or some other member of the series of metamorphic or crystalline schists. In the present case topaz is found in an eruptive rock, probably of early Tertiary age, while the appearance of the associated minerals certainly suggests that they may all be sublimation products, though it is not capable of direct proof. The sanidine crystals from the druses, examined microscopically, contain gas inclusions, while neither fluid nor glass inclusions were seen.

ART. XIV.—*On the occurrence of the Lower Burlington Limestone in New Mexico;* by FRANK SPRINGER.

THE Burlington Limestone has been generally recognized as a well defined group of the Subcarboniferous; but its division into upper and lower beds has not been favorably received by geologists outside of those who have collected at Burlington, Iowa, for the reason, as alleged, that the existence of two distinct beds in this group is a local phenomenon, confined to the typical locality, and cannot be demonstrated elsewhere, though the group is well developed in many other places in the Mississippi Valley. The separation of the two members of the group, as well as that of the group itself from others of the Subcarboniferous, is based chiefly upon the Echinoderms—the Mollusks being usually of greater vertical range, and many of the best known species being found throughout all the formations of the upper and lower Carboniferous. It is only at Burlington that extensive systematic collections have been made with reference to the stratigraphic position and distribution of the fossils, and there no difficulty is found in separating the two beds. The paleontological boundary between them is, indeed, much more sharply defined than that between the upper bed and the superincumbent Keokuk Limestone. No locality has been discovered which exhibits a commingling of types or species characteristic of the two beds, although it is to be observed that there are some interesting transitional forms, and a few persistent forms, mostly belonging to smaller types of crinoids, like *Cyathocrinus*, which range through the Burlington and Keokuk beds with such slight modifications as to render it very difficult, if not impossible, to recognize specific distinctions.

It is believed, however, that there are various localities in Missouri, in which the Lower Burlington is exposed. Prof. Worthen reports its occurrence at Mill Creek, six miles below Quincy, Ill. One locality is known in the vicinity of Sedalia, Mo., where both Burlington beds exist, although reduced to a few feet in thickness, each containing its characteristic species, and these identical with those found at Burlington. In a collection of about eighty species, examined by Mr. Wachsmuth, he did not find a single new form.

Some observations made by the writer in 1882, in the Lake Valley Mining District, in Southern New Mexico, have brought to light a number of interesting facts bearing upon this question, not only confirming the views of the Burlington geologists, as to the distinct character of the two beds, but demonstrating that the Lower Burlington Limestone has a geographical range not hitherto suspected.

The region adjacent to the town of Lake Valley is characterized topographically by a succession of comparatively low hills, many of them gently sloping, others sharply defined and abrupt. The latter character prevails especially to the southward, where the hills assume the proportions of small mountains, and are formed of igneous rocks, sometimes in connection with large trachytic dykes, extending for miles in length. To the north and northwest limestone predominates, and the strata are upturned toward the west at an angle of about 20°, but there are a number of dislocations by which the whole series of strata are brought up to this angle several times, giving rise to a succession of faults on a north and south line, of several hundred feet vertical extent. These dislocations produce the limestone hills, whose general eastern slopes coincide with the dip of the strata, while the western declivities, in which the edges of the strata are presented, are abrupt, and sometimes perpendicular. Faults occur in other directions also, caused by the eruption or intrusion of veins of quartz, or other siliceous material, bearing mineral ores. Upon the eastern slope of one of these limestone hills, the celebrated group of Sierra mines occurs, from one of which—the Sierra Grande —over a million dollars in silver was taken within a year. These mines appear to be large deposits of ore lying irregularly between the limestone strata, where they have perhaps intruded from some subterranean fissure. The limestone in the vicinity of the mineral veins and deposits is greatly metamorphosed, usually bluish, fine-grained, and highly siliceous. In many places it is chert. In some localities it is fossiliferous, yielding good collections, and at one of these the following section was made—the measurements being only approximate:

No. 9. Cherty limestone, with irregular flinty masses. In places of a light gray color and full of crinoidal remains	30 feet.
No. 8. Heavy-bedded crinoidal limestone, pink to drab in color, siliceous in places, with marly partings between the strata, containing abundant crinoidal remains, bryozoa, corals, and brachiopods, mostly silicified,	40 feet.
No. 7. Thin-bedded bluish limestone, appearing mostly as a shale, containing crinoids, corals, brachiopods and bryozoa,	20 feet.
No. 6. Pinkish to bluish limestone, hard and granular, containing a large proportion of sand,	6 feet.
No. 5. Fine-grained, light yellow shaley clays with flinty nodules,	15 feet.
No. 4. Coarse ferruginous limestone, in irregular beds, with marly partings, containing corals, crinoid plates and stems,	30 feet.

No. 3. Dark brown ferruginous sandstone, heavy-bedded and hard below, shaly above,	12 feet.
No. 2. Very light yellowish shaly clays, with irregular flinty masses, without fossils so far as observed,	8 feet.
No. 1. Unexposed slope, covered by *debris*, probably similar to No. 2,	80 feet.

Beds Nos. 7 and 8 are the most important of this section paleontologically, and from them almost all the fossils collected were obtained. They are characterized by fragmentary disintegration, especially No. 7, which is generally found as a soft shale, and its fossils arc calcareous. From this bed were obtained most of the Blastoids, the *Agaricocrinus*, small *Rhodocrinus*, *Cyathocrinus*, *Barycrinus*. In No. 8, most of the fossils are wholly or partially silicified, and the larger species of *Platycrinus* and *Actinocrinus* seem rather to predominate. With these exceptions the crinoids are found irregularly throughout the two beds. The color of the rock is not a constant character, but is greatly affected by the proximity of mineral veins. In general appearance, and the mode of occurrence of the fossils, these two beds are rather like the upper part of the Keokuk limestone as it occurs at Keokuk. They do not in the least resemble the Burlington Limestone in lithological characters, but tested by their fossil remains, they belong unquestionably to the Lower Burlington, which is developed here to a thickness not attained at any other known locality.

Aside from the echinoderms, the fauna in general resembles more closely that of the Mountain Limestone of Belgium, than any other with which I am acquainted. It embraces types that have been found in the Kinderhook group, and its representatives, the Waverly, of Ohio, and the Choteau, of Missouri, and in all the formations from these to the Upper Coal-measures. In their specific affinities, however, the fossils are unmistakably Lower Carboniferous, the few exceptions being of types which have a great stratigraphical range, and are therefore of least weight in determining the equivalency of the rocks. Nearly all the forms described from the Burlington limestone are represented here, if not by identical species, certainly by similar types. The attempt to identify the brachiopods of this locality from descriptions, and by direct comparison with authentic collections from the Lower and Upper Carboniferous rocks of the Mississippi Valley, has not been in all respects followed by satisfactory results, but it has demonstrated very clearly that there is an opportunity for some very interesting and valuable work in the systematic study of the Carboniferous mollusks of Western America.

The notes here given of the fossils of Lake Valley must be regarded as only preliminary; they leave for future publication and illustration the results of a detailed study of the collections from this and other Lower Carboniferous localities in the Rocky Mountains, which I am convinced will yield very important data bearing upon the relations between the great Mississippi Carboniferous basin and its western equivalent.

Brachiopoda.

Productus semireticulatus, var. closely allied to the variety of this species recognized in the Kinderhook, and to the form described as *P. setigerus*, var. *Keokuk*, and its equivalent form in the Upper Burlington.

P. ——, closely allied to *P. vittatus* of the Keokuk, and a representative form in the Burlington.

P. ——, of the type of *P. scabriculus* of the Keokuk.

P. ——, of the type of *P. arcuatus* of the Kinderhook.

P. ——, of the type *P. Shumardianus* of the Kinderhook.

It is possible that the last two forms may be the young of the *P. semireticulatus*.

Chonetes ——, closely allied to *C. Logani* Norwood & Pratten (not Hall).

Strophomena rhomboidalis, of the form found in the Kinderhook, at Burlington, and also in the Waverly group in Utah and at Mountain Spring, Nevada, described by Dr. White in the Report of the Wheeler Expedition.

Hemipronites crenistria.

Orthis resupinata, very much like the *O. Swallovi* of the Upper Burlington.

Orthis Michelina, strikingly near to the Belgian form of the species.

Rhynchonella Missouriensis—the small form of the species described by Shumard.

Camarophoria occidentalis Miller—closely allied to *R. Coopernsis* of the Choteau, and still more to an undescribed form occurring in the Upper Burlington at Augusta, Iowa.

Spirifer extenuatus Hall, of the Kinderhook of Iowa, apparently identical with the form described under this name by Dr. White from Mountain Spring, Nevada. Also very similar to *S. Carteri* Hall (see Meek in Pal. Ohio, vol. i, p. 285), from the Waverly. Probably only a variety of the European *S. cuspidatus*.

S. striatiformis Meek, a well marked form closely allied to *S. striatus* of Europe.

S. centronatus Winchell.

S. peculiaris (?) Shumard, apparently identical with the form from Mountain Spring, Nevada, referred by Dr. White to this species. It is well represented, shows constant characters, and is probably a new species.

S. Nova Mexicana Miller.

Spiriferina ——, similar to *S. spinosa* of the Chester.

Martinia ——, of the type of *M. lineata.* A similar form from the Lower Carboniferous of Utah is referred by H. & W. to *M. setigera.*

Cyrtina ——, probably new; allied to *C. acutirostris* of the Lithographic Limestone of Mo.

Athyris lamellosa. A. incrassatus, Hall. *A. parvirostris*, M. & W. These three forms are not distinguishable from similar forms occuring in the Keokuk, Upper and Lower Burlington, and Waverly groups.

Terebratula Burlingtonensis White; Kinderhook.

T. Utah H. & W.—very similar to the form from the L. Carboniferous of Utah.

In addition to the brachiopods, there is an *Allorisma* like *A. Hannibalensis;* a *Conocardium*, probably new; *Chemnitzia;* two species of *Platyceras; Trematodiscus Rockymontanus* Miller; a *Phillipsia* and a *Proetus;* a *Zaphrentis* and two other corals; and a large number of *Bryozoa.*

ECHINODERMATA.

It is the Echinoderms, however, that constitute the most important feature of the collections, for they determine the equivalency of the formation. They consist of about 45 species of Crinoids, and 5 species of Blastoids, which are distributed as follows:

ICHTHYOCRINIDÆ.

Taxocrinus Thiemei.

CYATHOCRINIDÆ.

Cyathocrinus Iowensis; C. enormis. Vasocrinus macropleurus. Barycrinus Wachsmuthi; B. cornutus; B. rhombiferus. Coeliocrinus ventricosus.

PLATYCRINIDÆ.

Platycrinus subspinosus; P. planus; P. pocilliformis; P. pileiformis; P. verrucosus; P. regalis; P. corrugatus; P. Burlingtonensis; P. parvinodus; P. sculptus; P. Shumardianus; and 3 undescribed species.

Dichocrinus ——, undescribed.

RHODOCRINIDÆ.

Rhodocrinus Wachsmuthi; R. Wortheni; and one undescribed species.

ACTINOCRINIDÆ.

Actinocrinus proboscidialis; A. coelatus; A. multibrachiatus; A. opusculus; A. tenuisculptus; A. Copei. Agaricocrinus planoconvexus; A. pyramidotus. Amphoracrinus divergens. Eretmocrinus corbulis. Dorycrinus unicornis. Physetocrinus ornatus. Steganocrinus pentagonus; S. sculptus; S. araneolus.

SYMBATHOCRINIDÆ.

Symbathocrinus ——, 2 species undetermined.

BLASTOIDEA.

Granatocrinus ——, 2 undescribed species.
Troostocrinus ——, 1 undescribed species.
Codaster ——, 2 undescribed species.

Of the crinoids the most abundant species is *Actinocrinus proboscidialis*, which is found in all its varieties of ornamentation, size and form. This is probably the most characteristic fossil of the Lower Burlington Limestone, at the typical locality. It is subject to considerable variation in the features alluded to, yet is a very well marked species. Upon comparing a large number of well preserved specimens from Lake Valley, I am constrained to believe that *A. Dalyanus*, described by Mr. Miller from this locality (Jour. Cin. Soc. Nat. Hist., Dec. 1881), is only *A. proboscidialis*. Next to this the forms most frequently found are *Steganocrinus pentagonus*, *Platycrinus planus* and *P. subspinosus*, *Physetocrinus ornatus* and *Rhodocrinus Wortheni*, all peculiar to the Lower Burlington—the first and last of these, however, being among the rarer species at Burlington. Every one of the species named belongs to the Lower Burlington (leaving out *A. Copei*, which was described from Lake Valley), and the new species are of the same types. Not a single species has been discovered that is peculiar to the Upper Burlington, or any other group of the Subcarboniferous. No one familiar with the Burlington Crinoids will entertain the least doubt that the rocks which produce the species above enumerated are of the age of the Lower Burlington.

The Blastoids, although all of undescribed species, are of the types which prevail in the lower beds of Burlington.

Among the Crinoids the Ichthyocrinidæ are most feebly represented—but a single specimen having been found. Next in variety are the Cyathocrinidæ, of which only a few individuals were observed. The Rhodocrinidæ are comparatively common, while the Platycrinidæ and Actinocrinidæ are numerous in individuals as well as species.

The collection is remarkable for the entire absence of *Batocrinus*, which is one of the most common forms in the lower beds at Burlington. All observations as to the comparative abundance or the absence of certain forms must be taken with much allowance, for it has been found that here, as at Burlington, species which are very common at one locality are rare or wholly wanting at another not far distant; and while the facts above stated may be taken as fairly accurate indications as to the occurrence of the Crinoids at a few good exposures within a limited area, it is not improbable that they may be considerably modified by further researches, should other exposures be discovered in the same region.

The relations of bed 9, of the Lake Valley section, are not so clear. It exhibits in some places irregular layers of a light-colored semi-crystalline limestone, largely composed of the stem joints and plates of Crinoids, that strongly resembles the Upper Burlington. But among the few fossils discovered therein, I was unable to find any characteristic upper bed species, with the possible exception of two fragments of fish teeth—a *Chomatodus* and a *Petalorhyncus*—which are common forms in the Upper Burlington, but have not to my knowledge been as yet observed in the Lower. Further examinations may reveal a more chararteristic Upper bed fauna, but at present I am disposed to think this bed represents the cherty passage beds between the Upper and Lower Burlington.

The strata below No. 7 may be referred, in part at least, to the Kinderhook group, but I cannot determine the line of separation, because these strata, as well as those of No. 7, are mostly obscured by their own debris and the *talus* of the heavier beds above. The molluscan fauna of the lower part of No. 7 is in many respects similar to that of the Choteau Limestone. It may be that these mollusks were associated with many species of Lower Burlington Crinoids, and that in this case, as in some localities in Iowa, they have continued to flourish longer, and appear higher in the beds, than at the typical locality of the Choteau. Bed No. 3 is similar in appearance to No. 5 of White's section at Burlington (Bost. Jour. Nat. Hist., vol. vii, p. 215), and Nos. 1 and 2 are apparently not unlike No. 1 of that section. A *Rhynchonella* found in form of casts in No. 3 very strongly resembles White's *R. pustulosa*, and a small *Spirifer*, similar to his *S. solidirostris*, was collected from No. 6. Sufficient material has not yet been obtained from the beds below No. 7, for a satisfactory determination of their horizon.

Some collections were made by one of Lieut. Wheeler's parties at Mountain Spring, Nevada, and Ewell's Spring, in Arizona, which Dr. White has referred to the Kinderhook group (Rep. Wheeler Exped., vol. iv, p. 12). At the first locality some imperfect crinoids were found, and at the latter, in what was called the "upper horizon," a blastoid of the genus *Granatocrinus*. Considering the information we have of these localities, in connection with what has been observed at Lake Valley, I think it not improbable that further investigations will disclose the existence there also of one or both members of the Burlington group.

ART. XV.—*The Minnesota Valley in the Ice Age;* by WARREN UPHAM.

[Concluded from page 42.]

Two principal glacial epochs can be especially distinguished, each subdivided by times of extensive recession and re-advance of the ice, as shown by features of the drift in this State. In the first Glacial epoch, when the ice attained its greatest area, all of Minnesota except its southeast corner was deeply covered by the continental ice-sheet, and its border was several hundred miles south of this district, in Nebraska, Kansas, Missouri and southern Illinois, Indiana and Ohio, extending somewhat beyond the Missouri River, but terminating north of the Ohio River, except in the vicinity of Cincinnati, where it reached a short distance across that river into Kentucky, as recently proved by Professor Wright. In the later very severely cold epoch, the ice-fields were of less extent, and terminated in the central part of the United States from 50 to 300 miles within their earlier limit, covering all the basin of the Minnesota river, but not enveloping a large tract in the southwest corner of Minnesota and leaving uncovered a much larger area than before in the southeast part of the State. The terminal moraines, which form conspicuous belts of rolling and hilly drift in Wisconsin, Minnesota, Iowa and Dakota, were accumulated in the boundaries of the ice of the last glacial epoch. Between these epochs the ice was melted away within the basins of the Minnesota and Red Rivers, and probably from the entire State. The greater part of the till appears to have been deposited by the earlier ice-sheet; and during its retreat this till was overspread in some places, especially along the avenues of drainage, by beds of modified drift, or stratified gravel, sand, and clay, washed from the material that had been contained in the ice and now became exposed upon its surface to the multitude of rills, rivulets and rivers, that were formed by its melting.

In the principal interglacial epoch, this drift-sheet was channelled by water-courses until its valleys were apparently as numerous and deep as those of our present streams. The interglacial drainage sometimes went in a different direction from that now taken by the creeks and rivers; and the valleys then excavated in the drift, though partly refilled with till during the last Glacial epoch, are still, in some instances, clearly marked by series of lakes, as in Martin County, in the south edge of Minnesota. More commonly the interglacial water-courses must have occupied nearly the same place with the valleys of the present time; and there seems to be conclusive proof that this was true of the entire valley of the Minnesota River. A long period intervened between the great glacial epochs; the earlier ice-sheet gradually retreated northward; a lake was formed in the Red River Valley by the receding ice-barrier on the north; the outflow from this lake, and the drainage of the Minnesota basin itself appears to have excavated the valley of the Minnesota River nearly as it now is; and the further recession of the ice-sheet probably even allowed the drainage of the Red River basin to take its course northward, as now, to Hudson Bay; this being indicated by fossiliferous beds, containing the shells and vegetation of swamps, and trunks of trees, underlain and overlain by till, within the area that had been covered by this interglacial lake and was afterward occupied by Lake Agassiz at the close of the last Glacial epoch.

Since all this, a severely cold climate again prevailed, accumulating a vast sheet of ice once more upon British America and the greater part of Minnesota. Beneath this glacial sheet the valley of the Minnesota River was partly refilled with till, but it evidently remained an important feature in the contour of the land surface. Perhaps it had been the pathway, along the lower part of its extent, of a sub-glacial river during this later epoch of ice. At the final melting of this ice-sheet, its waters, discharged in this channel, quickly removed whatever obstructing deposits of drift it had received, and undermined its bluffs, giving them again the steep slopes produced by fluvial erosion. This partial excavation and sculpture anew were then immediately followed, during the retreat of the ice-sheet, by the deposition of the modified drift 75 to 150 feet deep, remnants of which occur frequently as extensive terraces on the sides of this valley, from its mouth to New Ulm, and less distinctly beyond. Had not the great valley existed nearly in its present form through the last Glacial epoch, it could not have become filled with this modified drift, which must belong to the era of melting of the last ice-sheet.

Modified drift, which was probably deposited during the recession of the ice of the earlier glacial epoch, was observed near New Ulm, forming a thick bed of stratified gravel and sand enclosed in the till. The section showing this is on the extension of Center street, a half mile west of New Ulm, where it rises to the top of the bluff, 180 feet above the river, but only some 100 feet above its old channel, which lies between New Ulm and this bluff. The height here reached is the general level of the vast prairie of gently undulating till, through which the Minnesota valley is excavated. The grade cuts to a depth of about forty feet at the edge of the bluff, and thence ascends, with decreasing depth of cut, along a distance of about twenty-five rods, to the surface of the drift-sheet. This excavation exhibits two deposits of true till, separated by modified drift which is probably an interglacial formation, supplied at the time of final melting of the earlier ice-sheet and spread beyond its receding margin upon the unchanneled surface of the till that had been formed during that earlier part of the ice age. The upper bed of till, thus apparently representing the total thickness of the drift deposited here in the last glacial epoch, is sixteen to eighteen feet thick, and is an entirely unstratified yellowish gravelly clay, containing occasional rock fragments up to six or eight inches in diameter, but showing only two or three of larger size, these being two to three feet in diameter. The bottom of this upper till, seen clearly exposed along a distance of about 250 feet, is an almost exactly level line. Next below is the modified drift which is supposed to have had its origin from the melting ice-sheet of the earlier Glacial epoch. Its thickness is also sixteen to eighteen feet and consists of yellowish gravel and sand, containing pebbles up to six or eight inches in diameter, quite ferruginous in the lowest one to three feet, levelly stratified throughout, but having the horizontal layers often obliquely laminated, the dip of this lamination being to the east or northeast, toward the Minnesota river, and varying in amount from two or three to fifteen or twenty degrees. The underlying till was seen along an extent of 100 feet, the greatest depth cut into it being about eight feet. Its upper line, separating it from the modified drift, is approximately level, but undulating, with its highest points two or three feet above the lowest. This till, like the upper bed, bears no marks of stratification; and neither shows any interbedding or transition, but both are bounded by definite lines, at their junction with the intervening gravel and sand. The lower bed of till is dark bluish, excepting for about twenty feet from the face of the bluff inward, where weathering has changed it to the same yellow color that characterizes the modified drift and upper till. In other portions of the Minnesota valley, its bluffs frequently exhibit modified drift interbedded, sometimes in deposits of large extent and thickness, with the till, which makes up the principal mass of these bluffs and of the drift-sheet.

A peculiar stratification observed in several of the deposits of clay which form part of the terraces of modified drift in the Minnesota valley in Scott and Carver counties, belonging to the time of departure of the last ice-sheet, appears to afford a measure of the rate of deposition. In Mr. Charles Rodell's excavation for brick-making at Jordan, the clay is bedded in distinct horizontal layers from three to eight inches thick, averaging six inches. These layers are dark bluish, often finely laminated, changing above and below to a nearly black, more unctuous and finer clay, which forms the partings between them. These divisions are clearly seen through the whole extent of this excavation, which reaches twenty-five feet below the top of the clay and is four rods long. The height of its top is estimated to be sixty-five feet above the river. The excavation of Nye & Co. at Carver, where the exposure is four rods long and fifteen feet high, with about the same elevation above the Minnesota River as the foregoing, exhibits the same stratification, except that here the layers all have a nearly uniform thickness of three inches. There is a tendency to split at the darker partings, which are seen to extend continuously, never passing one into another, and preserving a very constant width of three inches apart, through the whole of the section exposed. They are from an eighth to three-quarters of an inch thick, gradually merging above and below into the less dark clay that makes up the principal mass of these layers. The bedding is nearly level, but dips one to two degrees away at each side. In this depth of fifteen feet there are thus about sixty layers, all closely alike. The alternating conditions which produced them were evidently repeated sixty times in uninterrupted succession. The only explanation of this which seems possible is that these divisions mark so many years occupied by the deposition of this clay. Layers nearly like those in the clay at Carver and Jordan are also seen in other clay-beds in this valley and in that of the Mississippi in this State. The principal mass of each layer is regarded as the deposition during the warm portion of a year, and the very dark partings as the sediment during winter when the glacial melting was less and the water consequently less turbid.

At Chaska, situated in the Minnesota valley, two miles below Carver, the clay used for brick-making is modified drift of interglacial age. It varies from twenty to forty feet in thickness, being underlain by sand and covered by till from two to six feet thick, holding bowlders of all sizes up to five or six feet in diameter, many of which are planed and striated. This till forms the surface, thirty to thirty-five feet above the river. The only fossils found here were fresh-water clam shells, which occurred in considerable numbers upon a space four rods in diameter near the middle of Gregg & Griswold's excavation, lying in the upper foot of the clay, just beneath the till. This interglacial clay, overspread by till, testifies that an ice-sheet covered this region after the Minnesota valley had been eroded nearly as it now is.

Another observation which seems to give the same testimony, and to show that the modified drift forming high terraces and plains in this valley was deposited during the recession of the ice-sheet, is presented in the notably uneven surface of the broad part of the terrace of this valley drift in Carver county between Carver River and Beven's Creek. On this tract, composed, below the soil, of stratified gravel and sand, extending about two miles in width and elevated 125 feet above the river, are frequent depressions from ten to thirty rods in diameter and fifteen to forty feet in depth below the general level, often enclosed without outlet, and some of them containing lakelets and sloughs. Such hollows have not been seen elsewhere in our exploration of these terraces along the Minnesota Valley, which instead have generally a smoothly level contour. Their origin must apparently be referred to sedimentation while masses of ice occupied the places of these bowl-like depressions. Elsewhere the absence of such inequalities in the surface of the valley drift, as also the very rare occurrence of bowlders in it, and the fact that no portion of it, excepting that just mentioned at Chaska, is known to be interglacial by having become covered with till, together show that the deposition of these beds of modified drift took place outside the limits of the retreating ice-sheet. The valley appears to have remained from excavation in an interglacial epoch, and to have become rapidly filled with sediments as soon as the ice by which it had been enveloped was melted away.

Alluvial beds fill the Minnesota valley at Belle Plaine, as shown by the section of the salt-well, to a depth about 150 feet below the present river at its stage of low water. This well, situated on the bottomland at nearly the same height with the depot, or approximately 30 feet above the river and 725 feet above the sea, is reported by Professor Alexander Winchell to have passed through the following succession of deposits before reaching the bed-rock: soil and gravel, 9 feet; clay and gravel, 9 feet; sand and gravel, 18 feet; quicksand, 54 feet, having its base 90 feet below the surface; coarse sand, 1 foot; clay, 6 feet, in which was found, two feet from its top, a piece of grapevine with bark; sand, 38 feet, varying from quicksand to coarse sand, in which at 114 feet, inflowing water, under pressure from the bottom, filled the pipe twelve feet with sand, and a second time, at 125 feet, filled it five feet; then gravel, quicksand, and coarse sand, 45 feet, having its base 180 feet below the surface, yielding water at 144 feet, which filled the pipe with sand ten feet, and containing another piece of grapevine at 168 feet; next, from 180 to 200 feet, blue clay, 7 feet, and rock fragments, 13 feet, probably both bowlder-clay or till; and, lastly, gravel, 2 feet; the whole depth of alluvium and drift being thus 202 feet, extending about 170 feet below the river.

At the railroad bridge which crosses the Minnesota river close to its mouth, borings were made to a depth of 60 feet below the river-bed without reaching the bed-rock. In the deep well at Mankato, drift was found to extend 65 feet below the river.

A summary of the glacial history of the Minnesota valley, as recorded in its physical and geological features here described, is nearly as follows. This channel excavated in the Lower Magnesian or Calciferous formations far below the bottom of the present valley, appears to have been eroded by a river during the later Paleozoic and earlier Mesozic ages, before the Cretaceous subsidence which carried much of this state, with a large area farther west, beneath the sea. In the first principal epoch of glaciation, when the ice covered its greatest area, a thick drift-sheet, mostly unmodified, was spread over all this region, probably covering most of this pre-glacial valley with an unbroken, moderately undulating expanse of till. During the ensuing inter-glacial epoch, the drainage of this area cut a channel, which, because of the natural slopes of the basin determined by pre-glacial erosion, coincides along much of its lower part, where it crosses the nearly horizontal Paleozoic formations, with the old valley eroded in these strata before the ice age. The pre-glacial, and probably also the interglacial river lay far below the present stream. The till of the later glacial epoch appears to have only partially blocked up this river-course along the greater part of its extent, and portions which may have been obstructed were soon channeled anew, and this valley from its mouth to New Ulm or beyond was filled with modified drift, to the height of its present terraces of this formation, during the recession of the last ice-sheet. After the departure of the ice from the Minnesota basin, this avenue of drainage continued through a long time to be the outlet of Lake Agassiz, whence it received an immense volume of water supplied from the melting ice-fields of northwestern Minnesota and of a vast region reaching far to the north and northwest over the basin of Lake Winnipeg and the Saskatchewan River. As long as streams poured into this valley directly from the melting ice-sheet, its modified drift, gathered from the ice in which it had been held, continued to increase in depth; but when the great glacier had retreated beyond the limits of the basin of the Minnesota River, the water discharged here from Lake Agassiz brought no modified drift, and was consequently a most powerful eroding agent. By this mighty river the valley drift so recently deposited was mostly swept away, and the channel was excavated to a depth lower than the present river and perhaps quite the bottom of the gravel and sand in this valley at Belle Plaine, which is 150 feet below the river there and about 140 feet below low water in the Mississippi at Saint Paul. Since the ice-barrier which had caused Lake Agassiz disappeared and that lake was drained northeastward to Hudson Bay, the Minnesota valley and that of the Mississippi below, carrying only a small fraction of their former volume of water, have become considerably filled by the alluvial gravel, sand, clay and silt, which have been brought in by tributaries, being spread for the most part somewhat evenly along these valleys by their floods.

The changes produced by this post-glacial sedimentation have been pointed out and ably discussed by Gen. G. K. Warren, who thus added much to our knowledge of the geological history of the Minnesota and Mississippi Rivers. Lakes Traverse and Big Stone and Lac qui Parle occupy hollows in the outlet of Lake Agassiz due to inequalities of these recent deposits. At the mouth of the Minnesota River, the Mississippi has brought more sediment than its branch, which is thus dammed for a distance of thirty miles, to Little Rapids, with a depth of 20 to 25 feet at low water. The current of this part of the Minnesota through the dry season is very sluggish or imperceptible, and its surface often becomes considerably covered with the green scum of cryptogamous vegetation characteristic of pools and lakes. The channel here is from fifteen to twenty-five rods wide, with no lake-like expansions; but lakes from one to four or five miles long, and from a quarter to a half mile wide, lie near the river and parallel with it at each side, upon the bottomland. Lake Pepin, having a depth of about sixty feet, according to General Warren, lies in the continuation of this valley which was deeply channeled by the outflow from Lake Agassiz, because it has become unequally filled below the foot of this lake by the deposition of alluvium from the Chippewa River. Two of the tributaries of the Mississippi from the east were similar outlets of floods supplied by glacial melting after they had become free from their modified drift by flowing through a lake. Lake Superior, held by an ice barrier on the northeast at a level about 500 feet above its present height, overflowed at the head of the Bois Brulé River, by Upper St. Croix Lake and the St. Croix River. The Mississippi valley at the mouth of this river, as in the case of the Minnesota River, has become more filled by post-glacial deposits than its tributary, which is thus held as back-water twenty miles, to the head of Lake Saint Croix, which is 25 feet deep. Lake Michigan, till the receding ice-sheet was melted from its present outlet at the north, similarly discharged southward by the Illinois River, which, like the foregoing, is obstructed at its mouth by the alluvium of the Mississippi. At low water the greater part of its length is dammed, and has a very slight and often imperceptible current through the two hundred miles from La Salle by Lake Peoria to its mouth. Major Long remarked: "This part of the river may with much propriety be denominated an extended pool of stagnant water." All these results of recent fluvial action show that the drainage from the final melting of the ice-sheet excavated these valleys to depths much lower than they have now, and make it very probable that the deposits penetrated by the first 180 feet of the Belle Plaine salt well are wholly post-glacial.

The exposures of rock over which the Minnesota River flows at Little Rapids, ten miles below Belle Plaine, do not forbid this conclusion, for the topography of the valley in that vicinity indicates that a much deeper channel than that now occupied by the river may have existed there since the ice age, passing a mile and a half east and a mile northeast of the Little Rapids. This course of the river along which it is believed to have cut a channel in the easily eroded Jordan sandstone to a depth equal to that of the fluvial deposits penetrated by the well at Belle Plaine, extends northeastward diagonally across section 5, Sand Creek; then northerly through the west part of section 33, Louisville; and thence northwesterly through section 29. It thus leaves the present river a mile south of these rapids, and returns again to it about a mile south of Carver, after passing east and north of the island-like sandstone outcrops of section 32, Louisville. The recent accumulation of sediments that fill this avenue to a height slightly above the Little Rapids, has turned the river that way, so that it has abandoned its former course and now flows over ledges of sandstone.

Four features of the glacial drift in Minnesota seem to me very impressive and even grand. These are, first, the great thickness of the drift and its extent over large areas where it conceals and deeply covers all the surface of the older bedrocks; second, the terminal moraines; third, Lake Agassiz; and, fourth, the outlet from this lake, which has been the theme of the present paper. Professors J. D. Dana and J. W. Spencer, to the latter of whom we are indebted for valuable work in the Quaternary geology of the region of Lakes Erie and Ontario, have expressed the desire, in which I heartily join, to recognize in the nomenclature of American geology the work of the engineer who in the years 1866 to 1869, made a survey of the Minnesota valley from Big Stone Lake to its mouth, and from whose observations and writings, already several times referred to, this essay has received most important contributions and suggestions. Therefore it seems fitting to propose here for the ancient river which flowed in the Ice Age where Lakes Traverse and Big Stone and the Minnesota River now are, this name, the *River Warren*, in honor and *in memoriam* of Gen. G. K. Warren, the author of the first adequate description of this valley.

ART. XVI.—*Glacial Drift in Montana and Dakota;* by CHARLES A. WHITE.

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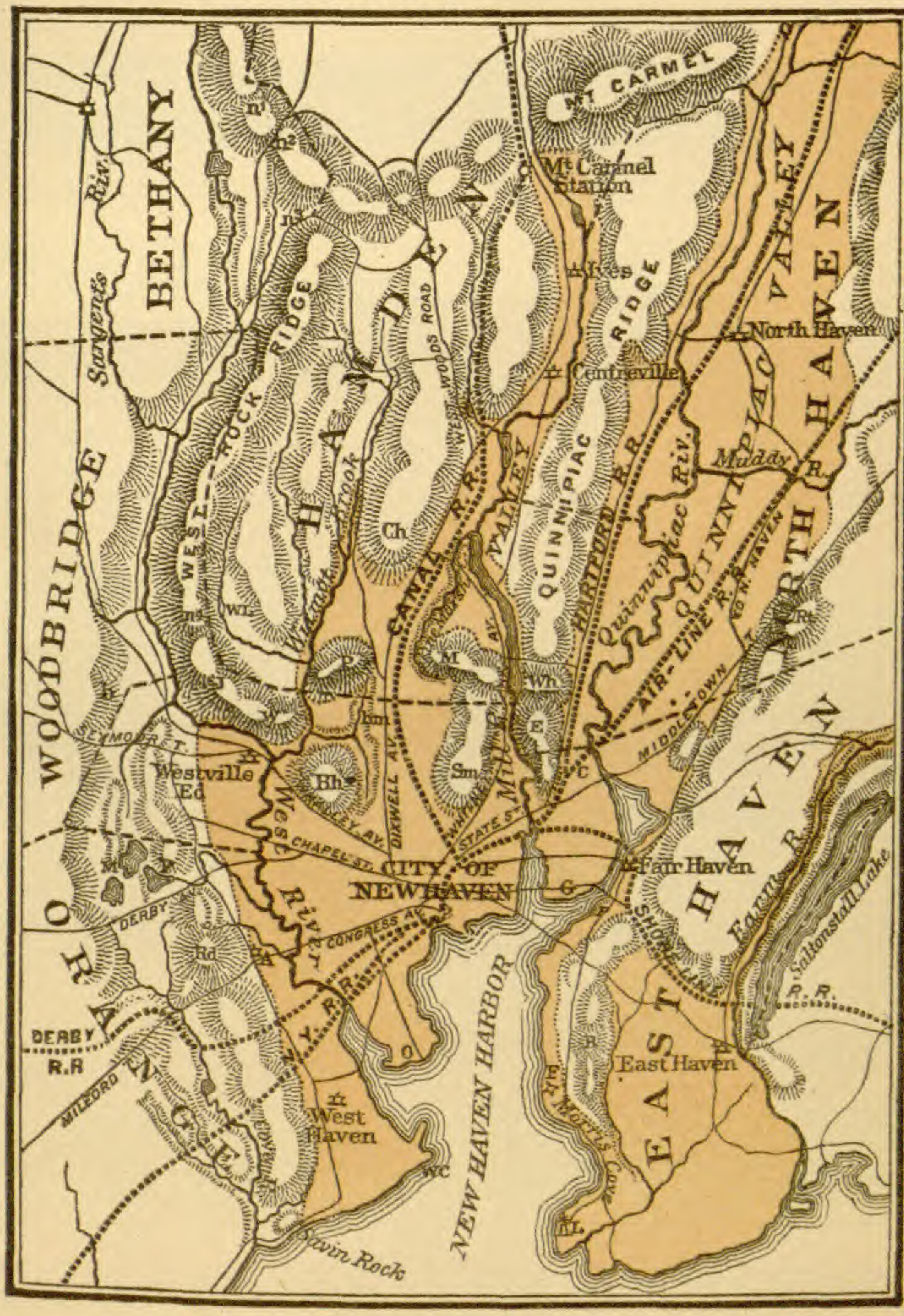
IN this Journal for March, 1883, page 206, I announced the presence of true northern glacial drift in the region about the mouth of Yellowstone River. While prosecuting geological work in Northwestern Montana last summer, including a row-boat journey down the Missouri River, my observations of that drift were extended much farther westward. These observations were largely confined to the immediate valley of the Missouri River, but a part of them extended to the vicinity of the Bear Paw Mountains. They extended continuously from the Great Falls of the Missouri, to Bismarck, Dakota; and more or less of the drift material was seen at intervals all the way, a distance of more than a thousand miles. As a rule, the northern drift material in all that region seems to be small in amount, as compared with that of the region farther eastward. In a few places I observed a little drift clay, but usually only sparsely scattered bowlders and pebbles were seen; the former were generally small, but a few were seen that would weigh several tons.

This northern drift material is quite distinct in lithological character, as it is in its origin, from the coarse pebble drift which is so common in all the valleys of the great Rocky Mountain region as well as upon a large part of the adjacent upland surfaces. It is composed of bowlders and pebbles of granitic and schistose rocks, such, for example, as characterize the northern drift in Minnesota. Among them also, not unfrequently occur masses of fossiliferous rocks, such as also frequently occur in the drift of the region to the eastward. These fossiliferous rocks appear to be of Cambrian or Silurian age, as a rule; but at a point in the valley of the Missouri river about 100 miles above the mouth of the Yellowstone, I found a bowlder of Devonian limestone among the other drift material.

The most satisfactory observations were made in the neighborhood of the southern side of the Bear Paw group of mountains. Here in the valley of Eagle creek, which is shallow and several miles wide, the surface is largely covered with characteristic drift-knolls; and a couple of small drift lakes were also seen there. It is interesting that although this accumulation of drift is at the southern side of these mountains, it consists mainly of the granitic and schistose material which characterizes the northern drift elsewhere. Mingled with it, however, are numerous fragments of the trachytic rocks which constitute the bulk of the mountains.



MAP OF THE NEW HAVEN REGION.

The colored part is the area of the terrace formation. Scale $\frac{1}{10}$ inch = 1 mile.

Explanations.—A, Allingtown. B, Beacon Hill. Bh, Beaver Hills. Ch, Cherry Hill. E, East Rock range, consisting of East Rock to the north, next south Indian Head, and further south Snake Rock. Ed, Edgewood. F, Fort Hale. *F*, Ferry Point, or Red Rock, on the Quinnipiac. G, Chapel Street. J, Judges Cave, on the West Rock ridge. L, Old Light House. M, Mill Rock. M P, Maltby Park. O, Oyster Point. P, Pine Rock. Rd, Round Hill. Rt, Rabbit or Peter's Rock. Sm, Sachem's ridge. T, Turnpike: also Tomlinson's bridge, across the head of New Haven Bay. V, Whitneyville. W, West Rock, the south end of West Rock ridge. W C, West Cape, or West Haven Point. Wh, Whitney Peak. W L, Wintergreen Lake. *b*, 1200 ton bowlder in Woodbridge. *bm*, Beaver Pond Meadows. *n*1, *n*2, *n*3, *n*4, different notches in the West Rock ridge; *n*1, *n*2, the upper and lower Bethany Notches; *n*3, the Hamden Notch; *n*4, the Wintergreen Notch.


MAP
OF THE
NEW HAVEN PLAIN
SHOWING
ITS ORIGINAL FEATURES,
THE OUTLINES OF THE TERRACE AREA,
THE RIVER-CHANNELS AND KETTLE HOLES
AND ADJOINING AND INCLUDED HILLS.
Based on the BACHE Coast Survey Chart.
SCALE: 2 inches = 1 Mile
Dotted line shows the Terrace outline.
Figures indicate height above mean tide.
Cross-lined part of river channels is tidal.
CENTERVILLE
AUGERVILLE
CHERRY HILL
QUINNIPIAC RIDGE
Quinnipiac Station
WINTERGREEN LAKE
Hamden Church
MILL RIVER
Pine Marsh Brook
Wilmot Brook
PINE ROCK
MILL ROCK
WEST ROCK
Judges Cave
WHITNEYVILLE
EAST ROCK
SACHEM'S RIDGE
BEAVER HILLS
BEAVER POND MEADOWS
WEST RIVER
WESTVILLE
QUINNIPIAC RIVER
NEW HAVEN 1638
CHAPEL STREET
COLLEGE STREET
STATE STREET
West Cr.
East Cr.
Allingtown
NORTHERN PART OF NEW HAVEN BAY
WEST HAVEN
EAST HAVEN
BEACON HILL
72° 57'
72° 56'
72° 55'
72° 54'
41° 22'
41° 21'
41° 20'
41° 19'
41° 18'
41° 17'

These observations were all incidental to other work, and therefore incomplete; but they are deemed important as indicating the broad extent of the region over which the northern glacial drift has been distributed.

ART. XIII.—*Phenomena of the Glacial and Champlain Periods about the mouth of the Connecticut Valley—that is, in the New Haven Region;* by JAMES D. DANA. (With Plates I and II.)

IN the last volume of this Journal the phenomena of the Glacial era in the New Haven region were described and discussed. It remains to describe—

II. THE PHENOMENA OF THE CHAMPLAIN PERIOD, OR THE CONSEQUENCES OF THE GLACIAL FLOOD IN THE NEW HAVEN REGION.

In order that the facts connected with the flood-deposits may be clearly understood the map used for illustrating the former paper is here reproduced (Plate I) with the area of the great flood-plain or terrace-formation colored. The scale of this map is *four-tenths* of an inch to the mile. Another map on a much larger scale—*two inches* to the mile—of the middle portion of the region is presented on Plate II, giving the details with regard to the topography along the valleys and over the plain, the heights above mean tide, and by contour-lines the features of the adjoining country. The dotted line at the base of the hills is the boundary of the flood-plain or terrace-formation.

The basis of this map is a reduction from the Bache Coast Survey Chart, referred to on page 343 of the last volume. The contour-lines across the plain have been omitted, and instead the actual height of the plain above mean-tide level from the Sound northward is in figures. These heights have been obtained by levelling, using as a base the heights of street curbs from the Report of the City Surveyor, and occasional points along the contour-lines of the Coast Survey chart. In all cases in and about the City of New Haven they give the *original* height of the plain. They are not always the present actual height, for city grading has made large changes; but happily some portions of the plain still remain in places where the buildings are most crowded. Outside of the crowded portion of the city, the plain is still mostly undisturbed except adjoining or along the roads crossing the valleys. Moreover, the shore-line along the head of the bay is restored to its former outline. The tidal flats along the rivers are cross-lined. The contour lines are for every 20 feet; in the Coast Survey chart mean high tide is the base, but the heights in the map are above mean tide, which is 3 feet below mean high tide. The map (Plate II) gives the original square of the city, half a mile each way, as laid out in 1638; the city now extends over the whole breadth of the map.

Before describing the "Kettle-holes" of the plain and the valley-like depressions that look like deserted river channels, it is necessary, preparatory to a discussion of their origin, to review briefly the facts relating to the transporting agents of the region, although the facts are contained, for the most part, in former papers by the author.

I shall treat *first*, of the rivers; *secondly*, of the deposits made by the flooded rivers; *thirdly*, of the depressions over the flood-plain or terrace-formation.

1. *The Rivers.*

The order of size in the three streams which traverse the New Haven Region on their way to the Sound, is now as follows:

	Length.	Approximate drainage-area.
1. Quinnipiac River	33 miles	120 sq. m.
2. Mill River	15 "	50 "
3. West River	15 "	38 "

In the era of maximum flood the relative rank of the first two rivers was reversed, through a gain in length, on the part of Mill River, of 15 miles from the Quinnipiac, the upper half, and also the larger part of Farmington River. (This Journal, xxv, 441, 1883). The size of the three streams thus became—

	Length.	Drainage-area.
1. Quinnipiac River	18 m.	65 sq. m.
2. Mill River	75 "	450 "
3. West River	15 "	38 "

The first two of these streams were changed by the flood also in the altitude of their sources. Mill River, as a consequence of the addition of the Farmington, drained the high plateau of southwestern Massachusetts and northwestern Connecticut, one of the Massachusetts branches commencing near the Becket Survey Station, which has a height above the sea of 2194 feet, and another near the Sandisfield Survey Station, 1698 feet. The abbreviated Quinnipiac flowed from regions mostly less than 300 feet above the sea, only very short lines on trap ridges extending higher. West River flowed, as before, from the high town of Bethany, averaging 500 feet in elevation, above the sea-level.

But the working force of these streams and their influence on the features of the New Haven deposits depended much on their slopes just north of and within the region, and especially south of the latitude of the Mt. Carmel gap. The level of maximum flood in the latitude of the gap, as determined from the height of the upper terrace, was (1) on the Quinnipiac 70 feet above mean-tide; (2) on Mill River 118 feet, or 48 feet higher than on the Quinnipiac; and (3) on West River, 300 feet. Nine miles south, in the line of the head of New Haven Bay, the normal terrace-levels, and therefore flood level, was about 40 feet above mean tide. Hence for the interval, the descent was

	Descent in 9 miles.	Descent per mile.
On the Quinnipiac	30 feet.	$3\frac{1}{3}$ feet.
On Mill River	78 "	$8\frac{2}{3}$ "
On West River	260 "	29 "

Thus the Quinnipiac was relatively feeble not only through its smaller supply of water, but also in its much less slope over the northern part of the New Haven region. Even West River was a stream of more power. In view of the relation in drainage areas and slope, I am led to conclude that the energy or effective force of these streams, the Quinnipiac, West River and Mill River, may be approximately represented by the ratio 1 : 4 : 25.

The slope of the land was probably less than now through a change of level, as deduced in a former paper; but any diminution of slope would increase, not diminish the contrast; for 2 feet less would be a large deduction from $3\frac{1}{3}$ feet, but from 9 or 29 very small.

At the present time the tides extend up West River to Westville, and up Mill River to Whitneyville, in each case $2\frac{1}{2}$ miles north of the latitude of the head of New Haven Bay. On the Quinnipiac they reach 7 miles north of the same line, or a mile above North Haven; and the four more northern of the seven miles are over very broad tidal meadows, as shown on Plate I.

2. *Deposition by the three streams.*

The three rivers emerged from their valleys on passing the extremities of the West Rock and East Rock ridges; thence they worked to some extent unitedly. This united action is proved by the fact that the plain from this line southward is continuous across its breadth of $4\frac{1}{2}$ miles, and has nearly a common normal height, along east-and-west lines. Moreover, the deposits have throughout the same kind of structure and constitution, the flow-and-plunge style of cross-bedding being common in all parts, and the whole formation bearing evidence of simultaneous fluvial origin.

Further, the work of the several streams as measured by the deposits they made corresponds well with the estimate which is given above of their relative capability.

a. The Quinnipiac River.—The *Quinnipiac* made deposits of sand, with some fine gravel, on its east side, east of its present broad marshes, but almost none on the *west* side; which fact is evidence that the river transported but little, and that the material of the east-side deposits were mostly from tributary supplies. Along the borders of the Quinnipiac meadows there are clay-beds; but these are bottom or early deposits of the terrace formation, of quiet water origin, not those of full or half flood. They appear to rest on the unstratified drift or till that covers the sandstone, and derived the clay from the till.

South and southeast of East Rock, a high terrace, full a mile wide, stretches from Mill River eastward to Fair Haven, and for four-fifths of this distance it fronts, or is south of, the wide Quinnipiac meadows. Topographically it is a Quinnipiac terrace; and yet not so in origin, for it is in reality, as shown beyond, a *Mill River terrace.*

Thus the Quinnipiac has little to show of its work in the New Haven plain.

b. West River.—In contrast with the Quinnipiac, West River, on the west side of the New Haven region, contributed largely to the plain. Its terrace depositions south of Westville are three-fourths of a mile wide on the *west* side of the river alone. About Westville, where the stream escaped from its valley, the deposits are of the cobble-stone kind for a depth from the top of 30 feet or more, and they are but little less coarse on the east side of the river, where it received the contributions of Wilmot brook. The coarseness gradually diminishes southward; and three miles south, about its mouth, the deposits consist mainly of sand—a change attributable to loss of velocity.

c. Mill River.—Mill River, the great central stream, spread its flood waters across the whole region, mingling its depositions with those of West River on one side, and, on the other, taking possession as above stated, of the Quinnipiac valley. The latter result, like the former, was a consequence of its great slope and volume. The hurrying stream passed the Whitneyville gap at a level full seven feet above that of the Quinnipiac just east of it; and on reaching, a mile below, the end of the intervening East Rock ridge (at E) it must have made a violent dash eastward, carrying as it went its load of sand and gravel into the Quinnipiac area. The coarse gravel deposits of the terrace on the Mill River side attest to the violence of the flow at this point; and a diminution of coarseness eastward corresponds to the loss of velocity as the waters spread eastward. Moreover the terrace deposits to a depth of 25 feet from the top have the cross-bedded structure that would have been produced by the flow of Mill River, proving that it had complete control in the deposition. The direction of dip in the cross-bedding is the reverse of that in the finer and redder beds of the *lower* 25 feet, and the transition is an abrupt one.* Only this earlier portion, made before the waters were above half flood height, was stratified by the Quinnipiac current.

The torrential character of Mill River in the Whitneyville gap is attested to by a number of large pot holes made in the sandstone of the west bank near the flood-level of the era. One of these pot-holes (4½ feet wide and 7 deep) may now be seen by the road side, 140 yards above the dam and nearly 60 feet above tide level; and two others were opened to view and cut away in the grading of the road a few years since.

Mill River, therefore, was the chief source of the stratified drift or terrace deposits of the New Haven region. We have, consequently, to look to it for an explanation of the more prominent features of the New Haven plain.

The general southward slope of the terrace-formation from Mt. Carmel to the Sound has been already given. The facts are still better before the reader on the maps accompanying this paper, the height being stated on the larger map, in figures. A review of them in this place is therefore not necessary.

3. *The depressions of the New Haven plain.*

The depressions of the plain are:

(1.) The flood-made river-channels, bounded for the most part by the terrace-fronts facing the existing streams.

(2.) Depressions in the plain made by drainage from its surface.

(3.) The area of a low terrace, of 20 to 25 feet elevation, bordering the bay on the north side, and Mill River on the west and less widely on the east.

(4.) Two long depressions that look like portions of large river-channels.

(5.) The "Kettle-holes."

(1.) *The flood-made river-channels.*—These broad river-ways of the flood era answer to the channels of the modern stream between the terrace-fronts—the banks as they are called—of its modern flood-ground, and had, as I have elsewhere explained, the same mode of origin. Like them: (1) they were made along the course of the greatest velocity in flood-time; (2) their depth below flood-height is (excluding some later erosion at bottom) the depth of scour, which depth was dependent mainly on the velocity and the kind of bottom; and (3) the

* See Geol. of New Haven Region, Trans. Connecticut Acad., vol. ii, 1870, and this Journal, III, vol. i, p. 173, where the section of the formation showing the reversed dip is introduced.

bordering terrace and terrace fronts are a consequence of loss, on either side, of velocity in the transporting waters resulting in deposition.

(2.) *Depressions from surface drainage.*—Of the depressions which look as if referable to surface-drainage, two are of special interest. These are *East Creek* and *West Creek*, east and west of the original New Haven square, as shown on the map of Plate II. Both streams flowed in part between abrupt terraces for nearly half a mile from the bay, and the latter of the creeks admitted the ships of the early colonists for half that distance;* but under city grading both creeks have disappeared, and the channels are fast becoming obliterated. The map renders further description of them in this place unnecessary. The size of the channel of West Creek between the terraces, and certain features common to both soon to be stated, lead to the conclusion that they may have a long history, even antedating the existence of the plain, and are only in some later modifications a result of surface-drainage.

(3.) *The low-terrace area.*—This area, as the larger map shows —by the heights given on it and a band of shading—extends from the bay and West Creek valley northeastward over the lower half of the central square of New Haven and onward for a mile up the west side of Mill River, and also over a small region east of the southern part of this stream. In height the terrace is 15 to 20 feet below the normal upper terrace. On glancing over this area on the map (Plate II) and noting its relations to Mill River channel, it is manifest that it is simply the area of a low Mill River terrace; and the facts show that its existence was determined by the velocity of the waters during the flood; that it lies where the depth of scour was too great for the building up of the terrace-deposits to their normal height, or that of the New Haven plain elsewhere. Part of the evidence consists in the exceedingly coarse, largely cobble-stone, character of the underlying gravel. The direction of the band of coarsest gravel indicates that Mill River followed a nearly straight course from Whitneyville to the head of the Bay, this being one of the numberless examples of a straight cut made in rivers by the great flood.

The low terrace is hence one of the phenomena manifesting the power and influence of Mill River.

(4.) *The long depressions resembling fragments of former river channels.*—These channel-like depressions are called the *Beaver Pond Meadows* and *Pine Marsh Creek.* Their location is given on both maps, and their special features on the larger one, Plate II. As there seen, they stretch southward through the middle part

* The vessels came to anchor at what is now the corner of Congress Avenue and Oak Street.

of the New Haven plain, between Mill Rock on the east and Pine Rock on the west, and each is about 1¾ths mile long.* They are sunk 25 to 35 feet below the level of the plain, and are confined for the most part by terrace fronts of this height. They have a width mostly of 800 to 1,000 feet, and a bottom of peat meadows, though with some encroaching areas of sand deposits; the level of the marshes in the Beaver Pond depression is 27 feet above mean tide, and in the Pine Marsh, 33 to 35 feet. They are much like the West River channel-way between its terrace fronts; or, rather, like fragments of it, for they are marvelously short for the great breadth and depth. The western depression—that of the Beaver Pond Meadows—is wholly isolated from any of the rivers of the region both to the north and south, but has a lateral connection by a valley with Mill River valley. Each has its stream, one emptying by the *lateral* channel referred to into West River, the other joining Mill River by its *north* end. These streams, although not two miles long, which is very short for the great valley they occupy, are abundant in waters, that of the Beaver Pond depression supplying a mill the year around. These copious waters are almost wholly *subterranean*—whence it is that the deeper pools do not freeze over with the thermometer at 0° F.

As shown on the map, the more northern of the two depressions, Pine Marsh Creek, comes to its southern end abruptly in the plain southwest of Mill Rock; while the other, the Beaver Pond depression, begins almost as abruptly just west of this place; the terrace-plain between them is for the most part at its normal height.

The depth through the peat to hard bottom is another singular feature. In a recent survey of the Beaver Pond Meadows, by Mr. Sylvanus Butler, under the direction of the city of New Haven, the depth through the peat to firm gravelly bottom was found, at one place just northeast of the outlet, to be 52 feet, *which is* 25 *feet below the level of mean tide.* The soundings were made along the water-course, which is not in all parts the line of greatest depth. A little outside of it, and nearly a third of a mile south of the above-mentioned place, other soundings of 48 to 52 feet were obtained.

No borings have been made through the bottom gravel to the underlying sandstone, and hence the actual depth of the trough to solid rock is unknown; we know only, from the fact just stated, that it is more than 25 feet below mean tide. From this it appears to be certain that the Beaver Pond channel is not simply a depression in the plain or the terrace deposits;

* The Beaver Pond depression terminates southward near the junction of Goffe and Crescent streets, and extends northward along the west side of Crescent street. The Pine Marsh depression has its southern termination near the extremity of Shelton Avenue, north of Morse street.

on the contrary it covers probably an excavation in the subjacent sandstone. On the western margin of the depression, rise the low "Beaver Hills," and these are sandstone hills with a thin covering of unstratified drift. These hills (see map) have the trend of other sandstone hills of the region whose outline was plainly determined by the direction of movement of the ploughing glacier.

No similar soundings have yet been made in the Pine Marsh depression. But the fact that the waters are subterranean, and its close resemblance to the Beaver Pond depression in all its features, are favorable to the conclusion that the two are alike in depth of excavation and of one mode of origin.

As to *origin*, we have the following basis for a conclusion:

1. The resemblance in each to the channel of a great river, both in width and in steep terrace-fronts.

2. The depth of the trough :—that of the Beaver Meadows extending much below the sea level, as if channeled out of the New Haven sandstone region by the glacier.

3. The fact that the Pine Marsh depression or channel-way, and Mill River valley for three miles next north, have approximately the same compass course, coincident with the glacier flow, making them one channel-way; and that this channel-way points directly through the open center of the New Haven region (between Pine and Mill Rocks) nearly toward the head of the bay (which bay it is to be noted, is the termination of the Connecticut river valley or trough); while the course of Mill River *below* the junction with Pine Marsh Creek makes an angle of 40 degrees with that of the glacier-flow, and passes through a narrow gap, in trap, at Whitneyville.

Objections to the conclusion here indicated are apparent (1) in the abrupt southern termination of the Pine Marsh depression, and (2) the isolation of the Beaver Pond depression.

Before considering further this question of origin, the facts respecting the "Kettle-holes" need to be surveyed.

4. *The Positions and Characteristics of the Kettle Holes.*—The kettle holes are nearly seventy in number. Of these, (1) *twenty* are situated on or near the borders of the Beaver Pond depression; (2) *thirty*, by the Pine Marsh depression; and (3) *seventeen* at Augurville, near the junction of Sluice-way Brook with Mill River. The map Plate II shows their positions.

All occur in the *stratified drift;* that is, the well-bedded material of the New Haven plain, or that of the terrace-formation, gravel-made and sand-made portions irrespectively, away from all *unstratified* material, or till. This formation in their vicinity has its usual horizontal bedding and flow-and-plunge structure. Whether the horizontal feature usually extends quite to the edge of the kettle-hole has not been ascertained, because of the want of exposed sections. In a section of one near Pine Marsh Creek, made in laying out a new track for a railroad, an upper layer of the terrace formation, about 6 to 8 feet in thickness, followed down the steep slope of the depression conformably to its surface; but this single case is not sufficient for any general conclusion; it may have been due to a slide, though not looking like it.

The kettle-holes are usually isolated; the coalescence of two or three in a single oblong or irregularly-shaped depression is also common. They vary in diameter from 100 feet to more than 500 feet, and in depth from 15 feet to 50. The sides have the same slope as the terrace fronts along the river-channels, or generally 30° to 38°. They are often dry (if shallow), but generally are marshy at bottom, and not unfrequently contain a pond of water.

The distribution, sizes, forms, positions, and relations to the Beaver Pond and Pine Marsh depressions of the kettle-holes are so clearly exhibited on the accompanying map (Plate II) that detailed descriptions are not necessary. It is seen that the most of them range along parallel with these depressions. On the west side of the Beaver Pond depression the holes are partly in coalescing groups of two to four ranging parallel with the depression, or oblong in the same direction. On the east side are other oblong holes which are *transverse* in direction instead of parallel, yet still have an undoubted relation in position to the great depression.

The cluster of kettle-holes near Augurville (see map, Plate II), at the junction of Sluice-way Brook with Mill River, is peculiar in its position. A map of the region on a larger scale (5 inches to the mile) is here introduced to show better their forms and their position in relation to the two streams. The map is from the Coast Survey chart and gives its contour lines. The kettle-holes vary from small circular shallow bowls to large irregular depressions having a marsh at bottom which is 45 feet below the surface and on a level with the water in the river. As the contour-lines show, they do not connect directly with the Mill River Channel. The contour line of 83 feet occurs among them as well as on the western border, and that of 63 between them and Mill River.

Sluice-way Brook is the modern representative of the stream that, in the time of the glacial flood, came down from the Mt. Carmel gap (see map, Plate I), and had its chief source in the waters above the ice-dam through the sluice-way at its western end, as described in volume xxv of this Journal (1883). The sluice-way waters, after passing the barrier of trap at the dam, flowed southward (as has been described) in a channel, 25 or 30 feet wide, worn by the waters out of the red sandstone, and then—re-enforced by tributaries from high hills to the northwest—followed the valley of the existing brook for three miles before reaching Mill River at Augurville. The descent in this distance is 25 feet a mile, while that of Mill River from the dam to the same point was only 10 feet a mile. The two

Kettle-holes at the mouth of Sluice-way Brook.

flooded streams came together with velocities corresponding to these different slopes; and the coarse gravel deposits at the place of junction, some of the stones a foot or more in diameter, are evidence of the violence of the sluice-way torrent.

4. *Facts bearing on the Origin of the Kettle-holes and the long channel-like depressions.*

1. The relations between the kettle-holes and the Beaver Pond and Pine Marsh depressions, above pointed out (as exhibited on the map), make it almost certain that there was community in origin for the two if not unity in method of origin.

2. This community of origin as regards the two great depressions was, with hardly a doubt, unity in origin and method. For they are partially connected by outreaching arms and kettle-holes. From the southwest angle of the northern or Pine Marsh depressions an arm extends out *westward*, and at the end

of the arm there is a large and deep kettle-hole continuing the line toward the Beaver Pond depression. Further, the latter depression just southwest stretches out two long arms *eastward*, suggesting former junction. A dozen other kettle-holes lie to the south and southwest of the Pine Marsh depression; and other arms extend toward them from the Beaver Pond area. Although the plain around has the normal height (as the map shows) the arms and kettle-holes look exceedingly (more so in the field than on the map) as if a former channel had existed and had become mostly obliterated by sand and gravel deposits.

3. A former union of Pine Marsh channel with the Beaver Pond channel almost necessarily implies a continuation of the channel to the head of the bay; and such a continuation is plainly indicated by the ranges of arms and kettle-holes extending from the *southeastern* portion of the latter channel toward and into the *East Creek* channel (see map). The arms leading from the depression are in fact kettle-holes partially coalescing with it; and the kettle-holes make two almost continuous arm-like channels extending into the creek valley.* The southern of the two lines is over 1,000 feet long. Again, farther south, near the south end of the Beaver Pond depression, still another line about 2,000 feet long, consisting of two kettle-holes (one 500 feet in diameter with formerly a pond at bottom) and a long depression,† make another connection with the East Creek channel. A boring in this channel, ¾ *m. from the bay, descended* 40 *feet below mean tide before reaching rock.*

A connection of the Beaver Pond depression with *West Creek* can not be so clearly made out, and yet it has facts in its favor. East of south from the south point of the depression, separated by a low neck, lies a large (500-foot) marsh-containing kettle-hole.‡ In the same south-by-east direction, 2,000 feet away, commences the West Creek channel, which soon becomes 700 feet wide with a steep terrace-front on either side. The size of such a channel-way is out of all proportion to its mile-long stream; but it is well explained if there were once a connection with the Beaver Pond channel to the north of it.

4. The conclusion seems to be inevitable in view of all the facts just stated (including those before adduced, as to the depth of the Beaver Pond trough and the conformity of the Pine Marsh depression and Mill River north of it in course to the direction of glacier movement) that the two now isolated depressions are dissevered parts of the deep Mill River channel of the Glacial era; that East Creek and West Creek are

* Munson street runs between the two ranges of kettle-holes.

† This depression is just south of Webster street.

‡ West of Goffe street, opposite the bell-tower square. It is much shallowed by city grading and will soon, like others, disappear.

within the boundaries of the same great channel as it passed into the greater channel of the bay; and that this broad Mill River channel of the Glacial era through the soft sandstone was deepened at that time, if not made, by the excavating action of the ice and running water. The phenomenon is one now known to have been a common result of the glacier flood, in which a stream had its Glacial-era channel partly obliterated by the depositions from the waters as the flood from the melting made progress. The deposits appear to have early blocked the channel, even before half-flood was reached, and thus forced Mill River to take its present course. It is probable that a diminished slope in the land aided the depositions in checking the stream.

The origin of the great depressions is thus traced to excavating-work in the Glacial era and subsequent depositions of drift material. They are the *unfilled* portions of the old channel, and were left unfilled, while deposition was going on so freely, because of the depth of the excavation, or, for parts of them, because of the position with reference to the main current. The waters of the rising flood made a new exit for each of them, the Beaver Pond depression having opened a western outlet to West River, and the Pine-Marsh depression taken its northern extremity for discharge into Mill River. The discharge of the Beaver Pond waters was of long continuance, and held on through the era of maximum flood; for the deposits of the terrace adjoining the exit channel are of very coarse gravel, while elsewhere about the depression they are of fine gravel or sand.

The mean width of the Pine Marsh and Beaver Pond depressions has been stated to be 1000 feet. But the actual width in some parts is 2000 to 3000 feet; and as these depressions are only what was left after the burial, the mean breadth was probably near the present extreme breadth, or at least *half a mile;* and this comports with the supposed size of the stream. The connecting lines between the Beaver Pond depression and East Creek are half a mile apart, and they may be the outer portions of the one broad channel half a mile wide. East and West Creeks are only two-thirds of a mile apart; and these may have been the sides of the channel at its mouth, for the channel would not there have been narrower but rather wider than to the north.

5. The *origin of the kettle-holes* remains for consideration. Their situation by the side of the great depressions, sometimes in lines parallel with them, and their lying also in lines more or less perfectly connecting the two depressions with one another and the more southern with West Creek channel, proves that they originated at the same time with the depres-

sions and under similar conditions. But was it by the same method?

The kettle-holes cannot be attributed to the removal of an underlying stratum of clay or of limestone, for we have no evidence of any clay or limestone underneath. Again, it is not probable that sands of the underlying beds could have been carried away by subterranean drainage, for the subterranean waters of the region are those within the terrace formation itself, in which movement is necessarily very slow, transportation difficult, and the determining thus of isolated kettle-holes hardly a possibility under the most favoring circumstances.

Besides these explanations, two remain for consideration:

(1) That they are, like the larger depressions, unfilled portions of the old and deep excavations which were left unfilled because of their depth, position, and the current-action in the waters.

(2) That they are the sites of ice-masses which melted finally only after the terrace-formation was wholly or nearly completed, and which hence left holes where they lay. This origin of kettle-holes through the agency of ice-masses was suggested long ago by Professor Edward Hitchcock.*

The theory of left or stranded ice-masses appears to apply to some cases; but not so here, for the following reasons:

In the New Haven region, (1) deposition of the terrace-material and (2) the making of the kettle-holes must have gone on together, as the stratification around the kettle-holes shows; and the latter were formed chiefly along either border, or the course, of the great central water-way, and that part of the water-way which became divided by obstructing depositions. Consequently, if ice-masses were concerned, they were stranded masses from the river, not ice left in place by the retreating glacier. Further, since these holes are 25 to 50 feet or more deep, the ice-masses must have been in place in the *early* part of the flood and have projected high above the waters during its whole progress.

Some of the difficulties are thence the following:

(1) In the early part of the flood (when only finer sand deposits of the terrace formation were in progress), there is no reason to believe that water enough existed in the stream to have floated masses 100 to 500 feet or more in diameter and 50 feet or more thick; for 50 feet of depth, at least, would have been required. The above are minimum numbers as no allowance is made for waste by melting.

(2) The waters which flowed by the stranded masses through the progress of the flood, deposited in their close vicinity beds of sand and gravel having the flow-and-plunge structure, and

* Report on the Geology of Massachusetts, 4to, 1841, ii, 370.

in some parts beds of the coarsest gravel; they were hence rapid and plunging waters, and the stranded ice-masses where exposed to them could not have remained long unmelted.

(3) The latter half of the era of the terrace depositions was that of the closing part of the melting, and therefore not the era of glacial cold, but one of milder airs, such as predominated in the Champlain period; and hence the winds would have helped in the dissipation of the ice.

The other explanation, also—that the holes are places unfilled by depositions because of their depth and for the other reasons mentioned—has apparently its difficulties. It is a matter for surprise that where so great depositions were in progress so many holes of the kind should have been left in the plain; and also that the terrace-formation should have been so generally built up to full normal height quite to their margins.

Such results lose some of their seeming improbability when the process of deposition is fully considered; that

(1) The shallowest part of a water-way, as its reefs or bars, are most likely to take the depositions because they occasion by friction lessened velocity and transporting power; and hence the deeper parts do not generally lose in depth by deposits, but become narrowed by the down-stream extension of the sand-reefs, and deepened also owing to increase of velocity in the narrowed passages; (2) that consequently, in a great flood, if the amount of transported material is large, almost as much as the waters under the rate of flow could carry—as was the fact during the flood from the melting glacier—the reefs, or the flood-grounds, would be built up rapidly toward flood-level through the abundant deposits, and become extended at flood-level height in the direction of the flow, and thus the shallowest parts over these grounds might or would have taken the larger part of the depositions; (3) that when an isolated depression was encountered, the waters would have taken often some rotary movement, which would have promoted abrasion and removal, and caused deposition outside instead of inside.

The writer, while admitting the sources of doubt, inclines to adopt the latter explanation of the New Haven kettle-holes rather than the former for the reasons already stated.

(1) At the time of the supposed stranding, the ice-masses could not have had water enough to float to their places.

(2) Under the conditions that existed during the flood, the isolated ice-masses could not have lasted long enough, or a hundredth part of the time, necessary to keep the spaces open.

(3) The intimate and systematic association of the kettle-holes with the great Pine Marsh and Beaver Pond depressions and East Creek appears to put all into one category as to method, as well as community, of origin.

The cluster of kettle-holes at the mouth of Sluice-way Brook may be looked upon as a case similar to those of the great depressions just mentioned. For the large irregularly-outlined kettle-holes making the center are much like a small example of a Pine-Marsh depression with kettle-holes bordering it. It is probable that in the Glacial era the course of Mill River from Centerville *southward* was a straight one right through the deep kettle-hole area, where the violent waters of Sluice-way brook struck (see map); and that the eastward bow-shaped bend of the present stream at Augurville, was a consequence of the depositions of drift, which forced the Mill River channel to a more eastward position.

Conclusion.

The history of the New Haven region during the Glacial era probably included the deepening if not the excavation, by ice and water, of a wide channel passing through the center of the region from Centerville to the head of the bay—the Mill River channel. The moving glacier had to rise over the trap ridges, Mill Rock and Pine Rock, standing on either side of the passage, and may have ploughed all the deeper into the sandstone region between them.

At the beginning of the Champlain period—dating it from the beginning of the northern subsidence of the land (actual or relative) that characterized it, which was followed by the melting—the river commenced its increase in waters and transportation. But the progressing subsidence just referred to tended to cause diminished velocity, which, there is reason to believe, the increasing depth of water hardly balanced; and hence the channel, as it widened southward (below the mouth of Pine Marsh Creek), became obstructed in places by sand-bars; and these increased as the flood made progress, and coalesced into the wide terrace formation—that of the New Haven plain. Mill River in this way was early shut off from its central way to the bay by the depositions of the plain, only fragments of which survive in the Beaver Pond and Pine Marsh depressions.

A westward set in the water and its depositions would have resulted from the earth's rotation, and either through this means or some other the river was forced to take its present eastward channel against the sandstone hills of the "Quinnipiac" Ridge. The Beaver Pond and Pine Marsh depressions, after their isolation, continued to be filled full with waters from the flood until maximum flood was reached, and they remained deep depressions, but shallowed in part by sands, because of the river-like discharge of their waters, one into West River, the other into Mill River. These depressions and the kettle-holes were one in origin and history.

Note on the Glacial flood of the Connecticut River Valley.

As the explanations given in my paper on the Connecticut valley terraces* have been imperfectly understood, I add here a few words on the subject. Professor C. H. Hitchcock, in a paper read before the American Association in 1882 (Proc. Am. Assoc., p. 325), after accepting the distinction adopted by Mr. Warren Upham between "delta-terraces" and "highest normal terraces," and objecting to taking the so-called "delta-terraces" as the normal highest, as done for many localities by me, remarks that "if we are not required to accept the deltas as a measuring rod, we shall greatly reduce the depth of the stream and thus learn why the velocity as calculated by Dana was far too great."

No calculations of the velocity corresponding to the reduced depth are given.

In my paper I state that one prominent purpose before me in my investigations was to ascertain whether the so-called delta-terraces were true Connecticut valley terraces or not; and the conclusion reached was that the most of them so directly border the Connecticut valley and for so long distances (some of them for miles) that they could not have been deposited at the delta level unless the Connecticut river waters were at that level to transport and deposit. The tributary and the main stream must have risen in level together, as in all other floods, and I found that the so-called delta-terraces were, in general, the sand and gravel of the tributary deposited and arranged in beds by the on-flowing Connecticut. The flood-level deposits *now* made on the sides of a river where it receives one of its larger tributaries are evidently as much delta deposits as those made during the progress of the glacial flood; and yet they rise but little, where at all, above the flood plain of the main stream, and have no claim to so distinctive a name.

Again, if the level of the "highest normal terraces" of Upham are taken as marking flood-level, they indicate an impossible water-surface for the river, since the heights given vary greatly in a few miles.

At Barnet, the height of the "highest normal," as reported by Mr. Upham, is 166 feet above the Connecticut at low water; 10 miles below, it is 113 to 123 feet (while the mean pitch in the modern stream in this distance is 4½ feet a mile); 12 miles farther south, at Bradford, it is only 80 feet (the mean pitch in the river for the interval being 1½ feet a mile); 9 miles farther south, at Ely, only 60 feet (the mean pitch here being 1 foot a mile); then, only 2¼ miles farther south, at North Thetford, the height is 146 feet; and farther south, 170 to 180 feet for many miles. (The "Delta-terraces" are in part still higher).

Thus, within 33 miles, the following variations in the level of flood waters are indicated, if we take Mr. Upham's "highest normal terraces" as showing the water mark: 166, 118, 80, 60 and

* This Journal, xxii, 451, 1881, xxiii, 87, 179, 360, xxiv, 98, 1882.

146 feet. Such variations in the water surface of a flooded stream in an open valley of nearly uniform pitch are obviously incompatible. The slopes are those of two face-to-face cataracts, the southern having a fall *northward* of more than 30 feet a mile. Mr. Upham has an explanation of these differences as to level, based on the assumption that the glacier-mass of the Connecticut valley made the flood and the terraces south of it *pari passu* with its retreat northward, he holding that it was a retreating ice-barrier retreating through melting, and thus keeping the flood up to flood-level south of it. This hypothesis (which has obvious objections, as I have shown) is not adopted or mentioned by Prof. Hitchcock.

Note on the two courses of the Glacier over the Connecticut River Valley.

The courses of flow in the glacier—that of the general mass and that of the valley—have been made out by me to be simultaneous on the theoretical ground that the flow in the direction of the valley—west-of-south—would have necessarily been most rapid, supposing the slope of the land the same, *when the ice of the valley to the north was thickest;* that the ice would have been thickest when the general glacier-mass was thickest, which was the time when the *southeastward* movement of the general glacier, or that determined by the slope of the *upper* surface, would have been most rapid. One condition would thus have produced the two results. This fact of two movements is not so difficult to understand when it is considered that the flowing of a glacier, however to be explained, is like that of a viscid liquid over an uneven grooved surface. It follows from the coexistence of the two movements that the upper stream did not cause, by its pressure in the direction of motion, so much friction between the lower ice and the east side of the Connecticut valley, or between itself and the bottom ice, as to prevent the valley movement. This friction would be too great to be overcome when a valley was narrow and abrupt, or had a direction approximately transverse to that of the southeastward flow; neither of which conditions existed in the case of the Connecticut valley.

One fact referred to in my paper as sustaining the theoretical conclusion was this: that variations in the bottom directions of movement (shown by the glacier scratches) often accompanied quite small changes of form in the subjacent surface, and various directions occurred within short distances. It is exceedingly improbable that all these bottom courses should have existed also in the ice of the upper surface.

Another fact bearing on the question is presented by the *absence* from the New Haven region and the adjoining part of the Connecticut valley (and from the valley north through the State of Connecticut) of all traces of south-southeastward glacier scratches, and of underlying drift deposits derived from the north-northwestward. If the valley movement were *subsequent* to the southeastward flow and the latter had gone on through the chief part of the Glacial era, the earlier drift, or that from the northwestward, should be found in spots somewhere over the bottom of the valley, beneath the valley drift; and southeastward scratches as well as drift. But none such occur. The bowlders of the upper current, or those from the northwestward, are mingled with the valley till, occurring within it, and on top of it. All evidence opposes the idea that it was brought in before the valley movement supplied the valley drift; and all facts accord with the explanation given that the bowlders of the upper glacier current sunk into the lower or valley current, and were deposited by the latter. Some of the bowlders taken from the region *west* of the valley in Massachusetts were carried 70 miles southward without going eastward more than half away across the valley, or about ten miles.

ART. XVIII.—*Supplement to Paper on the "Paramorphic Origin of the Hornblende of the Crystalline Rocks of the Northwestern States;*" by R. D. IRVING.

IN my paper on the above subject in the July number of this Journal it was my design to show how widespread is the alteration of augite to hornblende in the rocks of the region referred to; so widespread, indeed, that, as stated therein, "after an examination of about a thousand thin sections, representing the crystalline schists, acid eruptives and basic eruptives of a region some 400 miles in length by 300 in width, and of three distinct geological systems, I have found no hornblende that is not clearly, or very probably, secondary to augite." It was of course not my design to claim the first discovery in the rocks of this region of this elsewhere well known form of alteration. Such a claim would have been manifestly absurd. As far as concerns all the different classes of rocks mentioned above except the basic eruptives, my descriptions and those of my assistant Professor C. R. Vanhise were indeed the first notice for this region of such a change, so far as I am aware; but in the basic eruptives of the region it had previously been repeatedly noticed by several lithologists, including myself. Since the matter of this form of alteration is not unlikely to assume some considerable importance, and since several geologists have been of late working independently on the rocks of this region, it may tend to prevent possible future misconceptions if I give a brief historical account of the microscopic work hitherto done, and the bearing of the results on this question. This historical account was omitted from my paper, above referred to, through fear of making it too lengthy, it being supposed that lithologists would be sufficiently cognizant of the facts.

The earliest microscopic work upon the crystalline rocks of the northwest that I have learned of was that of Mr. C. E. Wright, of Marquette, Mich.; indeed his work was among the earliest done anywhere in the country. He published in 1873, in the second volume of the Report of the Geological Survey of Michigan,[1] descriptions of 78 sections of rocks of the Marquette Iron-Bearing Series, including a number of massive and schistose greenstones, to most of which the names of "diorite" and "diorite-schist" are given, though one is doubtfully referred to diabase.[2] But these descriptions are very meagre, being barely more than macroscopic; and, having been made at a very early day, when the microscopic characters of the rock-forming minerals were much less well known than now, they have little present value.

In 1877, A. Streng published a description of a number of crystalline rocks from Minnesota, among them several augitic greenstones from the Keweenawan and older formations. The gabbro from Duluth, Minnesota, he describes as "hornblende-gabbro," it containing hornblende in addition to the augitic ingredient, though he does not regard the hornblende as secondary in nature, which I think it undoubtedly is.[3]

In the same year Mr. C. E. Wright published descriptions of 37 rocks from Central Wisconsin.[4] A number of hornblendic schists are here included, but no mention is made of any augite, although several of these same rocks were subsequently found to carry it as cores to the hornblende individuals.

Next in point of time should be placed the admirable paper of Dr. Wichmann, which, though not published until early in 1880, left the author's hands as early as 1876.[5] It is a systematic treatise on the lithology of the Huronian of the Marquette and Menominee regions of Michigan and Wisconsin, and is based upon the examination of some 500 thin sections, and several times that number of hand specimens, collected by Major T. B. Brooks, all of whose collection Dr. Wichmann saw, though he never examined these rocks in the field. It is the only systematic treatise yet published upon the lithology of this formation, and is one which will long be a standard, even though the science has advanced beyond it in some respects. Besides bringing out many other interesting points, Wichmann shows for the first time that the greenstones of the formation are nearly altogether *diabase* (using the Rosenbusch nomenclature), contrary to the previously received views, and in some of these he shows that there occurs a uralitic altera-

[1] pp. 213–231. [2] p. 221.

[3] Leonhard's Jahrbuch, 1877, p. 113; also R. Pumpelly, Geology of Wisconsin, vol. iii, p. 35.

[4] Geology of Wisconsin, vol. ii, pp. 637–642.

[5] Geology of Wisconsin, vol. iii, pp. 600–656.

tion to the augite.[6] He also shows that there are transition forms between the relatively rare diorites and the diabases,[7] though he does not express the opinion that the former are altered from the latter. He also shows that the microscopic characters of these greenstones indicate plainly their eruptive origin,[8] thus confirming the early views held by Foster and Whitney and numerous others, as against the later views of Kimball, Brooks, et al.

In 1878 appeared Professor Pumpelly's "Metasomatic Development of the Copper-Bearing Rocks of Lake Superior,"[9] a masterly account of the augitic greenstones of the Keweenawan series, and of the metasomatic changes they have undergone. In this account the nature of the Keweenawan traps and amygdaloids was first shown, but no hornblende-bearing varieties are mentioned.

Besides Wichmann, already mentioned, several other lithologists give descriptions in the third volume of the Geology of Wisconsin, their work having mostly been done between 1876 and 1878. Pumpelly, whose manuscript left him in 1878, describes a number of sections from the copper series of Northern Wisconsin,[10] among them several uralitic gabbros,[11] in which the hornblende constituent has resulted from the change of diallage to augite. Pumpelly's sections and manuscript descriptions were in my hands in 1878, and through them I first became acquainted with this form of alteration. In Part III of this volume[12] I myself give briefly, the descriptions having been written in 1878–79, the results of a study of some 200 thin sections from the Laurentian, Huronian and Keweenawan of Northern Wisconsin, among them a considerable number of sections of hornblendic or uralitic gabbros[13] in addition to those described by Pumpelly. One of the latter besides several others are figured on the colored plates.[14] I also describe a peculiar greenstone carrying "basaltic" hornblende and argue that the hornblende in it also is secondary to augite and show that in all the Keweenawan greenstones carrying hornblende, and then examined, that mineral is secondary to augite. In Part III, Appendix B, A. A. Julien gives descriptions of eleven rocks, among them some hornblendic greenstones from the Huronian of the Penokee region, but evidence of the secondary origin of the hornblende was not found in his sections, though it is evident now that these too are uralitic.

In Parts IV and VIII of the same volume Mr. C. E. Wright describes a large number of sections from the Huronian of the Penokee and Menominee regions, but although he

[6] pp. 607, 627, 628. [7] p. 624. [8] p. 627.
[9] Proc. Am. Acad. Sci., vol. xiii, pp. 253, 309. [10] pp. 30–49. [11] pp. 35, 36.
[12] pp. 53–238. [13] pp. 170, 171, 179, 180, 181, 182, 183.
[14] Plate XVE, fig. 1, and Plate XVC, figs. 4, 5, 6.

occasionally notices[15] the occurrence of augite in the greenstones, he still regards them as mainly diorites, even speaking of one case from the Menominee region as the only instance of diabase in the Huronian then known to him.[16] Of the others who give descriptions of the Marquette and Menominee rocks in this volume Alport, Hawes, Julien, Rutley and Törnebohm, the last named only, so far as I have found, describes any of the secondary hornblende; but the exception is an important one, since he says of the hornblendic rock of Light House Point that it is "no true diorite, since it contains remains of augite.[17] The others, however, confirm Wichmann in saying that *diabase* is widely represented in the Marquette and Menominee Huronian,[18] and Hawes says that to judge from the sections some of the diabases are eruptive.[19] Brooks also says of the greenstones of these regions that the hornblendic and augitic varieties "appear to graduate into each other, but whether through alteration or original differences in composition, cannot always be ascertained." [20]

Three months after the publication of the third volume of the Geology of Wisconsin appeared Mr. M. E. Wadsworth's "Notes on the Iron and Copper Districts of Lake Superior."[21] In these he gives the general results of the examination of a large number of thin sections. So far as the Copper Series is concerned his only new lithological work is in connection with the pebbles of the Keweenawan conglomerates,—which had before been described macroscopically only, though correctly, by Pumpelly and Marvine—in which he shows the frequent presence of the peculiar "quartz de corrosion" described by Fouqué and Lévy, he regarding them as old trachytes and rhyolites. Of these pebbles certain granitoid kinds, called by Wadsworth "granitoid trachytes," carry hornblende, which is beyond doubt I think a secondary hornblende, though Wadsworth does not hold this view. In the notes on the iron district he gives field descriptions from which he argues that many of the rocks—including greenstones—described by Brooks and others as sedimentary, are eruptive, and among numerous other kinds, he describes briefly a number of greenstones from the vicinity of Marquette, Ishpeming, Republic, Humboldt, Champion and Negaunee, and shows that they are in the main *augitic*, thus confirming the conclusions reached by Wichmann in 1876. But he goes further and shows that many of the hornblendic Huronian greenstones, as previously shown by Pumpelly and myself for the hornblendic Keweenawan greenstones of Northern Wisconsin, are but altered or uralitic augitic rocks, and expresses the opinion,

[15] p. 251. [16] p. 691. [17] p. 567. [18] pp. 533–599. [19] e. g., p. 570.
[20] p. 519. [21] Bulletin of the Mus. Comp. Zool., vii.

which so far as I know he was the first to do, that all of the hornblendic kinds of this Huronian region were originally augitic. Speaking of the basic intrusive rocks of the region collectively, he says: "They would pass, according to the ordinary definitions, macroscopically and microscopically, for diorite, quartz diorite, diabase, chlorite-schist, hornblende-schist, etc., yet we regard them all simply as more or less altered forms, according to age and conditions, of rocks that were originally the same in origin, structure, composition and name,—basalt."[22] In his view that these ancient greenstones were once "basalt," Mr. Wadsworth is not wholly peculiar, since the same generalization has been extended by others as well as by him over all ancient hornblendic eruptive rocks,[23] while the "diorites" of many other regions have been shown to be merely altered augitic rocks.[24]

In 1880–81, I was engaged in a microscopic study of the rocks of the entire extent of the Keweenaw series, the results of which study are given in a memoir forming vol. v of the monographic series of the publications of the U. S. Geological Survey, and in an abstract of this memoir in the Third Annual Report of the Survey, which publications though in type over a year since, are only just about being issued. A brief preliminary announcement of my results was given in the Second Annual Report of the Survey. In these publications I conclude that all of the hornblende of the eruptives of the Keweenawan, acid as well as basic, is secondary to augite.

In 1880–81 I studied a suite of specimens from the Flambeau valley, Wisconsin,[25] and in connection with my assistant Professor C. R. Vanhise the crystalline rocks of the Wisconsin River valley[26] belonging to the Archean. In this study not only did we find that all of the hornblende of the greenstones examined (including gabbro, diabase, diorite, etc.) was secondary to augite, but also all of that of the hornblende gneisses, hornblende schists, syenites, and hornblende granites. Since the paper above alluded to was printed we have examined many more sections from the Archæan rocks, from Lake Huron to the Mississippi, and have thus far found nothing to change our views.

[22] p. 46.

[23] e. g. Judd, "Volcanoes," 1881, pp. 261–268; see also Wadsworth, Bull. Mus. Comp. Zool., 1879, v, 275–287; Science, 1883, i, 127–130.

[24] e. g. Belgium, see Geikie's Text-Book of Geology, 1882, p. 143. See also Wadsworth, Proc. Bost. Soc. Nat. Hist., 1877, xix. 217–237.

[25] pp. 618–622.

[26] Geol. of the Wis., vol. iv, pp. 625–714.

ART. XIX.—*On Herderite (?), a glucinum calcium phosphate and fluoride, from Oxford County, Maine;* by WILLIAM EARL HIDDEN and JAMES B. MACKINTOSH.

IN the January number of this Journal, page 73, attention was called to the mineral here described. Our specimens were obtained in October, 1883, from Mr. Nathan H. Perry, of South Paris, Me. They were then thought to be topaz, so much did they resemble that mineral in form and color, and also from the fact of their being from the same ledge, though not from the same pockets, that yielded the fine crystals of topaz noticed in this Journal, III, xxv, p. 161.

Mr. Perry has since informed us that these specimens were found in October, 1882, on a bleak ledge near Stoneham, in Oxford county, Maine, at a point about 14 miles, a little west of south, from West Bethel station on the Grand Trunk R. R.

Some weeks after they were received, we noticed that the basal cleavage, characteristic of topaz, was absent, and that the hardness of the mineral was 5, instead of 8, as in topaz.

The crystals are implanted in small clusters, and separately, on quartz crystals, and are often partly embedded in them: they also occur on muscovite: some little albite (var. cleavelandite) is often associated with them. The average size of the crystals is about 3^{mm} diameter, though one of 1^{cm} and another of nearly 2^{cm}, length and thickness was noticed. This last crystal was the only one which gave a hint of cleavage possibly existing in the mineral; a distinct pearly luster was observed while looking into it on the basal pinacoid.

All the crystals, and we have not yet found the mineral massive, are bright, well formed and rich in planes, which, however, are not usually suited for exact measurement from the presence of minute prominences over their surfaces. No regular striations seem to be present on any of the planes. The faces of one of the octahedrons are invariably dull and waxy-looking and in this respect differ from the other planes observed.

Apparently the crystals are orthorhombic, with $I \wedge I$ 116°. A macrodome measured over edge, $I \wedge I$ gave 91° 30′, which would require 134° 15′ for the angle of this plane on O, and a brachydome measured over O gave 113°. The observed planes are O, I, i-$\breve{2}$ (?), three brachydomes, two macrodomes, three octahedrons and two other octahedral planes beveling the edges between the regular octahedrons and the brachydomes.*

The best crystals which we have received have been placed in the hands of Mr. E. S. Dana for crystallographic determination, and his results will be published in the next number of this Journal. He has given us the following data for publication here: The fundamental angles obtained are 1-$\breve{i} \wedge 1$-$\breve{i}$, over O, The mineral is colorless to faintly yellowish, and is transparent to sub-transparent. Streak white. Crystals very brittle, with fracture small conchoidal. As the form, hardness, streak, color, associations and mode of occurrence were nearly if not quite the same as those recorded for the rare species herderite, it was concluded that these crystals must belong to that species and accordingly tests were made to positively identify it. A specific gravity determination on a small quantity gave the result of 3, and on testing for phosphoric acid it was found to be present in large quantity.

These results, together with previously obtained crystallographic data, seemed to point conclusively to the fact that it was herderite, or a new mineral species. As no quantitative analysis of herderite has ever been published and as the qualitative analysis accorded to it was uncertain, we commenced a quantitative analysis of it in order to determine its formula. The methods pursued in its analysis were as follows: For the determination of phosphoric acid, 300^{mg} were fused with sodium carbonate. The fused mass when treated with water and nitric acid left an insoluble residue which was decomposed by heating with sulphuric acid; the solution of the residue contained only a trace of phosphoric acid. The two solutions were mixed and used for the determination. 500^{mg} were treated with silica and sulphuric acid to eliminate fluorine and, after driving off the excess of acid, dissolved in dilute hydrochloric acid The residue was fused with sodium carbonate, the silica separated

$(011 \wedge 0\bar{1}1) = 45° 54'$, and $1\text{-}\breve{i} \wedge 3$ $(011 \wedge 331) = 57° 7'$. From these the axial ratio has been calculated $\breve{a} : \bar{b} : c = 1 : 0{\cdot}6823 : 1{\cdot}6114$. The axial ratio obtained by Haidinger for herderite is $1 : 0{\cdot}6783 : 1{\cdot}5971$. Some of the more important angles (supplement angles) of the Maine phosphate, compared with the corresponding angles of the original herderite, are as follows:

		Maine phosphate.	Herderite.
$I \wedge I\,(110 \wedge 1\bar{1}0)$	=	63° 39′	64° 7′
$1\text{-}\bar{i} \wedge 1\text{-}\bar{i}\,(101 \wedge \bar{1}01)$	=	68° 37′	68° 18′
$1\text{-}\breve{i} \wedge 1\text{-}\breve{i}\,(011 \wedge 0\bar{1}1)$	=	45° 54′	46° 2′
$6\text{-}\breve{i} \wedge 6\text{-}\breve{i}\,(061 \wedge 0\bar{6}1)$	=	137° 2′	137° 8′
$O \wedge 1\,(001 \wedge 111)$	=	38° 46′	38° 41′
$O \wedge 3\,(001 \wedge 331)$	=	67° 27′	67° 25′

These angles show that the form of the Maine phosphate approaches closely to that of the original herderite.

* "Herderite, as originally described, is orthorhombic, $I \wedge I = 115° 53'$, $O \wedge 1\text{-}\bar{i} = 145° 57'$, observed planes O, I, 1, 3, 4, $\frac{3}{2}$-ĭ and 6-ĭ. Cleavage: I interrupted. H. = 5. G. = 2·985. Luster vitreous, inclining to sub-resinous. Color various shades of yellowish and greenish white. Translucent. Fracture small conchoidal. Very brittle. Composition, probably, after trials by Turner and Plattner: an anhydrous phosphate of *alumina* and lime with fluorine. B.B. fuses to a white enamel with difficulty; becomes blue with cobalt solution. Dissolves when finely powdered in muriatic acid. Found very rarely at the tin mines of Ehrenfriedersdorf, Saxony ('also a good topaz locality'). Resembles the asparagus variety of apatite. (Dana's Syst. Min., 5th ed., p. 546).

and the solution added to the main one. The solution was diluted to 500^{cc} and used to determine the other constituents. 200^{cc} were taken and the lime precipitated as oxalate in an acetic acid solution. 100^{cc} were taken and precipitated with ammonia. The precipitate contained all the phosphoric acid combined with part of the lime and all the other bases present. In the filtrate the excess of lime was determined as oxalate.

The fluorine was calculated from the excess of lime. The glucina was determined by subtracting the lime and phosphoric acid known to be present from the ammonia precipitate and proved to be glucina both by its equivalent weight and by its reactions when afterwards separated.

The results obtained are:—

Found.		Calculated.	
CaO	33·21	CaO	34·33
GlO (or Gl_2O_3)	15·76	GlO	15·39
P_2O_5	44·31	P_2O_5	43·53
F	11·32	F	11·64
	104·60		104·89
less O	4·76	less O	4·89
	99·84		100·00

Corresponding to the formula

$$3CaO,\ P_2O_5 + 3GlO,\ P_2O_5 + CaF_2 + GlF_2$$

or as it might be written,

$$3(\tfrac{1}{2}CaO\ \tfrac{1}{2}GlO),\ P_2O_5 + (\tfrac{1}{2}Ca\tfrac{1}{2}Gl)F_2.$$

The differences between the obtained and the calculated values are to be expected when the quantities used are considered. The methods employed also would tend to make the lime low and the glucina high. There is no doubt, however, that the above formula represents the true composition of the mineral. When heated on charcoal before the blowpipe, this mineral phosphoresces brightly and becomes white and opaque. When moistened with cobalt solution and reheated it becomes dark externally, but when fractured the interior surfaces show in part an amethystine color.

The results of the analysis are of great interest, since it is the first time that glucina has been recognized in any mineral in any other form of combination except as a silicate or aluminate.

In case the original determination of herderite, by Turner and Plattner, was correct, namely, an *alumina* lime phosphate fluoride, then this mineral from Maine is not herderite but a new species. However, the probability is, from the imperfect nature of the work previously done, that this mineral from Maine is identical with the herderite of Haidinger (Phil. Mag., iv, 1, 1828, Dana's Syst. Min., p. 546). Should it prove to be otherwise, we suggest the name of *Glucinite* as appropriate.

Feeling under obligation to Mr. Perry for furnishing us with a supply of specimens for the purposes of this article, we take pleasure in here thanking him for his kindness.

New York, January 3, 1884.

ART. XX.—*Note on the Decay of Rocks in Brazil*; by ORVILLE A. DERBY.

IN examining a collection of specimens from two borings made in the coal basin of Arroio dos Ratos, Province of Rio Grande do Sul, Brazil, the following observations bearing on the decay of rocks were made.

These borings were made in a search for coal in a basin of a few square leagues of surface, of horizontal sedimentary strata resting on crystalline rocks. Near the center of the basin a coal mine is being worked at a depth of 62 meters from the surface, from which I have seen a large specimen of Lepidodendron in a moderately hard blue shale. This establishes the Carboniferous age of the coal; and although no complete geological study of the basin has ever been made, the proprietors of the mine have evidently assumed that the whole sedimentary series of the basin is of the same age. As no other formation has been recognized, and as the borings traversed several thin layers of a highly bituminous character containing unrecognizable plant remains and approaching an impure coal, this assumption is probably correct.

The deeper boring, which had been carried to a depth of 141 meters from the surface, was sunk, for the most part, through a large series of beds varying from a few inches to several feet in thickness, of reddish, drab, greenish, black and umber-colored clays that present every appearance of being decomposed shales. This series commences at 4 meters from the surface, being overlaid by clayey soil, and extends to a depth of 120 meters. Below that level the shale is sufficiently hard to be called stone, but in all other respects except hardness the upper and lower parts of the boring are so similar that I cannot but consider them as belonging to the same geological series which, in some way, has suffered decay to the extraordinary depth of 120 meters.

The other boring, 98 meters deep, traverses 20 meters of superficial sands and clays, terminating below with a gravel bed.

Then come 60 meters of clays (decomposed shales) very similar to those above described, and evidently belonging to the same series, although it is impossible to exactly coördinate the beds of the two borings. This, however, is not surprising, as such thin and rapidly alternating beds are not likely to preserve the same order and relative thickness over any considerable area. At the depth of 80 meters a gneissoid rock is met with which is quite as much decayed as the overlying shales. This rock appears to have been a highly micaceous gneiss containing a few scattered crystals of feldspar which are completely kaolinized. The mica is in part completely altered to a bluish unctuous clay, part is only partially decomposed, presenting ill-defined flakes with a silvery luster, while occasional scales of black and unaltered mica can still be distinguished in the rock. The mass effervesces slightly with acids and has apparently received a portion of lime from the overlying shales which contain calcareous layers.

So far as can be judged from the small fragments taken from the boring, this mass is a true gneiss decomposed *in situ* and not a bed of arkose intercalated in the shale. The shale bed immediately above it, about a meter thick, is homogeneous and of a dark umber color, without any appearance of having derived its material from the underlying rock. It appears, on the contrary, to have been deposited on a hard surface of undecomposed gneiss which has afterwards decayed along with the overlying shales. The boring penetrated the gneiss to the depth of 18 meters, but no hard rock was met with.

Without a more complete knowledge of the geology and topography of the region it is impossible to assign a reason for the decay having extended so much deeper at the place of the borings than at the coal mine only a few miles away, in what is presumably the same geological series. The occurrence of hard undecomposed shale in the bottom of the first boring appears to connect the rocks of the two borings and of the coal mine, and to render unnecessary the hypothesis of the pre-Carboniferous decay of the gneiss.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the perfect Elasticity of chemically-definite Solid bodies.*—Spring has sought to determine experimentally whether the specific volume of a chemically-definite solid is permanently diminished by pressure. With certain metals, the density differs according as the specimen has been produced by casting or rolling; but the question arises, is this increase of density by rolling or hammering due to an actual condensation of the metal itself, or to the disappearance of gas bubbles formed in the process of casting? It is noticeable that metals like platinum, gold, silver and copper which absorb gases readily when melted and give them up only partially on cooling, are those which exhibit the greatest increase in density on subjecting them to pressure. For his experiments, Spring selected several metals and several chemically pure salts and subjected them to pressures of about twenty thousand atmospheres, the specific gravity being carefully determined both before and after pressing. The duration of the experiment lasted three weeks; and then after determining the specific gravity, the substance was again subjected to pressure, this time for only a few days. A third measurement of specific gravity was then made. Thus lead, whose density before pressing was 11·350 at 14°, had a specific gravity of 11·501 at 14° after the first pressing, and of 11·492 at 16°, after the second. Antimony was 6·675 at 15·5° before, and 6·733 at 15° and 6·740 at 16° after pressing. Zinc, 7·142 at 16°, was 7·153 at 16° and 7·150 at 16° after it was pressed. Potassium sulphate, 2·653 at 21°, was 2·651 at 22° and 2·656 at 22°, after the pressure. Potassium alum, 1·758 at 21°, became 1·756 at 16·5° and 1·750 at 16·5°. Potassium chloride, 1·980 at 22°, became 2·071 at 22° and 2·068 at 21°, after pressure. It will be noticed that after the first pressing, the density of some of these bodies was slightly increased; but that then it reached its maximum, and did not change on pressing a second time. With the exception of the haloid salts, which were fused to remove moisture and hence were vitreous, the condensation observed cannot be due to a compression of the substance itself, but is due rather to a filling in of cavities or cracks. The condensation is collateral, not fundamental. Moreover this permanence of density is not due to the incompressibility of the materials, since their volume continually diminished as the pressure increased. On removing the pressure however, the original volume was completely resumed, the elasticity of these solids being as perfect as that of liquids and gases. Some time ago the author had shown that bodies capable of existing in two allotropic states, one of which was denser than the other, showed a change of density under pressure, the lighter form being always converted into the heavier. Thus prismatic sulphur on pressure becomes the heavier octahedral form, yellow

amorphous mercuric iodide changes to the heavier red crystalline variety, amorphous arsenic becomes the heavier crystalline arsenic. Hence Spring enunciates the following law: Pressure can produce no permanent condensation in solid bodies, unless these bodies can be converted into an allotropic state specifically heavier. The applications of this law to allotropism and to the elasticity of solids are discussed in the paper.—*Ber. Berl. Chem. Ges.*, xvi, 2723, Nov., 1883. G. F. B.

2. *On nitrogen selenide.*—BERTHELOT and VIEILLE have examined thermochemically a specimen of nitrogen selenide placed in their hands by Verneuil. They determined the heat evolved by the explosion of this dangerous substance, much in the same way as with nitrogen sulphide. Two experiments, in each of which 3 grams of material were used, gave the following equation: NSe (93 grams)$=N+Se$: 42·9 and 42·4 calories, or, as a mean 42·6; or 42·3 calories at constant pressure. Nitrogen selenide therefore is formed with absorption of heat (−42·3 calories), like its congeners nitrogen sulphide (−31·9 calories) and nitrogen dioxide (−21·6 calories); the heat absorbed increasing with the chemical equivalent, following the ordinary law.—*Bull. Soc. Chim.*, II, xl, 420, Nov., 1883. G. F. B.

3. *On Hyponitrous acid and silver Hyponitrite*—BERTHELOT and OGIER have examined the hyponitrous acid of Divers and also its silver salt. The latter was prepared by the process of the discoverer, dissolved in very dilute nitric acid and reprecipitated with ammonia. Finding the salt to undergo decomposition at 100° C. the authors dried it in vacuo at the ordinary temperature and in the dark. Thus prepared it contained a trace of water but no reduced silver. On analysis it gave a slightly different formula from that ordinarily accepted, viz: $Ag_4N_4O_5$. The acid would then be $H_4N_4O_5$. The authors believe that this formula accords better with the results obtained by a quantitative study of its reactions and with the existence of the acid salts discovered by Zorn. The action of heat upon silver hyponitrite was tested in four ways: 1st, the salt was placed in an exhausted tube and heated to dull redness, the nitrous vapors evolved being re-absorbed by the silver; 2d, the salt was heated in a current of dry CO_2 which carried off the nitrous vapors and condensed them in a solution of hydrosodium carbonate which was then titred. The reactions are $Ag_4N_4O_5=N_2O_2+N_2O_3+Ag_4$; and then the re-absorption $(N_2O_3)_2+Ag_2=(AgNO_2)_2+N_2O_2$; 3d, the silver hyponitrite was heated over a naked fire and yielded a mixture of metallic silver and nitrite, the latter requiring a prolonged calcination to destroy it; 4th, the salt was decomposed with a dilute acid and then heated to boiling. Nitrogen monoxide is evolved as Divers states; but the reaction is not as simple as he supposed, all the nitrogen not being evolved in this gas, but a part going to form nitric acid thus:

$$(H_4N_4O_5)_4=(N_2O)_7+(HNO_3)_2+(H_2O)_7.$$

Oxidation with iodine, bromine and potassium permanganate were resorted to. Iodine seems to have no action upon hyponitrous acid either free or combined; but bromine produces a characteristic reaction:

$$Ag_4N_4O_5+(H_2O)_7+Br_{14}=(HNO_3)_4+(HBr)_{10}+(AgBr)_4.$$

The action of permanganate is irregular unless a large excess of sulphuric acid be employed; the oxygen absorbed is about eight per cent corresponding to three equivalents. Nitrogen monoxide is produced as follows:

$$Ag_4N_4O_4+O_3+H_2O=N_2O+(HNO_3)_2+(Ag_2O)_2.$$

The silver oxide unites with the sulphuric acid. The heat of formation of silver hyponitrite was determined by oxidizing it with bromine water. Five calorimetrical experiments made between 12° and 14° gave 29·65 calories. From this the value −9·3 calories is deduced as the heat absorbed by $N_2+O_{1\frac{1}{2}}+Ag_2$, and −16·3 calories for $N_2+O_{1\frac{1}{2}}+Ag_2O$. For the acid itself the heat evolved in the reaction of dilute hydrochloric acid upon silver hyponitrite was measured, and from it the heat of formation was calculated as 38·6 calories. It is formed from its elements then with absorption of heat; whence its instability.—*Bull. Soc. Chim.* II, xl, 401, November, 1883. G. F. B.

4. *On certain new Compounds of Silver.*—In 1879, Gutzeit proposed a reaction for arsenic depending on the fact that if a piece of filter paper, moistened with a drop of concentrated silver nitrate solution, be exposed to hydrogen arsenide a lemon-yellow color is developed. POLECK and THÜMMEL have investigated this reaction. The silver solution should be concentrated—equal weights of silver nitrate and water—and then the reaction is given by hydrogen sulphide, phosphide and antimonide as well as arsenide. With hydrogen sulphide a yellow to yellowish-green spot appears, surrounded by a black edge, the whole becoming black after a time. Moistened with water, the same change takes place. The spot shows a distinctly acid reaction. To isolate the yellow compound, H_2S was passed into a concentrated solution of silver nitrate until the escaping gas blued a solution of iodide of zinc and starch. A yellowish-green precipitate was produced, which, washed with dilute nitric acid and dried in the air, became darker in color, and on analysis gave the formula $(Ag_2S.AgNO_3)$. Its formation is given in the equation:

$$(AgNO_3)_3+H_2S=(Ag_2S.AgNO_3)+(HNO_3)_2.$$

On gently heating it decomposes thus:

$$(Ag_2S.AgNO_3)_4=(NO_2)_4+Ag_4+(Ag_2S)_3+Ag_2SO_4.$$

This compound is obtained also by treating silver sulphide with fuming nitric acid. But if the nitric acid have a specific gravity of 1·18, a violet-brown kermes-colored powder is also obtained. This latter body is also produced by heating in a water bath a solution of 40 parts silver nitrate and 35 parts of water and adding

5 parts of sulphur gradually with constant stirring. This powder has the composition ($Ag_2S.Ag_2SO_4$). The compound which arsenic forms, was obtained as a yellow crystalline mass which decomposed on drying, Analysis of the solution led to the formula $Ag_3As.(AgNO_3)_3$. Hydrogen phosphide gives a precisely similar body $Ag_3P.(AgNO_3)_3$, and so does the antimonide, $Ag_3Sb.(AgNO_3)_3$. With reference to the toxical application of this reaction the authors say that the lemon-yellow spot produced by arsenic, with its brown-black edge, becoming immediately black when moistened with water, is easily distinguished from the more greenish-yellow spot given by sulphur, which water does not affect, and the antimony spot which shows on its brownish edge a gray-white mirror. The spot produced by phosphorus is not easily distinguished from that of arsenic. But since phosphoric acid is not reduced to hydrogen phosphide by nascent hydrogen, it will seldom interfere. With regard to the delicacy of the reaction, six thousandths of a milligram of arsenous oxide introduced into the evolution flask gave a distinctly recognizable yellow spot after 15 or 20 minutes and 0·015 milligram gave the reaction in 5 minutes, the spot becoming black on moistening it with water. Its delicacy is therefore quite equal to that of Marsh's method.—*Ber. Berl. Chem. Ges.*, xvi, 2435, Oct., 1883. G. F. B.

5. *Velocity of Sound in Air.* — Mr. J. D. BLAIKLEY has determined the velocity of sound in small tubes with the idea that, by taking tubes whose diameters are in definite ratios, the calculation might be extended to embrace the case of the velocity of sound in a tube of infinite diameter—or in other words—in the free air. Before the author's results are given certain criticisms of the results of previous observers are made. Determinations of the velocity of sound in the open air are effected by the uncertain element of the humidity of the air and by the want of homogeneity of the layers of air. Kundt's method, which consists in exciting vibrations inside a tube and observing the nodes and segments by means of lycopodium powder is suited for comparative rather than for absolute results. LeRoux's method, which consists in the employment of a tube closed by two membranes, one of which is tapped, and the interval between the blow and the response of the other membrane is measured gives uncertain results on account of the want of equality in the tension of the two membranes. Regnault's results in long pipes seem to require a greater rate of diminution in the velocity of sound, if extended to tubes such as are used in musical instruments, than actual experiments on these tubes show. Mr. Blaikley obtains for tubes of $11{\cdot}7^{mm}$, $19{\cdot}5^{mm}$, $32{\cdot}5^{mm}$ and $54{\cdot}1^{mm}$ in diameter, the following results for the velocity of sound: 324·56, 326·90, 328·78, 329.72. He also finds that waves near their origin are not of normal length, and he conjectures that some of the results obtained by LeRoux in gun-fire experiments would give closer results if they were corrected for this divergence.—*Phil. Mag.*, Dec. 1883, pp. 447–455. J. T.

6. *The Condensation of Aqueous Vapor as a source of Atmospheric Electricity.*—The evaporation of water and the condensation of vapor have each in turn been regarded by many as the source of the electricity of thunder storms. Late experiments of Freeman (Phil. Mag., v, xiii, p. 400, 1882) and of Blake (Wied. Ann., xviii, p. 525, 1883) seem to show that no electricity results from the evaporation of pure water. Mr. S. Kalischer has taken up the question whether condensation of aqueous vapor is a source of electricity. He used a Kirchhoff quadrant electrometer. The instrument and the leading wires were suitably protected from local disturbances. The outsides of twelve large beaker glasses were covered with tin foil and were filled with ice. They were then placed upon an iron plate which in turn rested upon a thick glass plate, and pieces of paraffine were placed beneath the corners of this glass plate. The beakers with their support were placed in a metal box which was connected with the ground. The cover of the box was a fine meshed metallic net which allowed the air entrance without friction. The moisture in the air condensed upon the beakers. One set of quadrants of the electrometer was connected with the beakers and the other set with the ground. It was noticed that the deflections of the instrument were of the same sign and the same amount, whether the beakers were filled with ice or not. The deflections were sometimes greater when the beakers were empty than when they were filled with ice. In order to test whether both kinds of electricity appeared at once, the condensation water was suitably examined but no trace of electrification was observed. Finally the beakers were filled with a freezing mixture so that a layer of ice was formed on their outer coverings. No electrical condition was observed, and the author concludes that by means of our present apparatus we are not able to show that condensation of vapor or the formation of hail is a source of atmospheric electricity.—*Wied. Ann.*, No. 12*a*, 1883, pp. 614–620. J. T.

7. *Red Sunsets.*—The foreign journals contain accounts of the peculiar sunsets which have also been noticed in America. In the Comptes Rendus of Dec. 3d, the marked sunsets of Nov. 26th and 27th are described and are supposed to be connected in some way with the November meteoric shower. No reference is made to the extent of the phenomenon. In the Comptes Rendus of Dec. 10th news had been received of the generality of the phenomenon. It is apparent to the observers that the peculiar sunsets are not auroral in character. M.M. Bertrand, Dumas and D'Abbadie give descriptions of the sunsets seen by them, and the latter refers to the extent of the phenomenon over the earth; and is inclined to attribute it to the eruption of Java. The snow in parts of Norway has contained a gray powder which analysis may prove to be of the same constitution as the dust from volcanic eruptions. The rosy light of the sunset is easily distinguished from the light of an aurora. It does not scintillate and has the appearance of light modified by layers of matter greatly

extended in high regions of the atmosphere. There are no contemporaneous magnetic disturbances and one does not observe a marked rain band. Apparently there is a band of absorption extending from D to the less refrangible portion of the solar spectrum.—*Comptes Rendus*, Dec. 10, 1883, p. 1384. J. T.

8. *Physical Studies of Lake Tahoe.*—Prof. JOHN LECONTE has recently published in the Overland Monthly a series of articles giving a discussion of the results of some physical observations made by him at Lake Tahoe in 1873. Lake Tahoe, also called Lake Bigler, is situated at an altitude of 6247 feet in the Sierra Nevada Mountains, partly in California, partly in Nevada. The lake has a length of 22 and a width of 12 miles. As regards its origin, the author regards it as a "plication-hollow," or a trough produced by the formation of two mountain-ridges, afterwards modified by glacial agency. The depth of the lake is remarkable, the observations taken at ten stations along the length of the lake gave the following depths in feet: 900, 1385, 1495, 1500, 1506, 1540, 1504, 1600, 1640, 1645. This depth exceeds that of the Swiss Lakes proper—Lake Geneva, for example, has a maximum depth of 1096 feet—but is considerably less than that of Lakes Maggiore and Como on the Italian side of the Alps. A series of observations of the temperature of the water were taken between the 11th and 18th of August. The average corrected results are as follows:

Depth in feet.	Temp. (C.)	Depth in feet.	Temp. (C.)
0 (surface)	19·4	330 (bottom)	7·5
50	17·2	400	7·2
100	12·8	480 (bottom)	6·9
150	10·0	500	6·7
200	8·9	600	6·1
250	8·3	772 (bottom)	5·0
300	7·8	1506 (bottom)	4·0

The temperature, therefore, diminishes with increasing depth to about 700 or 800 feet, and below this remains sensibly the same down to 1506 feet; or in other words a constant temperature of 4° C. prevails at all depths below about 820 feet. This is in accordance with the theory, the temperature named being that of the maximum density of water, and it confirms the recent observations of Professor Forel in Switzerland; he found, for example, that a constant temperature of 4° C. was reached in Lake Zürich at a depth of nearly 400 feet, the lake being then covered with 4 inches of ice. The explanation of the observed fact that Lake Tahoe does not entirely freeze over even in severe winters is found in the extreme depth; and the fact that the bodies of drowned persons do not rise to the surface after the lapse of the usual time is explained by the low temperature prevailing near the bottom which does not allow the necessary decomposition to go forward so as to produce the ordinary result.

The water of Lake Tahoe is remarkable both for its transparency and beauty of color. A series of observations made at the close of August or beginning of September showed that a horizontally adjusted dinner plate of about $9\frac{1}{2}$ inches diameter was visible at noon at a depth of 108 feet. The maximum depth of the limit of visibility as found by Professor Forel in Lake Geneva was 56 feet; he showed, moreover, that this limit is much greater in winter than in summer as explained in part by the greater absence of suspended matter and in part by the fact that increase of temperature increases the absorbing power of water for light. The maximum depth of visibility in the Atlantic Ocean, as found by Count de Pourtales, was 162 feet, and Professor LeConte states his belief that winter observations in Lake Tahoe would place the limit at even a greater depth than this. The author gives a detailed and interesting discussion in regard to the blue color of lake waters, reviewing in full the results of previous writers on the subject, and concludes that while pure water unquestionably absorbs a larger part of the red end of the spectrum and hence appears blue by transmitted light, the color seen by diffuse reflection is mainly due to the selective reflection from the fine particles suspended in it.

The last subject discussed by the author is that of the rhythmical variations of level, or "seiches," of deep lakes; he applies the usual formula to Lake Tahoe and calculates from it the length of a complete longitudinal, and of a transverse "seiche;" these are found to be 18 or 19 minutes in the first case and 13 minutes in the second.

II. Geology and Mineralogy.

1. *Geology of Wisconsin, Survey of* 1873–1879; T. C. Chamberlin, Chief Geologist; vol. I, xxiv and 726 pp. 8vo, with maps and figures; and vol. IV, xxiv and 780 pp., with 27 plates of figures of fossils, in 8vo, maps and sections in the text, and accompanied by an Atlas of maps.—These two volumes complete the series of Wisconsin Reports, volume II having been published in 1877 and volume III in 1880. The series is one of special interest and value, because of the range of the geological formations and their products, and also the able treatment of the various subjects that come under discussion.

Of the new volumes, volume I contains a popular review by Prof. Chamberlin of General Geology (300 pages), in which facts, figures of fossils, etc., and maps, from Wisconsin geology, are freely introduced; and also other brief reviews of the facts connected with the subject of minerals and rocks, by R. D. Salisbury and R. D. Irving; lists of fossils, plants, crustaceans, lepidopters and vertebrates among animals; an elaborate paper on the economic relations of Wisconsin birds, by F. H. King, and a review of the economic geology of the State by R. D. Irving, M. Strong and T. C. Chamberlin. Volume IV is occupied with a geological and topographical report on a northwestern portion of the State, by Moses Strong, and another on the Lower St. Croix district, by L. C. Wooster; a Paleontological Report, by R. P.

Whitfield, illustrated by 27 lithographic plates; report on the ore deposits (lead, etc.) of southwestern Wisconsin, by Prof. Chamberlin; on the crystalline rocks of the Wisconsin Valley, by R. D. Irving and C. R. Vanhise; and on other subjects.

In the course of the part on General Geology, Prof. Chamberlin gives his views on the origin of the iron, copper and lead ores of the State. The great iron ore beds of the Huronian are regarded as originally deposits made in waters or marshes, approximately as bog ores are now made. The same view is held by Prof. Irving. The opportunities for observation which the Archæan ore beds of the region afford give great weight to the opinion of these geologists.

The copper and silver of the Keweenaw formation are attributed to the same deep-seated source with the igneous rocks in and near which they occur, they having existed in some condition in the rocks that were melted to produce the lavas or trappean beds. Prof. Chamberlin holds also that after being brought up by the molten rock, they were chemically extracted thence by percolating waters and concentrated in the porous belts or fissures of the formation; that surface wear gave metallic ingredients to the adjacent sea, and so sediments became impregnated, which through subsequent concentration originated other copper and silver deposits.

Prof. Chamberlin refers to the view (favored by the writer) that the copper and silver may have been derived from rocks encountered by the molten material on its way to the surface, and objects to it on the ground that the underlying rocks, so far as determinable from their outcrops, "give no warrant for the supposition that they contain such ore deposits." But in the writer's understanding of the theory, the ores may have come from the rocks of any part of the walls of the fissure, even down ten, twenty or more miles, according to the depth of the region of fusion; the rocks may hence be part of the originally consolidated crust, nowhere within reach of observation; and the depths, those where the extreme temperature was over 1,000° F., and possibly little short of that of fusion, where, consequently, whatever material was movable by means of vapor or otherwise, would move, slowly or with a rush, according to the supply, into the opened fissure or vacuum, and so might accompany the molten material to the surface; and if the fusion were a local phenomenon within the crust, resulting from subterranean disturbance, the locus might be the region of fusion itself, in which case the two views in part coincide. The theory adopted by the writer brings the two classes of veins into one category; for the ores of granitic, quartzose and other veins in metamorphic rocks away from igneous ejections seem to have no other source but that indicated—the region adjoining some part of the fissure. The attending conditions embrace all the agencies needed for the gathering of the ore and other material, the alteration of the rocks, and the concentration and distribution of the ores; chief among which agents are heat and moisture, the former of almost indefinite amount, and the latter in large subterranean supply toward the surface if not abundant below. This "subterranean supply toward the surface" must have been very copious in the case of the Lake Superior eruptions.

Prof. Chamberlin discusses the subject of the erosion of Paleozoic formations in Wisconsin, with interesting conclusions. Speaking of the valley of the Mississippi, he observes that at La Crosse it now runs, according to an artesian boring in the gravel, at least 170 feet above its ancient bed. The basin of Lake Superior is made a geosynclinal trough (the bottom now 400 feet below the sea-level), formed in the period of the Keweenaw formation, though more or less modified subsequently by erosion. Lake Michigan—its bottom of mud now 300 feet below the ocean level (and its original bottom underneath the sediment probably 400 or 500 feet)—is referred to as a pre-Glacial basin, the site of a vast amount of erosion, but not wholly a result of erosion.

In volume IV, Prof. Chamberlin has (in its "Part IV," 150 pages) a very full account of the ore deposits in southwestern Wisconsin. It will be read with great interest in connection with the Missouri Report on the same general subject by Adolf Schmidt. The author, after an account of the observations of Dr. Percival in 1854–1855, and of J. D. Whitney in 1859, treats first of the ores that were original to the beds—the galenite, sphalerite, pyrite, marcasite, chalcopyrite, calcite, dolomite, barite; and next of those of secondary origin, as the lead carbonate and sulphate, zinc silicate and anhydrous and hydrous carbonates; iron carbonate, hematite and limonite; copper carbonates; with pyrolusite and gypsum. The forms and constitution of the ores are treated of, the distribution of the ore deposits, with map illustrations, the origin of the cavities which contain the deposits, and the conditions under which they were made. He points out that from Lake Superior to southern Illinois the feeble flexures or undulations of the strata have a general, but varying, east and west trend, showing a common direction of movement by lateral pressure through the Paleozoic as well as in Archæan time; and he presents as the common if not general fact that the ore-beds are most abundant in the ranges of the depressions. The cavities of erosion which contain the ore were determined in position by preëxisting crevices; these were largely due to the movement and flexure, just referred to. Many figures illustrate the form and origin of the cavities. The relations of the ores to each other and the changes in them since their deposition are also discussed. The theory of origin supposes that the deposits were made by oceanic waters, which owed their metalliferous salts to the leaching of adjacent lands; and that oceanic currents gave aid in the distribution of the ores. This solution of the question has its doubts, as the author admits. They would be much less, we think, if the oceanic waters were supposed to be those of large but partly confined shallow areas of the borders of the ocean. For the special views as to the means of solution by the waters and other points, the reader is referred to the volume.

Prof. Irving's lithological work, so far as reported in volume IV, is confined to the crystalline rocks of the upper Flambeau River and to those of the Wisconsin valley; the latter was carried on by himself and C. R. Vanhise. He gives an excellent review of the rocks and minerals of the State in volume I. His extended study of the copper-bearing rocks of Lake Superior is to be published as volume V of the monographic series of reports of the U. S. Geological Survey. A full abstract of this elaborate work has appeared in the Third Annual Report of the Director of the U. S. Geological Survey, of which it occupies 100 pages. A brief account of some of his important results is contained in his paper in the last volume of this Journal (page 27).

Prof. Wooster, in his account of the geology of the lower St. Croix district, speaks of the coarse beds of the Potsdam sandstone in the vicinity of Chippewa Falls as containing pebbles of feldspar, as well as quartz, with mica scales, proving that its material came from the Archæan granitic rocks on the northern borders of the formation. He also states that the green sand (glauconite) of the formation is confined mostly to its upper 300 feet, and where it occurs usually gives a green color to the soil above. J. D. D.

2. *The Geology of the Susquehanna River region in the six counties of Wyoming, Lackawanna, Luzerne, Columbia, Montour and Northumberland;* by I. C. White. Report of Progress G7 of the Geological Survey of Pennsylvania. 464 pp. 8vo, with sections in the text and a finely colored geological map in two parts. Harrisburg, Pa., 1883.—The area covered by this report of Professor White contains about 2000 square miles, and is situated within the northeastern quarter of the State. The facts connected with the Quaternary are first mentioned—the features of the terminal moraine, which crosses the area, the glacial scratches north of it, effects of flooded-river transportation, river gravels and terraces, and buried valleys. The terraces of the Susquehanna in the vicinity of South Easton, have the heights above low water of 35 feet (the modern flood-ground), 100, 150 and 200 feet. The last is quite narrow and has at top a deposit of nearly white siliceous clay "which seems to mark the uppermost limit of the river during the era of the flood." Near Northumberland the four terraces have the heights above the river of 25, 55, 80 and 175 feet. Coarse gravel deposits (bowlder beds) occur in some parts of the Susquehanna high terraces, and generally about the mouths of its tributaries.

One of the buried valleys is that of the "old Susquehanna" between Pittston and Kingston, north of the present channel, and passing under the town of Kingston. In different borings along it, near Kingston the bed rock was struck at depths of 212, 185, 210, 180 feet, showing the valley to be buried at 212 feet or more. At Pittston, the course of the Susquehanna changes from south-southeast to about west-southwest, the latter the course south of Pittston and of the buried valley. The west-southwestward or east-northeastward course is continued eastward by the Lackawanna River, and along this stream the buried valley extends for some distance, a boring two miles north of Pittston reaching the bed rock at a depth of 80 feet. This buried valley of the "old Susquehanna" was found by the outcrop of rocks not to extend westward beyond Berwick; the facts show that the bottom of the old valley near Kingston is 70 feet lower (referred to the sea-level) than the outcropping rocks flooring the river near Selinsgrove, 70 miles down stream. The facts naturally lead to enquiry for the continuation of the old waterway. Professor White's views on the point (referred to on page 27), are not given in the Report. He has sent a statement of them to the writer, and from that we learn that he rejects the idea of a northward discharge, which Mr. Carll suggested for the Alleghany and Beaver Rivers in pre-Glacial times) on account of the topographical difficulties; that he regards it as most probable that the old channel was excavated by the river in pre-Glacial times, when the land to the north was at a higher level than now; that the filling with sands and gravel took place during the era of subsidence following the Glacial, the era of floods and deposition; and that after this, in the elevation which followed bringing the land to its present level, the amount of elevation experienced by the different regions to the north and south was unequal.

The rocks of the region range from the Medina sandstone on the south to the top of the Devonian. Professor White identifies the Salina formation in its New York position between the Niagara and Lower Helderberg groups, but without its salt or gypsum.

Some of the most important facts in the Report relate to the wide range of fossils of well-known limited positions in the Devonian and Upper Silurian of New York. The Spiriferæ, *S. disjuncta*, *S. mesocostalis* and *S. mesostrialis*, as determined by Mr. Claypole for Professor White, instead of marking definite horizons of the Chemung group, as in New York, occur in *alternating* beds, which are regarded as intermediate between the Catskill and Chemung, and are called the Catskill-Chemung beds. Again *Chonetes setigerus*, a Hamilton species in New York rarely seen in the Chemung, is reported as found 2000 feet above the top of the Hamilton, along with the first two of the above Spiriferæ. *Halysites catenulatus* is reported as very abundant in the Lower Helderberg, in a bed underneath the Stormville limestone of the Lower Helderberg group, while, according to Hall (as stated on page xxiii of the report), "no one has ever before found it above the Niagara," and it has been seen lower than this group, and even in the Trenton. *Spirifer arenosa*, "or a form very much like it," characteristic of the Oriskany in New York, is here reported from beneath the Oriskany and in the Stormville conglomerate of the Lower Helderberg.

It has long been believed that a complete investigation of the

Paleozoic fossils of Pennsylvania would throw much light on the actual distribution of the species so well studied by Professor Hall in New York; and it is not at all improbable that commingling should exist of fossils that are confined in New York to distinct horizons, proving changes from migrations like those illustrated in modern geographical distribution. It is of the greatest importance therefore that the fossils and the beds be determined with all possible care in order that the doubts suggested by rules or conclusions regarded as "established" may be fully removed. Beyond the fact that the observations make out discrepancies between the New York and Pennsylvania distribution, nothing appears in the volume to discredit the detailed sections given by Professor White, one of the best and most careful geological observers on the survey.

3. *Das Antlitz der Erde*, von EDUARD SUESS, mit Abbildungen und Kartenskizzen. Erste Abtheilung, 310 pp. large 8vo. 1883. Prag (F. Tempsky) and Leipzig (G. Freytag).—The present volume forms the first of three parts of which it is announced that the complete work will consist. The whole subject, after the introduction, is to be discussed under four heads, entitled—(1) The movements in the outer rock-crust of the earth, (2) The mountains of the earth, (3) The changes of the form of the surface of the sea, (4) The face of the earth. Under this last division the subject matter in the preceding parts will be brought together and discussed and the existence of great transgressions of the sea in early times explained. The book will close with observations on the distribution of organic life on the surface of the planet.

The preceding statements, taken from the prospectus, will show the scope of the work, as it is to be finally completed. The volume, now published, embraces the first and part of the second division of the subject as above defined. The author opens the discussion with some general statements as to the grand features of the earth, calling attention to the wedge shape which characterizes the outline of the bodies of dry land, and questioning the correctness of the view accepted by many as to the essentially unchanged relation of land and sea since the early history of the planet. He speaks further of the *Pacific type* as characterized by a general correspondence between the course of the mountain chains and the ocean coast line, and the *Atlantic type*, characterized by a want of correspondence in these respects. The Indian Ocean and the neighboring land is regarded as belonging to the Atlantic type, the boundary between it and the Pacific region to the east extending from the Bengal depression northwest to the outer chains of the Himalaya, follows then the Indus to its mouth, along the Persian Gulf and the course of the Euphrates, and finally in complex relations westward through Morocco to the Atlantic coast of Africa.

In taking up the discussion of the first division of the subject—the movements in the outer rock-crust of the earth—the author first turns to the Flood, to which he devotes some 70 pages, regarding it as deserving this prominence as being the most important natural catastrophe of which there is any written record. Without following him in his examination of the biblical and other records, and of more recent phenomena in the same region which bear upon it, it is worth while to note his conclusion, viz: that the Flood was an event confined to the lower Euphrates, consisting in an extended and devastating overflow of the Mesopotamian depression, the essential cause of which was a great earthquake in the region of the Persian Gulf or south of this, and that during the time of the most violent shocks a cyclone probably broke in from the Persian Gulf on the south.

A second chapter takes up in detail several regions which have been liable to earthquake shocks. These are: (1) the northeastern Alps, in which the phenomena are not connected with a volcano; (2) Southern Italy, where volcanoes are present but not situated in a general line, although their connection with the shocks can be recognized; (3) Central America, where earthquakes are frequent though not known with exactness, where the peculiar arrangement of the volcanoes shows of itself the position of the great lines of disturbance; (4) West coast of South America, in which a question of especial importance comes up as to the elevation of the land in connection with earthquakes—a question which the author decides in the negative.

The third chapter discusses the general topic of dislocations in the earth's crust. The cause of these is found in the movements produced by the diminution in the volume of the earth giving rise to (1) tangential and (2) radial strains, of which the first tend to produce horizontal and the second vertical movements. The dislocations are discussed under these two heads. First, dislocations caused by tangential movement; here numerous interesting examples are given of the folding over of strata, as in the Alps; secondly, dislocations produced by sinking, for an example of which the author turns to the structure of the Plateau region of Utah as described by Dutton; finally, dislocations due to the two causes united, of both tangential movement and sinking.

In the fourth chapter the subject of volcanoes is taken up, the special object being to follow out the gradual uncovering and destruction of a volcanic mountain—or to investigate a so-called denudation-series. This series is traced from the recent volcanoes of Central America, not yet a century old, together with those like Stromboli and Kilauea which are in continuous activity; to the volcanoes which have frequent eruptions, as Vesuvius, Etna, or less frequent as Ischia, and still further to those of whose eruptions history gives no certain account, but which still retain the cinder cone, as the Puys of Auvergne; next come volcanoes which have been partially reduced to ruins, retaining only the skeleton of the cinder cone; then those cases in which the lateral intrusion or injection of acid lavas has become visible as in the Henry Mountains; and further till the rock masses of the depths are laid bare along the several lines of outbreak, or if the uncovering has gone still further till the connection with the common opening is visible; and finally to masses, "batholiths," which never reached the surface in fluid condition but which solidified in the depths, and of which evidence is sometimes had in the altered strata which formed a part of the original covering. The author thus passes from the ash deposits of the present to the granite masses of the Erzgebirge and the Drammen granite of Norway, and to the complex relations of the granites of the Alps.

The concluding chapter is devoted to the different classes of earthquakes, and their relation to earlier and more extensive movements in the earth's crust.

This memoir by Professor Suess promises, when completed, to be an important contribution to geological science. The author's extensive reading, together with his personal observations, gives him a wide and varied range of illustrations, which add much to the interest of his writings.

4. *Unconformability between the Upper and Lower Silurian formations in New Jersey, bearing on the question as to the limits of the Green Mountain disturbance.* (Letter from Prof. G. H. Cook to J. D. Dana, dated New Brunswick, N. J., Jan. 12, 1884.) —I notice in your comments on the Pennsylvania Geological Report, D3, vol. i, in the last number of the Journal of Science, the remarks on the unconformability of the Hudson River and the Oneida conglomerate rocks. In our Geology of New Jersey, 1868, p. 135, is a wood cut made to show the unconformability of the two rocks at Otisville. This was made from a sketch drawn on the spot in 1867. The various localities about Rondout have undoubtedly the best exposures for seeing the unconformability of these Upper and Lower Silurian rocks. Professor Smock and myself examined them in 1867, when we were looking for good examples to show the relation of these rocks to each other in New Jersey.

5. *General Geological Map of the area explored and mapped by Dr. F. V. Hayden, from the surveys under his charge,* 1869 *to* 1880.—This handsome geological map represents by colors the areas, severally, of the Tertiary, Post-Cretaceous or Laramie, Cretaceous, Jura-Trias, Carboniferous and Silurian formations, with those covered by metamorphic (mostly, if not wholly, Archæan) and by volcanic rocks, between the meridians of 100° W. and 110°–112° W., and the parallels of 36° and 48° N. It is made from the investigations carried on by the expeditions under Dr. Hayden, with corrections for parts "covered by reconnoissance only," "to some extent by the work of other expeditions." It is a chart of great interest, giving the first satisfactory connected view of the geological formations over this most important part of the Rocky Mountain region; and Dr. Hayden merits much for the part he has taken in the work, the results of which are here so finely displayed. The scale of the map is 1 : 2,600,000, or 41·03 miles to the inch.

6. *Emeralds from North Carolina.*—At a recent meeting

(January 7), of the New York Academy of Sciences, Mr. George F. Kunz exhibited some specimens of emerald collected by Mr. J. A. D. Stephenson, of Statesville, North Carolina. Mr. Stephenson says of them: "These emeralds occur on the property of Mr. J. O. Lackey, about one mile southwest of the Emerald and Hiddenite Mining Company's property, Stony Point, North Carolina, a short distance from the Lyons property (Smeaton's), and are found in a vein of black decomposed mica associated with quartz crystals, common rutile and hiddenite. I consider the locality a promising one, although there has been very little work done as yet." Mr. Kunz stated that the lot received by him consisted of 33 crystals, from half an inch to two inches in length, in color varying from colorless to a light emerald green, and nearly all had the curious saw markings in considerable number on each vertical edge of the prism, and some contained single crystals of rutile. Mr. Kunz called attention to the interest attaching to these crystals in the fact that they were found at some distance from the Emerald and Hiddenite Company's property, and that between these there is the Lyons property on which Mr. Smeaton found the same minerals, showing that the deposit is not an accidental one, and that there is encouragement for future work in this section of the State.

7. *Tourmaline from Auburn, Maine;* by WM. EARL HIDDEN. (Communicated).—Transparent tourmalines having the following planes, viz:— R, O, $-\frac{1}{2}$, $\frac{1}{2}^3$, I and i-2 have been found in considerable numbers at this new locality. The colors are pale shades of blue, green and pink, all these shades often present in the same crystal. The common form is a trihedral prism with rounded faces, terminated solely by the rhombohedron $-\frac{1}{2}$, and the scalenohedron $-\frac{1}{2}^3$. Not rare are crystals wholly terminated by $\frac{1}{2}^3$, which type, that of an acute peak, is new to the species. The faces are unusually smooth and bright for tourmalines. The following angles were obtained (with a hand goniometer), and are very nearly correct, viz:= $-\frac{1}{2}\wedge-\frac{1}{2}=133°$, $-\frac{1}{2}\wedge i\text{-}2=113°\ 30'$, $i\text{-}2\wedge\frac{1}{2}^3=142°\ 30'$, $\frac{1}{2}^3\wedge\frac{1}{2}^3=112°$ and $149°\ 30'$, $i\text{-}2\wedge R=128°\ 30'$. Hemimorphic crystals, consisting of the single plane O at one extremity, and with $-\frac{1}{2}$, $\frac{1}{2}^3$ and R at the other end were found. Gems of pale colors could have been cut from many of the crystals. For their crystallographic interest alone, aside from their beauty, they merit a place in every cabinet. The crystals varied in size from those of 3^{mm} in diameter, and 2^{cm} in length, to those of 1^{cm} in diameter, and 3^{cm} in length. A few very remarkable crystals were 5 to 8^{cm} long. Associated with them was some little cassiterite, considerable lepidolite, in unexampled crystals, and much quartz and cookeite. A single crystal of columbite, of 3 grams weight, was quite equal in polish and in richness of planes to those from Standish, Maine. The locality promises to be of financial importance regarding the production of material for gems. The pocket was much decomposed and nearly all the crystal contents were in detached pieces, or in broken fragments.

It is to Mr. Nathan H. Perry, of South Paris, Me., that we are indebted for discovering and bringing to our notice this valuable locality. As early as 1868, Mr. G. C. Hatch had found, while cultivating his farm in Auburn, a small bowlder containing tourmalines, but nothing of interest was discovered until, in July last, Mr. Perry found and opened up the pockets whose contents are above described.

III. Botany and Zoology.

1. *Botanical Fragments;* by Sir Charles J. F. Bunbury, Bart., F.R.S., etc. London, 1883.—A handsome volume of 370 pages, 8vo (including a full index), printed by Spottiswoode & Co., which, although not published, and therefore known only to a limited circle, is from beginning to end so thoroughly readable and instructive that it ought not to pass unnoticed. Two or three of the six articles it contains, or parts of them, have already appeared, one of them in the Transactions of the Linnean Society, a good while ago. The others are new, although based upon observations and notes made when this veteran observer was younger than he now is. The first essay is upon the "Influence of the Chemical Composition of Rock on Vegetation. The second, on some characteristics of South American Vegetation; and this is followed by Notes on the Vegetation of Brazil, and by Notes on the Vegetation of Buenos Ayres and the neighboring districts; while the fifth essay gives a similar and detailed account of the Vegetation of the Cape of Good Hope. These papers describe the aspect and general characteristics of these several floras, as they strike the botanical observer, and in such a clear and natural way that the reader may almost fancy himself as traversing the ground with a well-instructed companion. Moreover, the notes are not restricted to personal observations on the spot, but have been collated even with the most recent authorities. We know of no one who in our day has written such excellent and well-delineated sketches of vegetation, bringing to view not only aspect and general features, but also botanical characteristics. In his herborizations at the Cape of Good Hope the author had the companionship of the late Professor Harvey, then residing there. The last essay, on the Characters of Leaves, reviews the leading peculiarities of the foliage in the principal Dicotyledonous plants, and concludes "that, although in several instances the affinities of plants may at least be guessed from their leaves, this will seldom hold good throughout any large order, however natural." A. G.

2. *Illustrated Descriptive Catalogue of American Grape Vines, a Grape Growers' Manual;* by Bush & Son and Meissner. Third ed. St. Louis, Missouri. pp. 153, 8vo.—This is a wonderfully full account of the Grapes of the United States, wild and cultivated. The history of the cultivated varieties or forms, and the species from which they have been derived, are succinctly indicated. As to the indigenous forms, this third edition of the

catalogue is made more valuable to the botanist, as well as to the cultivator, by Dr. Engelmann's revised and largely new account of the True Grape-Vines of the United States, now brought up to thirteen species. The latest accession is of a very old species, *Vitis palmata* of Vahl, described in few words by this author from a plant which was cultivated in the Jardin des Plantes at Paris, perhaps a hundred years ago, which was also recognized as a species by the elder Michaux at the beginning of this century (for, although unpublished, it exists in his herbarium as *V. rubra*, but was merged by the witer of his Flora in the nearly allied *V. riparia*), he having collected specimens on the banks of streams in Illinois. Finally it has been detected by Mr. Eggert of St. Louis, on the banks of the Mississippi, above that town; and Dr. Engelmann has in this revision fixed its characters. Michaux's name must have been suggested "by its bright red branches, from which the bark separates in large flakes." For the identification of all the species, Dr. Engelmann adds a series of figures of seeds, thirty-three in number, in outline, of natural size, and a magnified view of the chalazal face of each, all drawn to scale. Considering the part which the American vines are to play in the future, it is fortunate that, at this early period of their cultivation and inter-breeding, and while they can be referred back to their wild types, they have been subjected to the close and prolonged scrutiny of such a critical investigator as Dr. Engelmann, and that he has taken care to publish successive monographical revisions, setting forth his latest additions to the stock of knowledge, which, from first to last, we mainly owe to him.

A. G.

3. *The Law of Heredity: A Study of the Cause of Variation and the Origin of Living Organisms.* By W. K. BROOKS, Associate in Biology, Johns Hopkins University. Baltimore: J. Murphy & Co. 1883. pp. 336, 12mo.—This small but full book, which we hasten to announce rather than to review, is perhaps the most considerable and the most ambitious contribution to the doctrine of the development of species which has appeared in this country. A discriminating and thorough critical notice of it could not be given in small space, and would require an amount of time and consideration which we cannot now afford. Heredity is the leading word of the title; but the second part of the title gives the key to the essay. It is a supplement to Darwinism on the speculative side, a contribution by a trained zoologist and comparative anatomist, with a genius for speculation, to what may be called molecular biology. The author understands natural selection—its weak points as well as its strong ones—is naturally attracted to pangenesis, and has built upon it his new theory of heredity; we should say rather of the cause or origin of variation. This is developed and expounded with a great wealth of illustration. The hypothesis is woven of the same tenuous material which forms the staple of Darwin's pangenesis; but it seems to be better adapted for wear than the original fabric. Darwin

himself, who appears not to have set great store by his own conception, would have hailed Mr. Brooks's version of it as an improvement. He would have pounced at once upon the fact (which the author announces and hopes to act upon), that a leading point in the new hypothesis—the idea that in reproduction variation is given by the male element—may be experimentally tested by the cross-breeding of plants. If it stands that test, there will be something tangible for the hypothesis to rest upon. But it will not be easy to prove that variation, commonly originating in reproduction, but sometimes without it, is due to the male element.

The proof-reading of this volume has been negligent, names of persons are sometimes wrongly written (Vilmorin is hardly recognizable as Vilmore); in a great gathering of facts some questionable ones find a place; and now and then there is an opinion or a bit of reasoning that may be assailed. A. G.

4. *Reports on the Results of Dredging under the Supervision of A. Agassiz in the Gulf of Mexico* (1877–8), *in the Caribbean Sea* (1878–9), *and along the U. S. Atlantic Coast* (1880), *by the Coast Survey Steamer Blake.—Report on the Echini* by A. Agassiz. 94 pp. 4to, with 32 plates. Memoirs of the Mus. Compar. Zool. at Harvard College, vol. x, No. 1.—Besides the descriptions and admirable plates of this Report, it contains a brief chapter on the *Origin of the West Indian* (*Caribbean*) *Echinid Fauna*, from which the following is taken. The deep-sea fauna of the Caribbean sea and Mexican gulf is far more closely allied to that of the Pacific than to that of the Atlantic; and this is attributed to a connection between the oceans before the Cretaceous period freer than that with the Atlantic. Many of the Pacific genera remain until now unchanged; while Atlantic types have been added that previously found less favorable conditions for their development than those which now exist. The view, besides explaining the mixed character of the fauna, also shows that the time elapsed since the separation of the oceans, however long, has not been sufficient to effect any very radical change in the Echinid fauna of the two sides of the Isthmus. Physical conditions, the author observes, are so nearly alike on the two sides that little change should be expected from this source, and that which occurred appears to be due mainly to immigration.

The Echinid fauna of the West Indies comprises more than a quarter of all known species; and out of it, 5 genera date back to the Jurassic; 10 to the Cretaceous; 24 to the early Tertiary; and only 4 to the later Tertiary. Seven of the genera are representatives of the *Ananchytidæ* and *Infulasteridæ* and of the *Pseudodiademidæ* of the Cretaceous period.

The great equatorial oceanic current is supposed by the author to have probably swept nearly uninterruptedly around the globe previous to the close of the Cretaceous era; and from that time "the specialization of the great Atlantic and Indo-Pacific marine realms began." The marine life of the Jurassic and Cretaceous periods about Great Britain has been thought to show that the Gulf Stream was probably flowing northward then as now and producing similar effects on British climate. This is not inconsistent with the conclusion above cited; since the connection between the Gulf and Atlantic, according to Mr. Agassiz's deduction, was imperfect enough to have interfered much with the transfer of deep-sea life from one to the other, which condition would have required that the depth between the two should not have exceeded 75 or 100 fathoms, and in that case there would have been an Atlantic as well as a Pacific branch to the so-called Gulf Stream.

5. *Glyptocrinus re-defined and restricted, Gaurocrinus, Pycnocrinus and Compsocrinus established and two new species described by* S. A. MILLER. Jour. Cincinnati Soc. Nat Hist., vi, Dec., 1883.—The following observations on the vault of *Glyptocrinus decadactylus* are from this paper, the author of which has in his collection all the species of the genus excepting two from the Trenton and Hudson River group. They are from a letter on the paper received from the author.—The vault in this species is slightly convex in the central part and undulating toward each interbrachial area. It is composed of very numerous plates. Those in the central part are the larger ones and each bears a central tubercle or spine. Toward the margin the plates are smaller and possessed of slight convexity. They unite in the depressions in the interbrachial areas with the plates of the calyx, or rather the interradials graduate through the interbrachials to the plates of the vault without any line of separation. The plates are smaller as they approach the inner face of the arms over the swelling undulations of the vault, and gradually decrease in size and form a continuous granular integument that covers the inner sides of the ambulacral furrows. This continuation of the vault up the inner side of the arms I have observed for more than an inch above the vault, and have specimens at hand illustrating it, and entertain no doubt that it extended as far as the arm furrows themselves. The pinnules do not cover the arm groove, but become free upon each side of it, leaving an angular roof between them which represents the extension of the plates of the vault.

Wachsmuth and Springer say (Revision of the Palæocrinoidea, p. 25): "It is important to note that in those genera in which the ambulacral groove is thus covered, no regular pinnules have ever been observed, and, moreover, the construction is such that no additional pinnulæ could have existed; while on the other hand, no covering has ever been discovered with true pinnulæ;" and, finally, they come to the conclusion that the plates covering the ambulacral groove were homologous with the pinnulæ, or as they say, "in fact rudimentary pinnulæ."

I do not understand how or why pinnules should, in any case, act as a covering to the ambulacral groove, and I have never seen any evidence of their performing such a function, and can distinctly disprove it by specimens belonging to several different genera.

The mouth (as I regard it) of *G. decadactylus* is situated subcentrally. It appears as a subcircular, rounded elevation composed of plates imbricating toward the center, while a few of the surrounding plates have rather long spines inclined toward the central part of the orifice. This imbricating arrangement of plates does not occur in any other part of the body, and is quite unique and peculiar. The vault, I believe, has never before been described, though parts of it have been known for many years and fragments are not rare.

6. *The Auk, a Quarterly Journal of Ornithology.* Vol. I, No. 1, January, 1884. Editor, J. A. ALLEN; associate editors, E. COUES, R. RIDGEWAY, W. BREWSTER and M. CHAMBERLAIN. 108 pp. 8vo. Boston, Mass. Published by Estes & Lauriat for the Ornithological Union. Continuation of the Bulletin of the Nuttall Ornithological Club. Price $3.00 a year.—This Journal has the best of American ornithologists in its editorial corps. It promises, as its papers show, to be attractive to the popular reader as well as to the scientific, and should have a large circulation.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The proposed Conference of Electricians at Philadelphia.*—In order to secure the advantage of holding the proposed International Electrical Exhibition in Philadelphia in September coincidently with the meeting of the American Association for the Advancement of Science and the anticipated visit of the British Association to the city, the Franklin Institute has appointed a special committee to confer with scientific men as to the best method to be adopted in order to make the conference a success. To defray the expense of such conference, a bill has been prepared asking for a small appropriation from Congress. Scientific men interested in the measure are earnestly requested to give it all the aid in their power. Communications on the subject should be addressed to the Committee, which consists of M. B. Snyder, Edwin J. Houston, William H. Wahl, with Wm. P. Tatham, President of the Franklin Institute.

2. *Bust of Liebig.*—Copies of the celebrated bust of the late Prof. Liebig which the sculptor, Prof. Wagmüller, made in 1872, and which is considered the best extant, are to be obtained from the widow of the latter. The price in gypsum is $6; in imitation bronze, $8; including packing. Frau Prof. WAGMÜLLER,

Bayerstrasse 25, München (Munich).

Repertorium der Deutschen Meteorologie. Leistungen der Deutschen in Schriften, Erfindungen und Beobachtungen auf dem Gebiete der Meteorologie und des Erdmagnetismus, von den ältesten Zeiten bis zum Schlusse des Jahres 1881; von C. Hellmann. 995 pp. large 8vo. Leipzig, 1883 (W. Engelmann).—An invaluable bibliography to all who are interested in meteorology and terrestrial magnetism, and who would be acquainted with its historical development.

Lehrbuch der vergleichenden Anatomie der Wirbelthiere auf Grundlage der Entwicklungsgeschichte, bearbeitet von Prof. Dr. Robert Wiedersheim, Director der anatomischen und vergl. Institutes der Universität Freiburg, etc. 2nd (and concluding) Part, with 261 wood-cuts.

OBITUARY.

General Andrew A. Humphreys.—Brigadier-General Andrew Atkinson Humphreys died in Washington, on the 28th of November last, in the seventy-fourth year of his age. General Humphreys was graduated at West Point with the rank of Second Lieutenant on July 1, 1831. After active service in the war against the Cherokee Nation in Florida, and in the Seminole war in 1836, he entered the service of the United States as a civil engineer, to assist Major Bache on the plans for the Brandywine Shoal Light-house and the Crow Shoal Breakwater, Delaware Bay, and he was engaged in this work until July 7, 1838, when he was reappointed to the army with the rank of First Lieutenant, Corps of Topographical Engineers. From 1844 to 1849 he was in charge of the Coast Survey office at Washington. The topographic and hydrographic survey of the delta of the Mississippi River was carried on under his direction in 1849-50, and he had general charge of this work until 1851. After a year spent in Europe in examining the means for protecting deltas from inundation, he was placed in general charge, under the War Department, of the office duties at Washington connected with the explorations and surveys for railroads from the Mississippi River to the Pacific, and geographical explorations west of the Mississippi, a position which he ably filled until the breaking out of the civil war in 1861. During the war of 1861-65, he was in active duty in the field, and was made brevet Brigadier-General, on March 13, 1865, for gallant and meritorious services at Gettysburg, and brevet Major-General, United States Army, on the same day, for his services at Sailor's Creek. On June 27, 1865, he was placed in command of the Military District of Pennsylvania, in the Middle Department, a command which he held until Dec. 9, when he was assigned to his old engineering work, being placed in charge of the examination of the Mississippi levees, a work which occupied him until Aug. 8, 1866, when he was placed in command of the Corps of Engineers and in charge of the Engineer Bureau, in Washington, and promoted to the full rank of Brigadier-General and Chief of Engineers.

General Humphreys remained at the head of the Engineer Bureau of the army until June 30, 1879, when he was retired at his own request, Colonel Horatio G. Wright succeeding him. During his service as commander of the Engineer Corps he also served on many important commissions, among which were the commission to examine into the canal routes across the Isthmus of Panama, from 1872 to 1877, the Board on Washington and Georgetown Improvements, the Revising Boards for Bulkhead and Pier Line of Brooklyn, of Staten Island, and of the Hudson River; the Board for the Survey of Baltimore Harbor and Adjacent Waters, and the Washington Monument Commission. His most important Report is the great work on the "Physics and Hydraulics of the Mississippi," prepared by him in conjunction with Lieutenant H. L. Abbott. He was the author, also, of a volume on the "Campaigns of the Civil War." He received the degree of LL.D. from Harvard, in 1868.

APPENDIX.

ART. XXI.—*Principal Characters of American Jurassic Dinosaurs;* by Professor O. C. MARSH. Part VII. *On the Diplodocidæ, a new family of the Sauropoda.* (With Plates III and IV.)

THE *Sauropoda* are now generally recognized by anatomists as a well-marked order of the Sub-class *Dinosauria*. In the previous articles of this series, the main characters of the two families of this order (*Atlantosauridæ* and *Morosauridæ*) already named by the writer have been given.* A third family is represented by the genus *Diplodocus*, a study of which, more especially of the skull, throws light on the whole group of Dinosaurian reptiles.

THE SKULL.

The skull of *Diplodocus* is of moderate size. The posterior region is elevated, and narrow. The facial portion is elongate, and the anterior part expanded transversely. The nasal opening is at the apex of the cranium, which from this point slopes backward to the occiput. In front of this aperture, the elongated face slopes gradually downward to the end of muzzle, as represented in Plate III, figure 1.

Seen from the side, the skull of *Diplodocus* shows five openings: a small oval aperture in front (*a*), a large antorbital vacuity (*b*), the nasal aperture (*c*), the orbit (*d*), and the lower temporal opening (*e*) (Plate IV, figure 1). The first of these has not been seen in any other Dinosaurs; the large antorbital vacuity is characteristic of the *Sauropoda;* and the other three openings are present in all the known *Dinosauria*.

* This Journal, xvi, 411, Nov., 1878; xvii, 86, Jan., 1879; xxi, 417, May, 1881; xxiii, 81, Jan., 1882; and xxvi, 81, Aug., 1883.

On the median line, directly over the cerebral cavity of the brain, the type specimen of *Diplodocus* has also a fontanelle in the parietals. This, however, may be merely an individual peculiarity.

The plane of the occiput is of moderate size, and forms an obtuse angle with the fronto-parietal surface.

The occipital condyle is hemispherical in form, and seen from behind is slightly sub-trilobate in outline. It is placed nearly at right angles with the long axis of the skull. It is formed almost wholly of the basi-occipital, the exoccipitals entering but slightly or not at all into its composition. The basi-occipital processes are large and rugose. The paroccipital processes are stout, and somewhat expanded at their extremities, for union with the quadrates.

The parietal bones are small, and mainly composed of the arched processes which join the squamosals. There is no true parietal foramen, but in the skull here figured (Plate III) there is the small unossified tract mentioned above. In one specimen of *Morosaurus*, a similar opening has been observed, but in other *Sauropoda*, the parietal bones, even if thin, are complete. The suture between the parietals and frontal bones is obliterated in the present skull, and the union is firm in all the specimens observed.

The frontal bones in *Diplodocus* are more expanded transversely than in the other *Sauropoda.* They are thin along the median portion, but quite thick over the orbits.

The nasal bones are short and wide, and the suture between them and the frontals is distinct. They form the posterior boundary of the large nasal opening, and also send forward a process to meet the ascending branch of the maxillary, thus forming in part the lateral border of the same aperture.

The nasal opening is very large, subcordate in outline, and is partially divided in front by slender posterior processes of the premaxillaries. It is situated at the apex of the skull, between the orbits, and very near the cavity for the olfactory lobes of the brain.

The premaxillaries are narrow below, and with the ascending processes very slender and elongate. Along the median line, these processes form an obtuse ridge, and above they project into the nasal opening. Each premaxillary contains four functional teeth.

The maxillaries are very largely developed, more so than in most other known reptiles. The dentigerous portion is very high, and slopes inward. The ascending process is very long, thin and flattened, inclosing near its base an oval foramen, and leaving a large unossified space posteriorly. Above, it meets the nasal and prefrontal bones. Along its inner border for nearly its whole length, it unites with the ascending process of the premaxillary. Each maxillary contains nine teeth, all situated in the anterior part of the bone (Plate III, figure 1).

Along their upper margin, on the inner surface, the maxillaries send off a thickened ridge or process, which meets its fellow, thus excluding the premaxillaries from the palate. Above this, for a large part of their length, the ascending processes of the maxillaries underlap the ascending processes of the premaxillaries, and join each other on the median line.

The orbits are situated posteriorly in the skull, being nearly over the articulation of the lower jaw. They are of medium size, nearly circular in outline, their plane looking outward and slightly backward. No indications of sclerotic plates have been found either in *Diplodocus* or the other genera of *Sauropoda*.

The supra-temporal fossa is small, oval in outline, and directed upwards and outwards. The lateral temporal fossa is elongated, and oblique in position, bounded, both above and below, by rather slender temporal bars.

The pre-frontal and lachrymal bones are both small, the suture connecting them, and also that uniting the latter with the jugal, cannot be determined with certainty.

The post-frontals are tri-radiate bones. The longest and most slender branch is that descending downward and forward for connection with the jugal; the shortest is the triangular projection directed backward, and fitting into a groove of the squamosal; the anterior branch, which is thickened and rugose, forms part of the orbital border above.

The squamosal lies upon the upper border of the par-occipital process. The lower portion is thin, and closely fitted over the head of the quadrate.

The quadrate is elongated, slender, with its lower end projecting very remarkably forward. In front, it has a thin plate extending inward, and overlapping the posterior end of the pterygoid.

The quadrato-jugal is an elongate bone, firmly attached posteriorly to the quadrate by its expanded portion. In front of the quadrate, it forms for a short distance a slender bar, which is the lower temporal arcade.

The palate is very high and roof-like, and composed chiefly of the pterygoids. The basi-pterygoid processes are elongate, much more so than in the other genera of *Sauropoda*.

The pterygoids have a shallow cavity for the reception of these processes, but no distinct impression for a columella.

Immediately in front of this cavity, the pterygoids begin to expand, and soon form a broad, flat plate, which stands nearly vertical. Its upper border is thin, nearly straight, and extends far forward. The anterior end is acute, and unites along its inferior border with the vomer. A little in front of the middle, a process extends downward and outward for union with the transverse bone. In front of this process, uniting with it and with the transverse bone, is the palatine.

The palatine is a small semi-oval bone fitting into the concave anterior border of the pterygoid, and sending forward a slender process for union with the small palatine process of the maxillary.

The vomer is a slender, triangular bone, united in front by its base to a stout process of the maxillary, which underlaps the ascending process of the premaxillary. Along its upper and inner border, it unites with the pterygoid, except at the end, where for a short distance it joins a slender process from the palatine. Its lower border is wholly free.

The Brain.

The brain of *Diplodocus* was very small, as in all Dinosaurs from the Jurassic. It differed from the brain of the other members of the *Sauropoda*, and in fact from all other known reptiles, in its position, which was not parallel with the longer axis of the skull, as is usually the case, but inclined to it, the front being much elevated, as in the Ruminant mammals. Another peculiar feature of the brain of *Diplodocus* was its very large pituitary body, enclosed in a capacious fossa below the main brain case. This character separates *Diplodocus* at once from the *Atlantosauridæ*, which have a wide pituitary canal connecting the brain cavity with the throat. In the *Morosauridæ*, the pituitary fossa is quite small.

The posterior portion of the brain of *Diplodocus* was diminutive. The hemispheres were short and wide (Plate IV, figure 1), and more elevated than the optic region. The olfactory lobes were well developed, and separated in front by a vertical osseous septum. The very close proximity of the external nasal opening is a new feature in Dinosaurs, and appears to be peculiar to the *Sauropoda*.

The Lower Jaws.

The lower jaws of *Diplodocus* are more slender than in any of the other *Sauropoda*. The dentary especially lacks the massive character seen in *Morosaurus*, and is much less robust than the corresponding bone in *Brontosaurus*. The short dentigerous portion in front is decurved (Plate III, figure 1), and its greatest depth is at the symphysis. The articular, angular, and subangular bones are well developed, but the coronary and splenial appear to be small.

The Teeth.

The dentition of *Diplodocus* is the weakest seen in any of the known *Dinosauria*, and strongly suggests the probability that some of the more specialized members of this great group were edentulous. The teeth are entirely confined to the front of the jaws (Plate III, figure 1), and those in use were inserted in such shallow sockets that they were readily detached. Specimens in the Yale museum show that entire series of upper or lower teeth could be separated from the bones supporting them without losing their relative position. In Plate IV, figure 2, a number of these detached teeth are shown. This series of teeth was found with the remains of *Stegosaurus*, and hence was at first referred to that genus, as was also the specimen represented in figure 3 of the same plate.* The teeth of *Stegosaurus* are now known to be of a different type, somewhat resembling those of *Scelidosaurus*.

The teeth of *Diplodocus* are cylindrical in form, and quite slender. The crowns are more or less compressed transversely, and are covered with thin enamel, irregularly striated. The fangs are long and slender, and the pulp cavity is continued nearly or quite to the crown. In the type specimen of *Diplodocus*, there are four teeth in each premaxillary, the largest of the series; nine in each maxillary; and ten in each dentary of the lower jaws. There are no palatine teeth.

The jaws contain a single row only of teeth in actual use. These are rapidly replaced, as they wear out or are lost, by a series of successional teeth, more numerous than is usual in these reptiles. Plate IV, figure 3, represents a transverse section through the maxillary, just behind the fourth tooth. The latter is shown in place (1), and below it is a series of five immature teeth (2 to 6), in various stages of development, preparing to take its place. These successional teeth are lodged in a large cavity (*c*), which extends through the whole dental portion of the maxillary. The succession is also similar in the premaxillary teeth, and in those of the lower jaws.

The Vertebræ.

The vertebral column of *Diplodocus*, so far as at present known, may be readily distinguished from that of the other *Sauropoda* by both the centra and chevrons of the caudals.

* This Journal, xix, p. 255, March, 1880.

The former are elongated, and deeply excavated below, as shown in Plate IV, figures 4 and 5. The chevrons are especially characteristic, and to their peculiar form the generic name *Diplodocus* refers. They are double, having both anterior and posterior branches, and the typical forms are represented in figures 6 and 7 of the same plate.

The Pelvic Girdle.

The most characteristic bone of the two families of *Sauropoda* previously described is the ischium. In the *Atlantosauridæ*, the ischia are massive, and directed downward, with their expanded extremities meeting on the median line. In the *Morosauridæ*, the ischia are slender, with the shaft twisted about 90°, directed backward, and the sides meeting on the median line, thus approaching this part in the more specialized Dinosaurs. The ischia referred to the genus *Diplodocus*, representing the new family here established, are intermediate in form and position between those above mentioned. The shaft is not expanded distally, nor twisted, and was directed downward and backward, with the ends meeting on the median line.

Size and Habits.

The type specimen of *Diplodocus*, to which the skull here figured apparently belongs, indicates an animal intermediate in size between *Atlantosaurus* and *Morosaurus*, probably 40 or 50 feet in length, when alive. The teeth show that it was herbivorous, and the food was probably succulent vegetation. The position of the external nares indicates an aquatic life.

The remains of the above specimen were found by S. W. Williston and M. P. Felch in the upper Jurassic beds, near Cañon City, Colorado. A second and smaller species is represented by remains found by Arthur Lakes near Morrison, Colorado. This species, which may be called *Diplodocus lacustris*, has much more slender jaws than the one above described. A maxillary bone contains eight teeth, and at the premaxillary suture measures 26^{mm} in thickness. The series of teeth occupy a space of 70^{mm}. A second specimen of apparently the same species has since been found in Wyoming.

The geological horizon of all the *Sauropoda* from the Rocky Mountain region is in the Atlantosaurus beds of the upper Jurassic. No Cretaceous forms of this group are known.

Classification.

The main characters of the order *Sauropoda*, and of the three families now known to belong to it, are as follows:

Order SAUROPODA.

Premaxillary bones with teeth. Large antorbital opening. Anterior nares at apex of skull. Post-occipital bones. Anterior vertebræ opisthocœlian; pre-sacral vertebræ hollow; each sacral vertebra supports its own transverse process. Fore and hind limbs nearly equal; limb bones solid. Feet plantigrade, ungulate; five digits in manus and pes; second row of carpal and tarsal bones unossified. Sternal bones parial.* Pubes projecting in front, and united distally by cartilage; no post-pubis.

(1.) Family *Atlantosauridæ.* A pituitary canal. Ischia directed downward, with expanded extrèmities meeting on median line. Sacrum hollow. Anterior caudals with lateral cavities.

(2.) Family *Diplodocidæ.* Dentition weak. Brain inclined backward. Large pituitary fossa. Two antorbital openings. Ischia with straight shaft, not expanded distally, directed downward and backward, with ends meeting on median line. Caudals deeply excavated below. Chevrons with both anterior and posterior branches.

(3.) Family *Morosauridæ.* Small pituitary fossa. Ischia slender, with twisted shaft, directed backward, and sides meeting on median line. Anterior caudals solid.

The *Sauropoda* are the order of Dinosaurs having the nearest affinities with the *Crocodilia*, especially through some of the extinct forms. *Diplodocus*, for example, resembles *Belodon* of the Triassic, particularly in the large antorbital vacuities of the skull, the posterior position of the external nasal aperture, as well as in other features. The genus *Aetosaurus*, from the same formation, is an intermediate form, and represents a distinct order, which may be called *Aetosauria.* The nearer relations of these groups will be discussed by the writer elsewhere.

Yale College, New Haven, Jan. 21, 1884.

* *Ceteosaurus* has been figured with a single sternal bone by Phillips and other authorities. The writer recently examined the original specimen at Oxford, and found portions of two of these bones, which strongly resemble the sternal plates of American *Sauropoda*.

EXPLANATION OF PLATES.

PLATE III.

FIGURE 1.—Skull of *Diplodocus longus*, Marsh; side view.

FIGURE 2.—The same skull; front view.

FIGURE 3.—The same skull; top view.

All the figures are one-sixth natural size.

PLATE IV.

FIGURE 1.—Skull and brain-cast of *Diplodocus longus*, Marsh; seen from above, one-sixth natural size; *a*, aperture in maxillary; *b*, antorbital opening; *c*, nasal opening; *c′*, cerebral hemispheres; *d*, orbit; *e*, lower temporal fossa; *f*, frontal bone; *f′*, fontanelle; *m*, maxillary bone; *m′*, medulla; *n*, nasal bone; *oc*, occipital condyle; *ol*, olfactory lobes; *op*, optic lobe; *p*, parietal bone; *pf*, pre-frontal bone; *pm*, pre-maxillary bone; *q*, quadrate bone; *qj*, quadrato-jugal bone.

FIGURE 2.—Maxillary teeth of *Diplodocus longus*, Marsh; side view, one-half natural size; *e*, enamel; *r*, root.

FIGURE 3.—Section of maxillary of *Diplodocus longus*, Marsh; one-half natural size, showing functional tooth (fourth) in position, and five successional teeth in dental cavity; *a*, outer wall; *b*, inner wall; *c*, cavity; *f*, foramen.

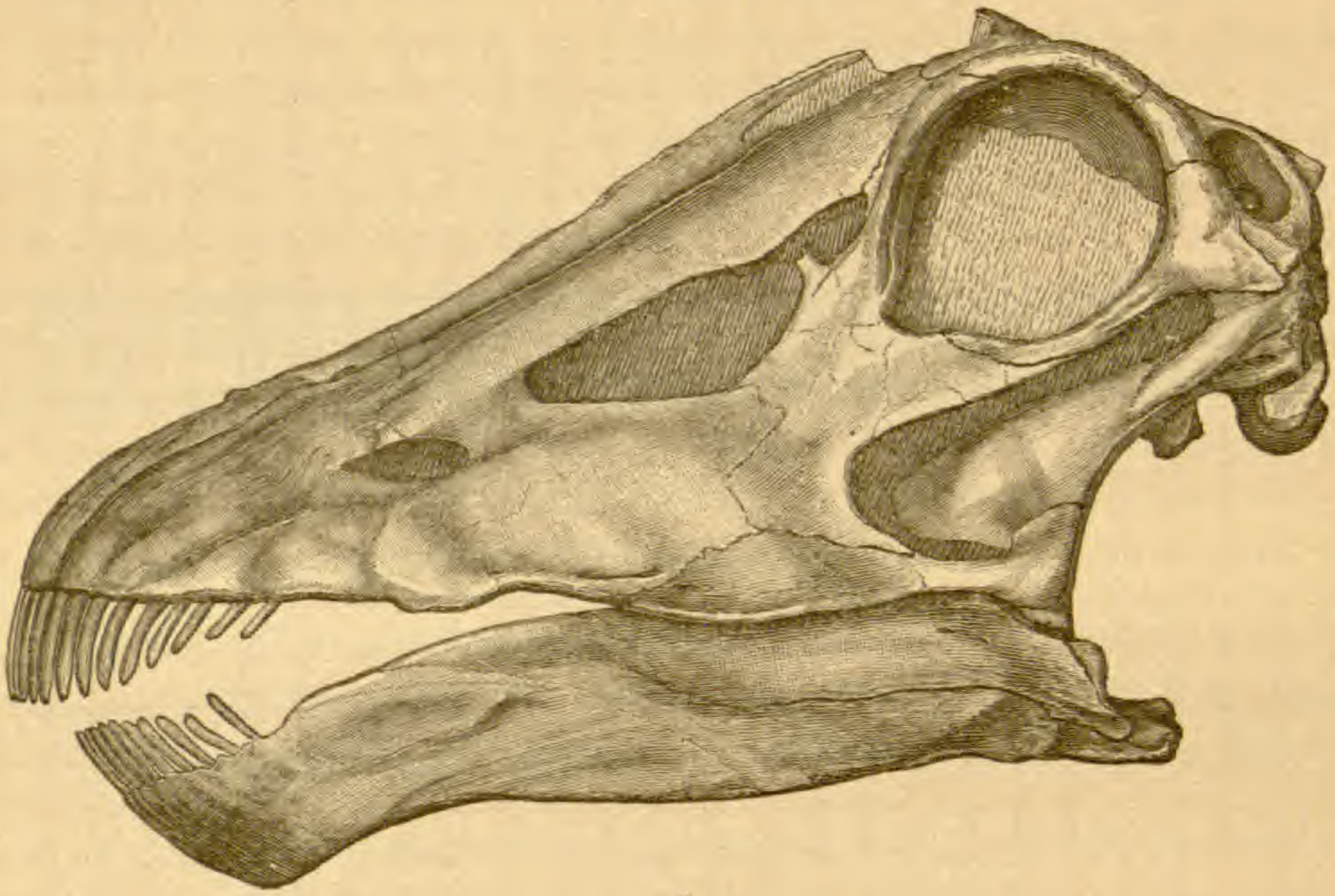
FIGURE 4.—Twelfth caudal vertebra of *Diplodocus longus*, Marsh; side view, one-sixth natural size; *c*, anterior face for chevron; *c′*, posterior face for chevron; *s*, neural spine; *z*, pre-zygapophysis; *z′*, post-zygapophysis.

FIGURE 5.—The same vertebra; bottom view; size and letters as in Fig. 4.

FIGURE 6.—Chevron found attached to tenth and eleventh vertebræ of *Diplodocus longus*, Marsh; top and side views, one-tenth natural size; *a*, anterior end; *p*, posterior end; *v*, faces for articulation with vertebræ.

FIGURE 7.—Chevron of another individual; top and side views; size and letters as in Fig. 6.

1.



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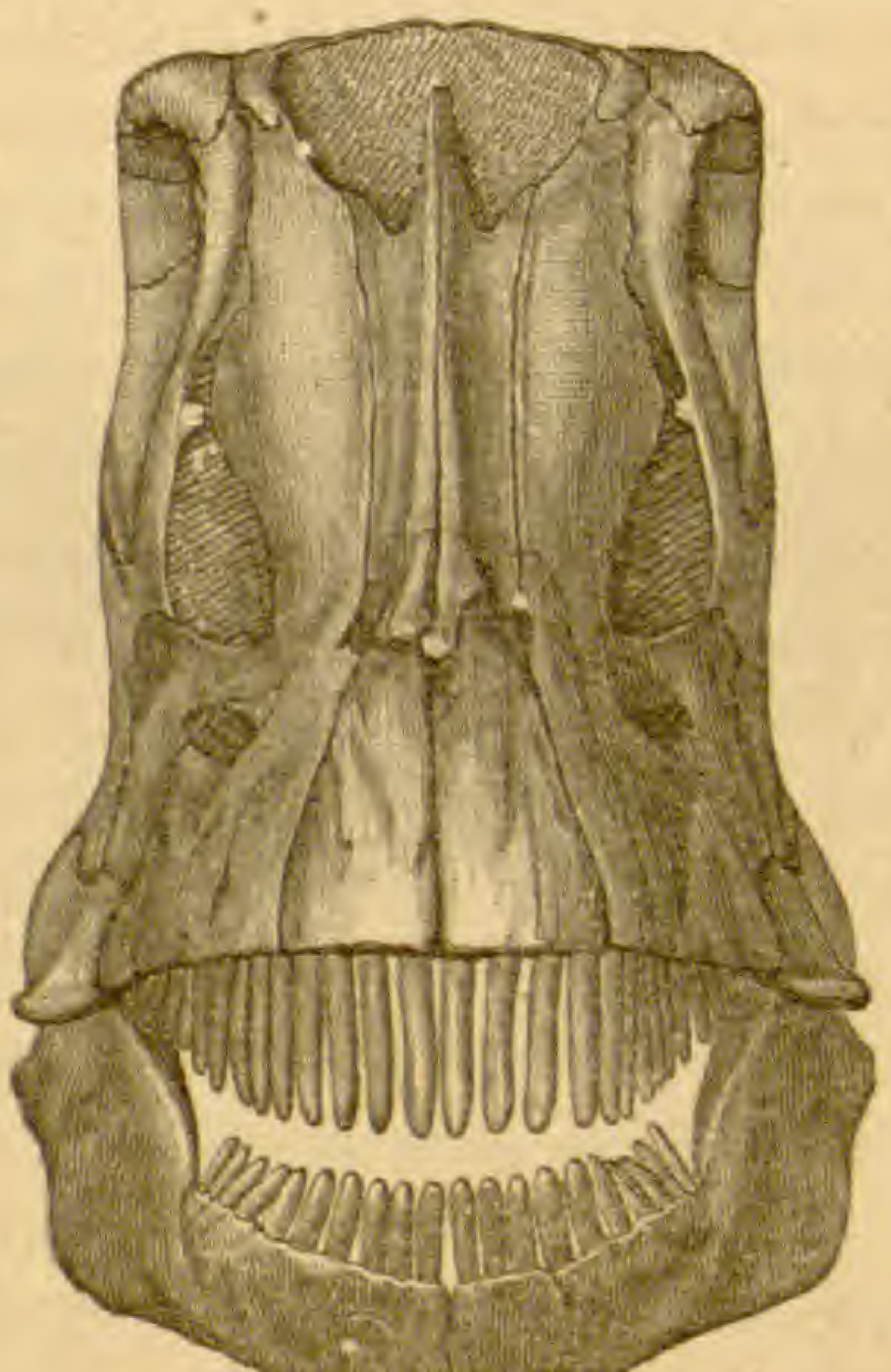

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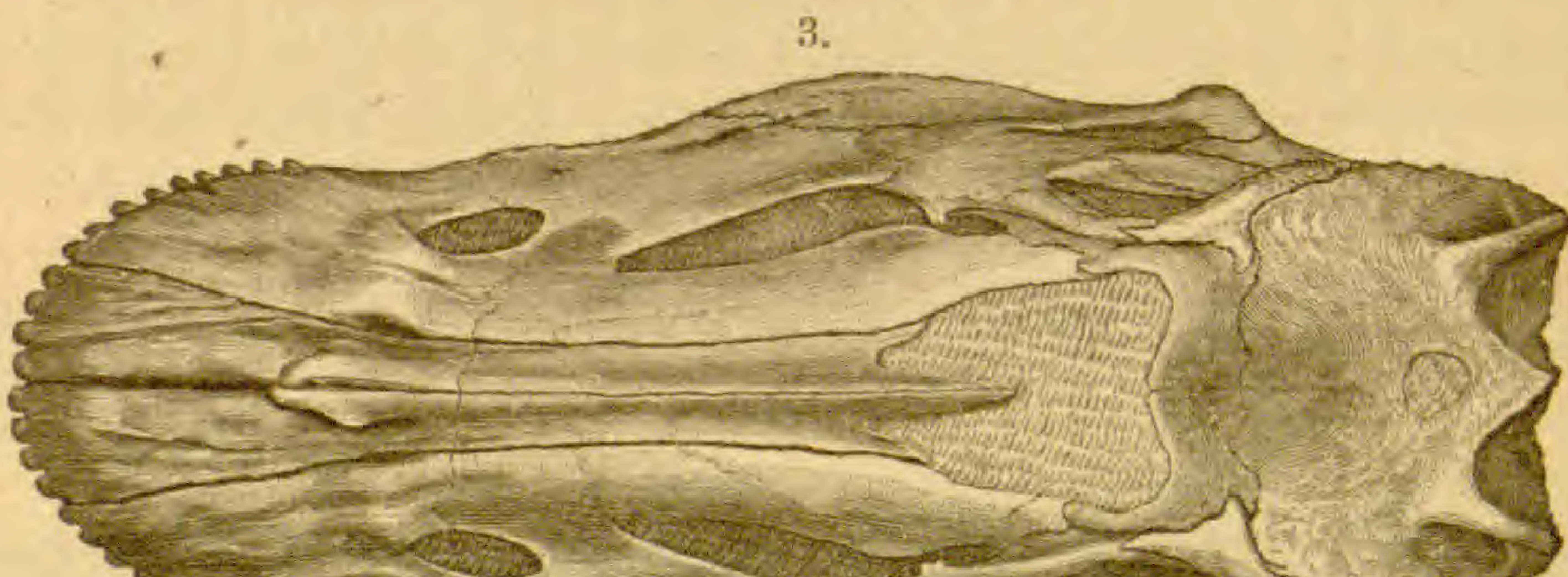


SKULL OF DIPLODOCUS LONGUS, Marsh. One-sixth natural size.

DIPLODOCUS LONGUS, Marsh.

THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. XXII.—*Experimental Determination of Wave-Lengths in the Invisible Prismatic Spectrum;* by S. P. LANGLEY. (With Plate V.)

NOTE.—The following investigation was made at the expense of the Bache fund and is published here by the permission of its trustees. It is the subject of a still unpublished memoir presented in April, 1883, to the National Academy of Sciences, in whose Transactions the unabridged communication will be found.

IN September, 1881, while engaged upon Mt. Whitney, in measuring with a linear bolometer the heat in the invisible spectrum of a flint prism, I came upon a hitherto unknown cold band whose deviation indicated a (probably) very great wave length.* We have had up to the present time no way of measuring such wave-lengths directly, but are accustomed to determine them by more or less trustworthy extra-polation formulæ, the best known of which is Cauchy's. Accordingly, I attempted to calculate the wave-length by Cauchy's formula, but was conducted to an impossible result, the formula declaring that no such index of refraction as I had measured was possible in the prism in question. But the measurement was a fact beyond dispute, and this drew my attention to the grossness of the errors to which the customary formulæ may lead.

Every prism gives a different map of the spectrum, nor when we find a band or line by the prism, have we any means of fixing the absolute place, except by a reference to the normal or wave-length scale, or to one derived from it.

It is desirable to define at the outset, the sense in which the term "Normal" is here used, as a synonym for "Wave-length" spectrum.

The amount of energy in any region of the spectrum, such as that in any color, or between any two specified limits, is a

* Since designated as "Ω."

definite quantity, fixed by facts which are independent of our choice, such as the nature of the radiant body, or the absorption which the ray has undergone. Beyond this, nature has no law which *must* govern us in representing the distribution of the energy, and all maps and charts of it are conventions.

Did the word "Normal," then, signify "absolute," there would be no spectrum exclusively entitled to such a name; but, in this connection, the word is always to be understood in its radical meaning of an accepted rule or type of construction. Such a type exists in the wave-length spectrum; and it has obtained general acceptance, not only on account of its simplicity and convenience, but of its, at present, unique claim to be a "natural" one. It is properly distinguished as the "natural" scale from its not merely representing a mental picture of the distribution of the energy, under a very simple law, but of actually being that which we do produce by our most efficient optical apparatus, and make visible and measurable at will.

While we remain at liberty, then, to represent the energy spectrum in terms of the wave frequency, or of the reciprocal of the square of the wave-length, or of any other function of it, and while we may often find occasion to use these scales for some special purposes, we are (and all the more especially that we habitually speak in terms of the wave-length) led by considerations of a very practical kind, to take as our normal or standard scale, that of the wave-length itself.

Since we have this normal spectrum, actually before us, through the concave gratings constructed by Professor Rowland, it may seem as though we might dispense with the prism; but this is not as yet possible for the lower part of the spectrum, where overlapping spectra and feeble heat make the use of the grating too difficult. If we could use the solar energy here, not in the form of heat, but of chemical action, as in photography, a great advance might be made; and there is reason, I believe, to hope that the labors of Professor Rowland and Captain Abney will ere long do this for us with precision. At present, however, we have only heat, and the thermopile or the bolometer; which latter, though less sensitive than the camera, can be made, as I shall show, to determine experimentally within known limits of error, the actual wave-lengths corresponding to given indices of refraction, and hence to afford here valid experimental data for passing from the prismatic spectrum to the normal one. The reason why this, so desirable information, has never been obtained before, is two-fold: (1st.) While the measurement in question can best be made by means of a prism and grating conjointly, the heat, which in the lower prismatic spectrum is very faint, becomes almost a vanishing quantity when it has passed the grating also, where the heat is on the average less than one-tenth that from the prism. We must use too, if possible, a narrow aperture to register this heat; for a broad one might (on account of the compression of the infra-red by the prism), cover the whole field in which its work should be to discriminate. (2d.) We must have not only an instrument more sensitive than the common thermopile, but we must devise some way of fixing, with an approximate precision, the point at which we are measuring, when that point is actually invisible.

The apparatus I have devised for this double purpose, has done its work with a degree of accuracy, which if it may be called considerable, as compared with what we have been used to in heat measurements, is yet necessarily inferior to that obtained by the eye, and less than we may hope for at some future time, from photography. Nevertheless, it has, I believe, given experimental data very far outside the visible spectrum, by which we may either construct an empirical formula and supply its proper constants so that it will be trustworthy within extended limits, or test the exactness of such formulæ as Cauchy's, Redtenbacher's, etc., which, while professing a theoretical basis, only agree in their results within the limits of the visible spectrum (from which they have been in fact derived, and where they are comparatively unneeded). They contradict each other, as will be seen, as soon as they are called on for information in the region outside of it, where they would be chiefly useful.

The present work has been preceded by a new map of the invisible prismatic spectrum, where the abscissæ were proportional to the deviations in a certain prism. (See this Journal, vol. xxvi, plate III.) And the immediate object of this research is to pass from the arbitrarily spaced prismatic scale, belonging to the particular prism in question, to a map on the normal and absolutely general one, which was indeed also presented in the same issue, but in advance of the present description of the means used to obtain it.

I should perhaps make the cautionary remark, that the general conclusions here offered, as to the relation of wave-lengths and indices of refraction, have been drawn from the observations on a single prism and have not been experimentally verified on others. This is on account of the extremely slow and laborious character of the process used (which has involved some months of labor for this special prism). Though there seems no reason to doubt the generality of our conclusions, it may be hoped that these experiments will be repeated with prisms of other material, and by other observers, now that the preliminary obstacles have been removed.

In order to map the spectrum on the *normal* scale, where the wave-lengths are equally spaced, from such a map as that shown in Plate III (this Journal, vol. xxv), in which the consideration of wave-lengths does not enter, it is necessary to establish some relation between the wave-lengths of rays and their deviations, or between their wave-lengths and refractive indices, which are connected with the deviations by the well-known formula,

$$n=\frac{\sin\frac{(a+d)}{2}}{\sin\frac{a}{2}},$$

where a = the refracting angle of the prism, d = the deviation, and n = the corresponding index of refraction. In the visible spectrum, the deviation, in any prism, of the Fraunhofer lines (whose wave-lengths have been very accurately determined) can be measured by means of an eye-piece with cross wires; and, from a sufficient number of such measurements, by making ordinates proportional to indices of refraction (or deviations) and abscissæ proportional to wave-lengths, a curve may be found whose equation is $n=(\varphi)\lambda$ or $d=(\varphi)\lambda$, representing the required relation to any degree of exactness.

In the invisible spectrum, the difficulties are immensely greater, and demand special means, not only on account of this invisibility, but owing to the absorption by the prism and to its compressing the rays.

The prism here used was made by Adam Hilger, of London, and its optical properties are in every way satisfactory. It is of a white flint, which has proved singularly transparent to the longest solar waves. Its principal constants have been given in this Journal, vol. xxv, p. 187.

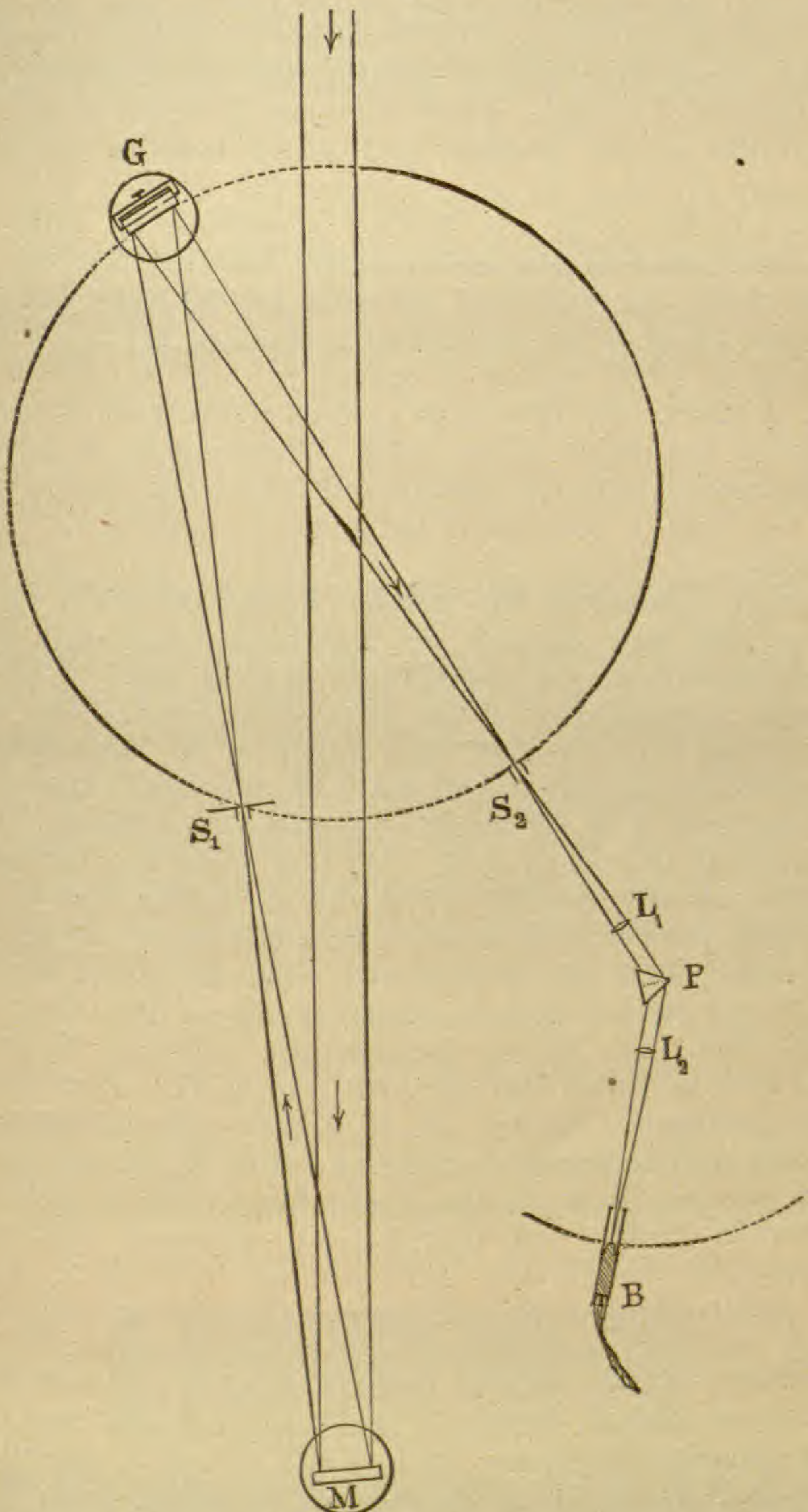
Apparatus for Measuring Obscure Wave-lengths.

In 1882, an apparatus was employed in which invisible rays, after passing through the Hilger prism, at a known deviation, fell on a Rutherfurd reflecting grating (either of 681 lines to the millimeter, or half that number) from which the diffracted invisible ray fell on the bolometer, at a measured angle with the grating. By the use of the known formula ($ns\,\lambda = \sin i + \sin r$) connecting the angle of diffraction with the wave-length, the wave-length was then found.

Several determinations were thus made of wave-lengths in the upper part of the infra-red, where the heat is relatively great; but, though the definition of the Rutherfurd grating was admirable, it was not large enough to supply sufficient heat to enable measures in the lower infra-red to be made with confidence.

In May, 1882, I had the good fortune to secure one of the very large concave gratings, then newly constructed by Pro-

1.



fessor Rowland, and which he was kind enough to make for me of a very short focus, so as to give a specially hot spectrum. After many essays, during which a great number of mechanical and optical arrangements for getting rid of the superposed spectra, were tried with unsatisfactory results, it became clear that, for this large and concave grating, it was necessary to let the ray fall first on it, and then on the prism, thus making the wave-length the known and the deviation the unknown quantity.

In the use of this form of grating, the slit is placed in the circumference of a circle, whose diameter is equal to the radius of curvature of the grating, and which touches its surface. The spectra are then formed, without the need of collimator, observing telescope or any further apparatus, all lying upon the circumference of the circle which contains the slit. The grating which was employed contains 18,050 lines, 142 to the millimeter, ruled on the surface of a concave mirror of speculum metal of $1^{m}\cdot63$ radius of curvature, and exposes a ruled surface of 129^{cm}. By this large surface a spectrum is produced sufficiently hot, even in its lower wave-lengths, to affect the bolometer strips after the various reflections and absorptions to which the heat is necessarily subjected in passing through the apparatus.

Figure 1 illustrates the means finally adopted, and the course of the rays through the apparatus; although, for the sake of distinctness, the mechanical devices used to maintain the proper arrangements of the parts are omitted. The rays of light, coming from the 300^{mm} flat mirror of the large siderostat, pass across the apparatus, and fall upon a concave speculum of 180^{mm} aperture at M, by which at a distance of about $1^{m}\cdot5$ they are converged to a focus at S_1. At this point is a vertical slit, adjustable to any desired width by a double screw, which moves both jaws at once, so as to keep the center always in the same place. This slit is protected from the great heat by a plate of iron pierced with an aperture only a little larger than the slit when open to the usual width. Beyond S_1 the rays diverge and fall upon the concave grating, G. Directly opposite the grating is a second slit, S_2, also double acting, and the apparatus is so arranged that the two slits, S_1, S_2, and the grating, G, always lie upon the circumference of a circle whose diameter is $1^{m}\cdot63$; and therefore in whatever manner the slits may be placed, the light coming through S_1 forms a sharp spectrum upon S_2. A very massive arm, carrying the grating, the slit S_2, and the heavy spectro-bolometer, is pivoted at the center of the circle, so that the relative positions of these parts are unchanged. The slit S_2 is automatically kept diametrically opposite the grating, and on the normal to its center.

The slit S_2 is the slit of the spectro-bolometer, provided with the same attachments as when used for mapping the visible spectrum (except that it is now fitted with simple collimating and objective lenses of the same special kind of diathermanous glass as the prism, instead of its own concave mirror.) Its eye-piece and the bolometer are interchangeable.

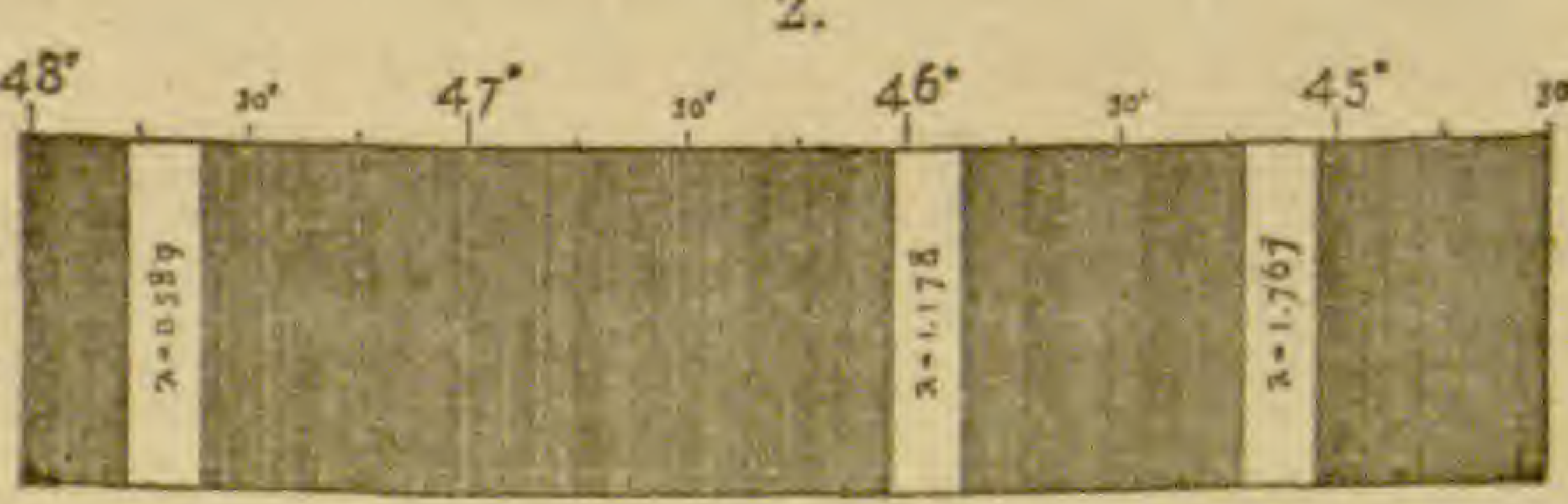
By means of the eye-piece and graduated circle, the deviation, and consequently the refractive index of the rays passing through the slit can be determined, if they are visible. If they are invisible, their exact wave-length is known by a simple ocular observation of the visible ones, on which they are superposed by the action of the grating, while their subsequent deviation is determinable by the bolometer placed at B, provided they retain sufficient energy to affect the instrument. It will be seen that, according to this method, all those invisible rays, which are *n* times the definitely known length of some visible ray, are caused to pass together through a slit, and then through a prism, which sorts out the ray of the first spectrum from that of the second; that of the second from that of the third; and so on, so that the corresponding index of refraction may be determined by observation; with the eye in the case of the visible, with the bolometer in that of the invisible ray.

To illustrate the use of the above described apparatus under somewhat unfavorable circumstances, let us consider as an example the observations of June 13, 1882, which were taken far down in the spectrum, where the heat is feeble, and the galvanometer deflection small, requiring a widely open slit. The apparatus having been previously adjusted, and the sunlight properly directed by the siderostat, the visible Fraunhofer line D_1, of the third spectrum of the grating, was caused to fall upon the slit S_2 of the spectro-bolometer. Then, according to the theory of the grating, there passed, through this slit, rays having the wave-lengths—

0^{μ}·589 (3d spectrum—*visible.*)
1·178 (2d spectrum—*invisible.*)
1·767 (1st spectrum—*invisible.*)

The prism having been removed, and the telescope brought into line, an image of S_2, of the same size as the slit itself, was formed in the focus of the object lens, and on testing

2.



with the bolometer, whose face was covered with a screen pierced centrally with a 2^{mm} slit, the heat of this image produced a deflection of the galvanometer needle of about 30 divisions. The prism was then replaced on the automatic holder and set to minimum deviation, and the image of the slit, containing superposed rays whose combined effect had produced the deflection just mentioned was separated into three similar images* (fig. 2) each composed of nearly homogeneous rays. Of these three bands, only the first or most refrangible, containing the D_1 line, was visible, and its deviation was found to be 47° 41′, agreeing with the value given by the table. It was the object of the experiment to find the place of the lower invisible band, by groping for it; *i. e.*, to determine its deviation by trials with the bolometer at intervals sufficiently close to avoid the possibility of missing it altogether. According to Briot's formula, the deviation should be 45° 21′, and in the preliminary search the circle was accordingly set to this reading. Beginning at this point, and exposing the bolometer at every five minutes of deviation, it was found that the maximum effect was obtained nearer 45° 15′. The approximate position having thus been found, the slit S_1 was narrowed to 2^{mm}, and the following measurements taken, the horizontal line giving the mean results of a series of thirty exposures of the bolometer, as it moved through the spectrum.

TABLE I.—*Determination of the refrangibility of feeble heat-rays.*

Prismatic deviation	45° 02′	45° 07′	45° 10′	45° 15′	45° 20′
Means of galvanometer readings	4·6	5·6	6·0	5·8	2·7

The maximum reading at 45° 10′ corresponds to a coincidence of the 2^{mm} bolometer aperture, with the 2^{mm} invisible image of the slit, whose position is sought. From a subsidiary curve drawn through the points whose coördinates are respectively (x=45° 02′, y=4·6), (x=45° 07′, y=5·6), (x=45° 10′, y=6·0), etc., it was concluded that the deviation of rays whose wave-length is 1^{μ}·767 is 45° 10′; and each point in this determination being obtained from the mean of five observations, the result is partly free from irregularities caused by changes in the state of the sky, and minute instrumental variations from extraneous causes, which here become of great relative importance, owing to the feeble heat measured.

Subsequent determinations, like the preceding, gave for the deviation of the same ray 45° 06′ and 45° 07′, and from a consideration of all, the deviation adopted was (instead of 45° 21′, as given by Briot's formula) 45° 08′, corresponding to a refractive index of 1·5549.

* These three images, being composed of rays of different wave-lengths, could not all be in the same focus of the same lens at the same time, since the collimator and objective of this spectrometer were simple lenses. The lenses were adjusted by means of a table of focal distances previously prepared, so as to throw a sharp (invisible) image of the band to be detected.

By means of measurements like the one described above, the deviations of various obscure rays of known wave-lengths were determined. The indices of refraction were then computed by the usual formula $n=\frac{\sin \frac{1}{2}(a+d)}{\sin \frac{1}{2} a}$ where $a=62° 34' 43''$. The results are contained in the following table, where, however, only the final results of successful days are given, most of the observations having been lost through changes of the sky during the course of one determination.*

TABLE II.—*Experimental determination of* d *or* n *as a function of* λ (*Hilger prism*).

Date of observation.	λ	d	n
April 1, 1882	$1^{\mu}\cdot010 \pm 0\cdot0053$	46° 12′	1·5654
April 9th	$1\cdot200 \pm 0\cdot0069$	45° 54′	1·5625
June 27th	$1\cdot658 \pm 0\cdot0091$	45° 16′	1·5562
June 13th–27th	$1\cdot767 \pm 0\cdot0094$	45° 08′	1·5549
July 14th	$2\cdot090 + 0\cdot0104$	44° 45′	1·5511
June 7th	$2\cdot356 \pm 0\cdot0110$	44° 25′	1·5478

We observe that where measures are taken in the prismatic spectrum alone, we can generally use with advantage a bolometer of as small an aperture as one-fifth of a millimeter, but that here it is advisable to open it to 2^{mm} owing to the relative expansion of the spectrum and to the very feeble heat.

Owing to difficulties arising from the almost infinitesimal amount of heat in question, numerous subsidiary observations are requisite for a single determination, which it therefore takes long to make, each final value resting upon between 20 and 100 readings. If it should possibly appear to the reader that in the three months of consecutive labor which were given to this part of the work, more than six points might have been determined in the curve, he is asked to remember that what is here difficult has till now been impossible.

Plotting the points given by the data in table II and drawing a smooth curve through them, we obtain the curve of "observation" showing n as a function of λ in the lower curve of Plate V.

There would be no gain in accuracy, at this stage, in attempting to work from a formula representing the equation of the curve obtained, as the graphical construction is fully as trustworthy as the data. This I say with special reference to

* All these observations, for discovering the relation between n and λ, can be conducted with at least as much advantage by a powerful and constant electric light as by sunlight. The latter only, however, was at the observer's actual command.

the large original charts* which have been drawn by Mr. J. E. Keeler, of this observatory, and which seem to me favorable specimens of the accuracy attainable by this method.

We are now prepared to test the accuracy of the various formulæ connecting refraction with wave-length, though it will be convenient to first prepare a table showing what this relation is in the visible part of the spectrum of the prism employed.

In the following table the deviations in the visible spectrum were measured by the spectrometer, reading to 10″ of arc, and which has been already described, in which for this special purpose, the bolometer was replaced by an achromatic observing telescope with a micrometer eye-piece, and the indices of refraction were computed by the usual formula. "O" in the ultra-violet was measured by aid of a Soret fluorescent eye-piece, and its wave-length is from Cornu. The other wave-lengths are taken from Ångström, but the unit is here the micron = $\frac{1}{1000}$ millimeter = (10,000 times the unit of Ångström's scale). "λ" is here the symbol for the wave-length.

The following indices in the visible spectrum, on which the computations for testing the formulæ are founded, are trustworthy to the fourth decimal place here given:

TABLE III.—*Observed indices in visible spectrum of Hilger prism.*

Line.		*d*	*n*
A	0^{μ}·76009	46° 49′ 05″	1·5714
C	0·65618	47° 15′ 45″	1·5757
D_1	0·58890	47° 41′ 15″	1·5798
b_4	0·51667	48° 21′ 05″	1·5862
F	0·48606	48° 44′ 15″	1·5899
H_1	0·39679	50° 34′ 05″	1·6070
O	0·34400	52° 43′ 00″	1·6266

A smooth curve, drawn through points whose positions are given by the above table, represents with accuracy the relation between n and λ in the visible part of the spectrum. This method is however obviously inapplicable to the very extended invisible portion, below the A line, and accordingly attempts were first made to effect the determination of corresponding indices and wave-lengths, by extending the curve derived from the above observations by means of formulæ. Several formulæ have, it will be remembered, been proposed by physicists, expressing n as a function of λ, and containing constants which are to be determined by observation. But it has never hitherto

* These original charts were exhibited to the members of the National Academy of Sciences, at Washington, in April, 1883. The engraving here given in illustration being on a much reduced scale, will merely indicate the exactness of interpolation possible by the originals.

been possible to test these formulæ far from the visible spectrum, whence their constants have been in fact derived. This desirable test we are now prepared to apply.

The simplest as well as the most widely used formula is that of Cauchy, which as it is commonly written

$$\left(n = a + \frac{b}{\lambda^2} + \frac{c}{\lambda^4}\right)$$

contains three unknown quantities, requiring for their determination three simultaneous equations. Selecting the lines A, D and H for this purpose, we have from the table just given the three equations,

$$1{\cdot}5714 = a + \frac{b}{(0{\cdot}76009)^2} + \frac{c}{(0{\cdot}76009)^4}$$

$$1{\cdot}5798 = a + \frac{b}{(0{\cdot}58890)^2} + \frac{c}{(0{\cdot}58890)^4}$$

$$1{\cdot}6070 = a + \frac{b}{(0{\cdot}39679)^2} + \frac{c}{(0{\cdot}39679)^4}$$

from which by elimination

$$a = 1{\cdot}5593 \qquad b = 0{\cdot}006775 \qquad c = 0{\cdot}0001137$$

so that for this prism, the formula becomes,

$$n = 1{\cdot}5593 + \frac{0{\cdot}006775}{\lambda^2} + \frac{0{\cdot}0001137}{\lambda^4}$$

which we find on trial satisfies the observations in the visible part of the spectrum within very narrow limits. When, however, we attempt to extend the application of the formula to the infra-red region, its results are not so satisfactory. Since b and c are both positive, the least value which n can have in our prism, according to the formula, is a, or 1·5593 corresponding to a deviation of 45° 35′, whereas the bolometric measurements show that in this prism the solar spectrum, after absorption, extends as low as 44°, with every sign that if it do not extend yet further, it is not on account of the prism but because below this point the heat is absorbed by some ingredient of our atmosphere.

We conclude then that Cauchy's formula gives grossly erroneous results, when extended far behind the limits within which the observations on which it is founded are made. Its implicit assertion, that the lower limit of the prismatic spectrum (however great the wave-length of the ray transmitted), is not so far below A as A is below D, is absolutely contradicted by these experiments, and all extra-polations made by it, far from the visible spectrum in which its constants have been determined, are wholly untrustworthy, as will appear more fully later.

Redtenbacher proposes the formula

$$\frac{1}{n^2}=a+b\lambda^2+\frac{c}{\lambda^2}$$

for expressing the same relation. Using the same lines as before for determining the unknown constants, we have for the Hilger prism

$$\frac{1}{n^2}=0{\cdot}412297-0{\cdot}00093711\lambda^2-\frac{0{\cdot}0039220}{\lambda^2}$$

a formula which also satisfies the observations in the visible spectrum, but fails when extended to the invisible. The curve representing it has a minimum point, corresponding to $n=1{\cdot}5647$ for a value of λ found from the equation $\lambda^4=\frac{c}{b}$ or in the special case of the formula above, where $\frac{c}{b}$ is positive, $\lambda=1{\cdot}430$; so that for every value of n greater than 1·5647, there are two real values of λ. This formula therefore is even less satisfactory than that of Cauchy.

Briot gives a formula which has been asserted by other investigators* to represent satisfactorily the results of observation throughout the whole spectrum, namely:

$$\frac{1}{n^2}=a+b\left(\frac{n^2}{\lambda^2}\right)+c\left(\frac{n^4}{\lambda^4}\right)+k\left(\frac{\lambda^2}{n^2}\right).$$

From four equations like this, using values of n and λ corresponding to the Fraunhofer lines A, C, F and H, the values of the constants were determined† as follows:

$a=0{\cdot}41028$ $b=-0{\cdot}0013495$ $c=-0{\cdot}000003379$ $k=+0{\cdot}0022329$

With the aid of these constants, the wave-lengths corresponding to given refractive indices were computed, and a curve representing the formula was plotted. This curve, as well as those representing Cauchy's and Redtenbacher's formulæ, is shown in Plate V where we may obtain by simple inspection the actual errors of all the formulæ in question, or we may take them from the following table, whose results, I hope, will supply useful data for those who are interested in theories of dispersion.

* Mouton, Comptes Rendus, vol. lxxxix, p. 291 and vol. lxxxiii, p. 1190.

† This formula has the practical inconvenience of leading to cubic equations, either in n^2 or λ^2, the solution of which is so tedious as to forbid its use where many places are to be independently found. I have been aided in the present lengthy numerical computations by Professor M. B. Goff.

TABLE IV.—*Approximate errors in wave-lengths by Briot's, Cauchy's and Redtenbacher's formulæ, for cold bands in infra-red.*

(Comparison of theories with observation.)

n By Obs.	Observ'd λ	Wave-lengths derived by extra-polation. From Briot's Formula. Value.	Error.	From Cauchy's Formula. Value.	Error.	From Redtenbacher's Formula. Value.	Error.	Value.	Error.
1·5714	0·760	0·760	0·000	0·760	0·000	0·760	0·000		
1·5697	0·815	0·815	0·000	0·818	0·003	0·820	0·005		
1·5687	0·850	0·850	0·000	0·853	0·003	0·862	0·012		
1·5678	0·890	0·891	0·001	0·900	0·010	0·915	0·025	2·230	1·340
1·5674	0·910	0·911	0·001	0·920	0·010	0·941	0·031	2·170	1·260
1·5668	0·940	0·942	0·002	0·960	0·020	0·990	0·050	2·060	1·120
1·5636	1·130	1·170	0·040	1·270	0·140	Imaginary.		Imaginary.	
1·5616	1·270	1·336	0·066	1·730	0·460				
1·5604	1·360	1·450	0·090	2·460	1·100				
1·5576	1·540	1·750	0 210	Impossible.					
1·5572	1·580	1·800	0·220						
1·5544 to 1·5535	1·810 to 1·870	2·105 to 2·260	0·295 to 0·390						
1·5520	1·980	2·460	0·480						
1·5515	2·030	2·524	0·494						

NOTE.—A part of the above values of n, where determined from observation by the bolometer, are liable to error in the fourth decimal place. For probable errors of λ, see Table II. "λ observed" is either from a direct observation or from an interpolation between two closely contiguous observations.

It is evident that Briot's formula, though not exact, yet gives results much more trustworthy than the others considered, and it was employed in constructing provisional maps of the normal spectrum from the prismatic, until an apparatus was completed for determining the wave-lengths of the invisible rays by direct measurement.

We must evidently conclude from the numbers in table IV and from the curve in Plate V which embodies them, that we in reality can scarcely assign any limit to the extent of the infra-red prismatic spectrum, and that far from the curve having an asymptote parallel to the axis of X as Cauchy's theory requires, our curve (so far as we can follow it) rather tends to ultimately coincide with a straight line cutting the axis at a finite angle, and (if this axis pass through the point $n=1$) at a great distance from the origin.

With the danger of extra-polations presented to us in such examples as have been cited, we shall not attempt to generalize the results of our observations, further than to remark that, for the prism in question, we find that the deviation tends within the limits of observation to become proportional to the wave-lengths, as the deviation diminishes, and that, as far as we can see at present, *there is scarcely any limit to the wave-length our prism can transmit except that fixed by its absorptive effect.*

The approximate limit of the solar spectrum of the Hilger prism is at $n=1{\cdot}5435$, which, according to Briot's formula, corresponds nearly to $3^{\mu}{\cdot}4$, but which according to our bolometric observations corresponds to an actual wave-length of $2^{\mu}{\cdot}8$. For this same point, as will be seen by Table IV, the values by Cauchy's formula are impossible, and those by Redtenbacher's formula are imaginary.

These last values rest, it will be remembered, on extrapolations founded on measures in the visible spectrum.

Wave-lengths of Cold Lines in Infra-red Prismatic Spectrum.

The following values (in table V) from Mouton, Abney and Draper are the ones I know previous to my own measures where the wave-lengths of cold lines are given with most accuracy. Of these it is just to distinguish those by Abney as possessing a degree of exactness before unknown. There are some doubts about the band at $1^{\mu}{\cdot}35$ having really been observed before, but I have included this among those whose existence was known or suspected before my measures.

The values here given were obtained by me in 1882, and first published in the Comptes Rendus, of the Institute of France, for September 11, 1882, in the form of charts, which were drawn from them. These charts were so much reduced by the first engraver that though these values are still determinable from them, it may be convenient to repeat them here in their original tabular form, with the addition of the probable errors.

TABLE V.—*Observed values of cold bands in infra-red by different investigators.*

M. MOUTON.*	W. DE W. ABNEY.†		J. W. DRAPER.‡		S. P. LANGLEY.§
		0·824	0·815	0·835	0·815 ± 0·003
0·850		0·854			0·85 ± 0·003
			0·893	0·930	0·89 ± 0·004
		0·905			0·91 ± 0·004
		0·941	0·935	0·980	0·94 ± 0·004
0·985	0·975	0·983			1·13 ± 0·007
1·230		1·240			1·27 ± 0·007
1·480	possibly Abney's "ψ"				{ 1·36 ± 0·008
					{ 1·37 ± 0·008
					1·54 ± 0·009 χ
					1·58 ± 0·009 ψ
					1·81 ± 0·010 } Ω
					1·87 ± 0·010 }
					1·98 ± 0·010 ω_1
					2·03 ± 0·010 ω_2

* M. Mouton, Comptes Rendus, tome lxxxix, p. 298; tome lxxxviii, p. 1190.
† W. de W. Abney, Phil. Trans. 1880, p. 653.
‡ J. W. Draper, Proc. Am. Acad. 1881, p. 223.
§ S. P. Langley, Comp. Rend., Sept. 11, 1882; Am. Jour. Sci., March, 1883, etc.

Lines known to previous Investigators.

(0·815.) Near the utmost limit of visibility. Appears to coincide with Capt. Abney's Z, and Draper's α.

(0·85.) Apparently agrees with Abney's 8540.

(0·89.) An inconspicuous line. Abney has a heavy line near here. Possibly corresponds to Draper's β.

(0·91.) Inconspicuous; possibly a part of Draper's β.

(0·94.) Very heavy line; marks the extreme limit of Draper's investigations, according to his own statement, and seems to be identifiable with the last definite gap in Lamansky's curve. (Allegheny observations make it probably telluric.)

(1·12.) Still colder than preceding. The gap represented by this line was taken by Lamansky for the end of the spectrum. (Allegheny observations make it probably of telluric origin.)

(1·26.) Inconspicuous line.

(1·35–37.) Very remarkable band. Almost absolutely cold and black. So broad and diffuse that it is difficult to mark its limits, but coldest part seems to have a wave-length of 1·36 and 1·37. (Allegheny observations make it probably of telluric origin.) Possibly the "ψ" of Abney's chart. It seems to be the extremest limit of previous investigations.

Newly-discovered Lines and Cold Bands.

(1·55 and 1·59.) Inconspicuous lines.

(1·81 to 1·87.) Great Cold Band, first discovered on Mount Whitney. Probably of telluric origin. It is not the furthest line, but is here called Ω on account of its being the last *conspicuous* break in the energy curve.

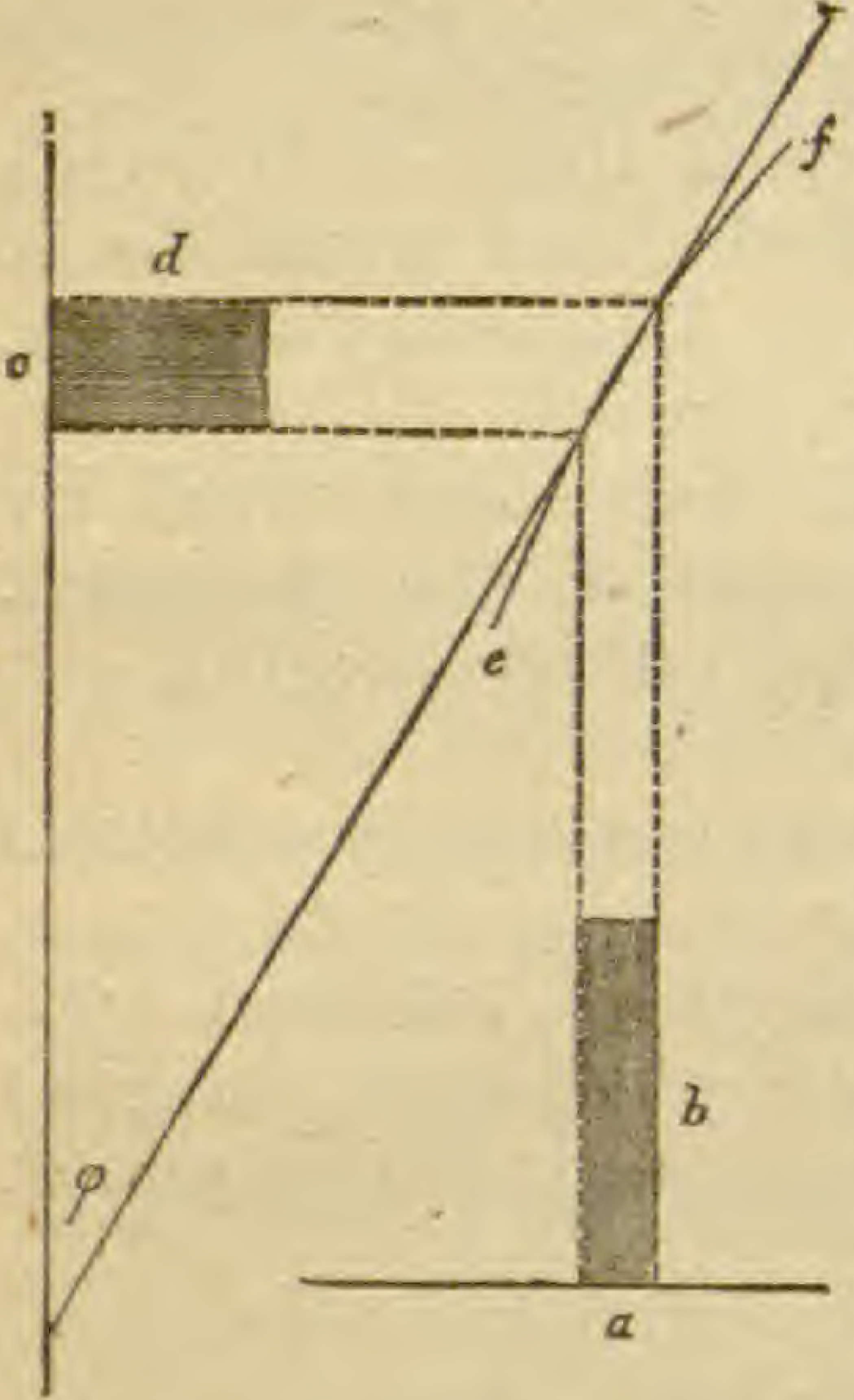
(1·98 and 2·04.) Small but definite lines. The last discovered by the bolometer. But the observable solar spectrum certainly extends to a wave-length of over $2^{m}·70$.

Distribution of Energy in the Normal Spectrum.

The curve $n=\varphi\lambda$ given in the plate enables us to mark off a wave-length scale upon the map of the prismatic spectrum, without any extra-polation, between our present extreme points of observation; a deviation of 50° 58′ (corresponding to $\lambda=0^{\mu}·344$), and a deviation of 44° 25′ (corresponding to $\lambda=2^{\mu}·356$); and also to construct a map in which the wave-length scale is an ordinary scale of equal parts, but in which the degrees of deviation, if represented, would be unequally spaced. Such a chart of the *normal spectrum* has, as we have already remarked, the advantage of being entirely independent of any particular prism or grating, and consequently of being directly comparable with all other maps of the same kind.

If, besides making a map of the normal spectrum, we wish to construct a curve representing the corresponding distribution of energy, a further consideration of the relations existing between the two charts is necessary. The law of dispersion of the prism causes the distribution of energy in its spectrum to be quite different from what would have been observed with a diffraction grating.* Disregarding the absorbing action of the apparatus, the amount of heat between two definite wave-lengths, as between the A and B lines, should be the same in both spectra, provided the total quantity of heat is the same in both. The area between any two ordinates of the curve† may be considered to represent the amount of heat in the part of the spectrum included between them, and the total area of the curve represents the total amount of heat. If then we suppose the area of the normal curve required to be the same as that of the prismatic one, the condition to be fulfilled by the former curve is, that the area included between the ordinates at any two wave-lengths, shall be equal to that included between the same wave-lengths in the latter, and from this condition we can deduce a construction for effecting the required transformation.‡

3.



* J. W. Draper, Phil. Mag., vol. xliv, p. 104, 1872.

† See this Journal, for March, 1883.

‡ See J. Müller, Pogg. Annalen, vol. cv; Lundquist, Pogg. Annalen, vol. clv, p. 146; Mouton, Comptes Rendus, vol. lxxxix, p. 298.

Lay off upon a line, AB (fig. 4), any convenient distance, and divide it into equal spaces to represent the normal wave-length scale, and upon a line CD, at right angles to the first, lay off the same distance and divide it into the same number of parts, spaced according to the law of dispersion of the prism, as in the wave-length scale marked on the bottom of the prismatic chart (Plate III, this Journal, vol. xxv). Erect ordinates at the points of division, and mark them with the proper wave-lengths, beginning on both lines at the ends which lie nearest to each other, as in the figure, where five ordinates are shown; through the intersection of corresponding ordinates draw the curve EF, and upon CD, draw the curve of distribution of energy in the prismatic spectrum.

Let *a*, fig. 3, be a very small wave-length interval on the prismatic scale; *c*, the same interval on the normal scale, and *b* and *d* the average heights of the energy curves over the two intervals, respectively; the shaded part of the figure representing, therefore, the portion of the total area included between these limits. *ef* is a portion of the curve EF, fig. 4. Then, according to the condition of transformation

$$cd = ab$$

whence

$$b : d :: c : a.$$

From geometrical considerations,

$$c : a :: 1 : \tan\phi$$

where ϕ is the angle which the chord EF, joining the intersections of the two pairs of ordinates makes with AB; consequently

$$b : d :: 1 : \tan\phi$$

Such a construction was applied to the prismatic energy curve of the Hilger prism.

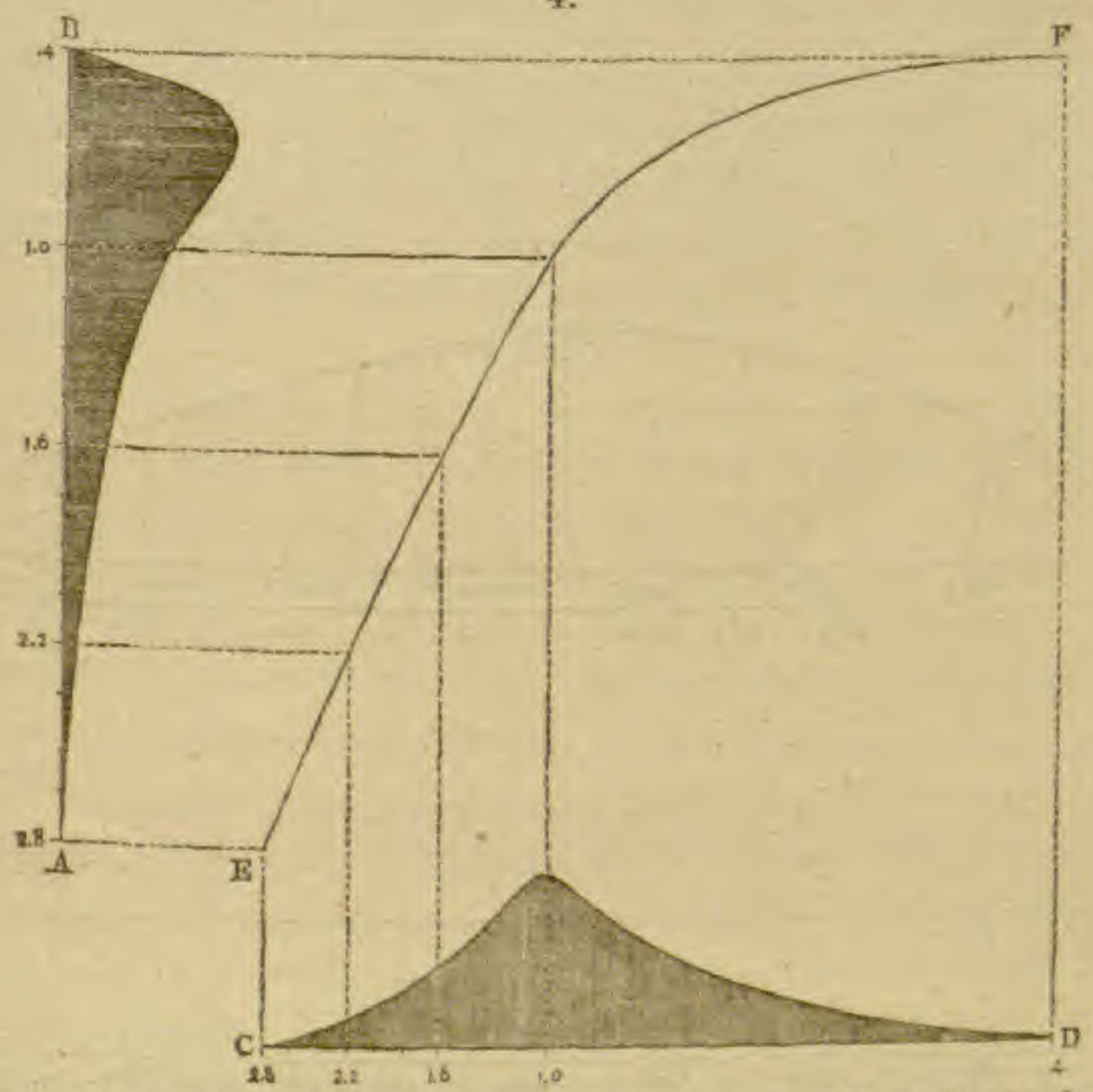
The true normal energy curve with all its inflections, maxima and minima, is easily drawn after this (dotted) bounding curve of normal energy,* is plotted, for the parts of the ordinate of the latter below and above its intersection with the former irregular curve, bear the same proportion to each other as in the prismatic spectrum, and we thus finally attain the object of the preceding labor.

If now it is desirable to map the distribution of the energy on any other scale, such as that on which the abscissæ are proportional to the times of vibration, this can be done with facility. Thus, in the supposed instance, we have only to find $\frac{1}{\lambda}$ for each vibration number to get the abscissæ, and (observing that since y now $=\frac{1}{\lambda}$, $\frac{dy}{d\lambda}=-\frac{1}{\lambda^2}$) to use the multiplying factor $\frac{1}{\lambda^2}$ to obtain the height of the new ordinate in each instance.

from which $d=b \tan \phi$.

Now, where a and c are indefinitely small, b and d are the ordinates of the prismatic and normal energy curves, respectively, at a given wave-length, and ϕ is the angle formed by the tangent to EF at their point of intersection. Hence, to find the height of the normal curve at a given wave-length, the corresponding ordinate of the prismatic curve must be multiplied by $\tan \phi$.

4.



* This Journal, for March, 1883, Plates III and IV (where, however, the maximum ordinate of the normal curve is through an error in the drawing not shown quite in its true position, nearly at $\lambda=0{\cdot}55$).


A.
0.30 0.50 0.70 0.90 1.10 1.30 1.50 1.70 1.90 2.10 2.30 2.50 2.70
B.
3.00 2.50 2.00 1.50 1.00 0.50
0.30 0.40 0.50 0.60 0.70 0.90 1.20 1.50 2.80
C.
9.50 9.60 9.70 9.80 9.90 0.00 0.10 0.20 0.30 0.40
0.30 0.40 0.50 0.60 0.70 0.80 1.00 1.30 1.60 2.00 2.80
D.
0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00 1.10 1.20 1.30 1.40 1.50 1.70 2.00 2.80
A. B. Schanz, Del.

If the length of the new energy curve between the limiting perpendiculars (which now represent the reciprocals of the wave-length), is to be the same as in the old, we must introduce a constant multiplier n, writing the equation of the interpolating curve $y=\frac{n}{\lambda}$, so that the multiplying factor becomes $-\frac{n}{\lambda^2}$.

I have drawn in this way (on a smaller scale than that of the normal or prismatic curves and following the smooth curve in the former as my original) four different schemes for the distribution of the energy. Curve A, fig. 5, represents the distribution of solar energy (after absorption by our atmosphere) on the normal scale. Curve B, fig. 5, represents the same distribution on the scale of wave-frequency (general equation of interpolating curve $x=\frac{1}{\lambda}$, proposed by Mr. Stoney.) Curve C, fig. 5, represents the distribution according to a proposal ($x=\log \lambda$) of Lord Rayleigh.

Curve D ($y=C$) is quite different from any of the preceding. It gives the distribution on a scale I have never seen proposed, but which I have found useful. In this, the bounding curve is a *straight line* parallel to the axis of X. This construction is not well suited to exhibit the cold bands, but if we consider only the general distribution of the energy we shall find that curve D is not merely suggestive as illustrating what has already been remarked here as to the conventional character of the methods of showing this distribution, but that it has more practical uses, for in this last construction, it is easily seen that the sums of the energies between any two wave-lengths whatever, are directly proportional to the distance between their ordinates, measured on the axis of X. If then we desire (for instance) to know what relation the invisible bears to the visible heat, or to enquire about what point in the spectrum the energy is equally distributed, these and similar problems are solved through curve D by simple inspection.

I have not been able yet to repeat the preceding determinations upon the lower part of the spectrum as often as I could wish. They are susceptible of improved accuracy by still longer experiment, but I think that within the limits of error indicated they may already be useful. I should add that throughout this investigation I have received constant and valuable aid from Mr. J. E. Keeler, not only in the graphical constructions, but in the experiments and in the computations, through all the details of which his aid has been more that of a coadjutor, than an assistant.

Allegheny Observatory, Allegheny, Pa., October, 1883.

NOTE.—Since the above was in type I have seen the interesting article by Mr. H. Becquerel in the Annales de Chimie for September, 1883.

The wave-lengths assigned by M. Becquerel to the band at the limit of his researches at $1^{\mu}\cdot460$ to $1^{\mu}\cdot480$ appear to me too great, for this limit corresponds to the diffuse margin of the wide band the wave-length of whose coldest part is given at $1^{\mu}\cdot36$ to $1^{\mu}\cdot37$ on my chart, published in the Comptes Rendus of the previous year (Sept. 11, 1882) and on a larger scale in the American Journal of Science for March, 1883, and in the Annales de Chimie for August of this year. I regret that M. Becquerel has not read the article in the Comptes Rendus. Had he done so he would have seen that the wave-lengths there given were not conjectural, but directly determined by the only practical method from the use of a grating. They were the result, in fact, of the measurements I have just described, and were specially intended to give information about the unknown region extending beyond the limit of M. Becquerel's researches, such as the great newly discovered band Ω, for instance, which stretches from wave-lengths $1^{\mu}\cdot80$ to $1^{\mu}\cdot90$, while M. Becquerel's farthest band as I have said is at $1^{\mu}\cdot48$ (according to him; but according to my measures more nearly at $1^{\mu}\cdot38$). The present memoir will show what degree of reliance may be placed on these measurements.

It is understood that a photographic map of the spectrum to $1^{\mu}\cdot6$, and therefore covering the ground of M. Becquerel's paper, but not extending as far as my Ω, will shortly be published from the joint labors of Professor Rowland and Captain Abney, and as their results from the nature of the method may be expected to be in this respect more exact than the preliminary explorations in which either M. Becquerel or myself have been engaged, we may await its appearance for the determination of a part, at least, of the points in question.

I would call attention to the fact that M. Becquerel has stated that the farthest band known to him in Sept., 1883 (except from my own researches), had a wave-length of not over $1^{\mu}\cdot50$, according to his own estimate.

ART. XXIII.—*The Quaternary Gravels of Northern Delaware and Eastern Maryland;* by FREDERICK D. CHESTER. (With Map.)

THE following paper contains the results of a study of the Quaternary clays and gravels of Northern Delaware and Eastern Maryland, comprising in area the larger portion of New Castle and all of Cecil county, and extending over a period of nearly a year and a half. During the continuous work in the field for the past three months, the northern boundary of the formation or shore line of the Quaternary estuary has been traced for a distance of forty miles, from the northeastern border of Delaware across the State into Maryland, to within a few miles of the Susquehanna, where it curves to the south, running parallel to the river until it reaches the head of the Chesapeake, west of Charleston. All of the area south of this line to a parallel marking the southern border of Cecil county has been systematically studied and is the territory presented for consideration. The entire Delaware and Chesapeake Peninsula is covered with estuary deposits of Quaternary age, and as the present season of field work has been closed, and as the accumulated facts of the whole area would be too great for a single paper, the author has thought it best to divide the whole peninsula into two or three divisions, and to treat each separately, and as fully as the facts deserve.

At the present time we shall therefore discuss what we shall call the northern area.

The history of these deposits forms a part of the history of the flooded Delaware whose record is written upon both sides of the river, as far north as Belvidere, where the much swollen stream entered the region of glacial ice and débris. Although any systematic study of the Delaware flood deposits has been, until lately much neglected, it is certain that whenever the scattered pages of this history shall have been collected, they will form an interesting addition to our present knowledge of glacial and postglacial geology.

General considerations.—South of the region of gneissic and granitic rocks, which are the highlands of both States, all the main topographical features are dependent upon surface formations, the chief among them being of a gently rolling and even morainic character due to the accumulation or irregular distribution of gravel, varying in nature from the finest sand and loam, to pebbles, cobble stones, and bowlders of several tons in weight. Were it not for the preconceived idea of a southern latitude, one might, from a narrow circle of observation imagine himself in the region of the *moraine profonde.* So great is the physical importance of these morainic gravels that one is immediately led to the study of them in their relation to the Delaware flood history.

Generally speaking, we may say that the whole region is covered with an upper stratum of yellow brick clay, sand, loam or loamy gravel, having an average thickness of about three feet, which is underlaid by a thicker stratum or series of strata of gravel and sand, varying largely in its characters and degrees of coarseness, and having a usual thickness of from 3 to 20 feet. The former homogeneous stratum we shall call, after Professor H. C. Lewis, the Philadelphia Clay, and the latter less homogeneous deposit, after the same author, the Red Gravel. Although the Philadelphia Clay and the Red Gravel are generally distinct deposits, with their well marked characters, such is not always the case, for the two often run into each other indistinctly, the underlying gravel becoming slowly argillaceous as the surface is reached, or again the junction between the two being entirely obscured, or at best but an indistinct wavy line. We therefore regard the two as contemporaneous deposits, with little or no break in the deposition, the one requiring quiet and the other troubled conditions of sedimentation. Considering these facts it seems proper that the two indistinct deposits, i. e., the Philadelphia Clay and the Red Gravel should be included under one head, which we shall hereafter call the *Delaware Gravels.*

The Philadelphia Clay.—The Philadelphia Clay or loam is the universal soil of the entire region, and is an unbroken continuation of the gneissic soil of the hills, distinguished from the latter only by the presence of highly water-worn quartzose pebbles. In lithological characters it varies greatly, but in all cases the sand particles are rounded so thoroughly that the sedimentary and remote origin of the clay is at once obvious. It ranges from a highly plastic brick clay to a loam, even at times becoming a fine white glass sand. It is usually highly micaceous, and although sometimes entirely free from gravel is upon the whole more or less filled with it, together with bowlders varying in weight from five to several hundred pounds. So true is this latter statement that often the deposit assumes the characters of a true bowlder clay, which fact has led other geologists to regard it as the same material transported from the glacier's foot. This is more particularly true of special regions, yet the illustrations might be increased indefinitely. Between Elkton and Chesapeake City, the Philadelphia clay is represented by one thick layer of gravel, cobble stones, and bowlders, cemented by the smallest quantity of a very stiff clay, and rising in high hills with intervening bowl-like depressions. This diluvial stratum which ranges in depth from 5 to

20 feet is found to rest directly upon the Cretaceous with an entire absence of the Red Gravel. Also between Gravelly Hill and Charleston the same features are prominent; the Philadelphia stratum varies from a refractory white clay to a coarse yellow and white gravel, while the surface is literally strewn with cobble stones and bowlders, making the country unusually barren.

Near the neighborhood of Christiana, and from there to New Castle, the clay rises in high hills along the creek, where it is, in places, entirely replaced by bowlders and cobble stones, representing the Potsdam, Millstone Grit, and Trias.

The true brick clay is confined to the low flat lands along the border of the Archæan hills, where the extensive brick yards of Wilmington, Newark and Elkton obtain material for the best variety of brick; but traveling to the south, especially between Kirkwood and the Canal, or to the southwestern limits of the region, the clay changes to a sandy loam or even a yellow and gray sand, which is always mixed with its due proportion of gravel.

The Red Gravel varies still more than the clay in its lithological characters, and consists of coarse red, yellow and gray sands, mixed with very characteristic white oval quartzose pebbles varying in size from a bean to a hen's egg.

From the similarity between widely separated sections, the Red Gravel seems to have a rough arrangement into three distinct strata with quite constant lithological differences. This arrangement is no doubt continuous, although there are local exceptions where only two out of the group of three are represented. In all cases, however, the order of superposition remains the same, while each stratum maintains its own individuality. Beginning with the base of the Philadelphia clay, the following is the order, with the characters of each stratum.

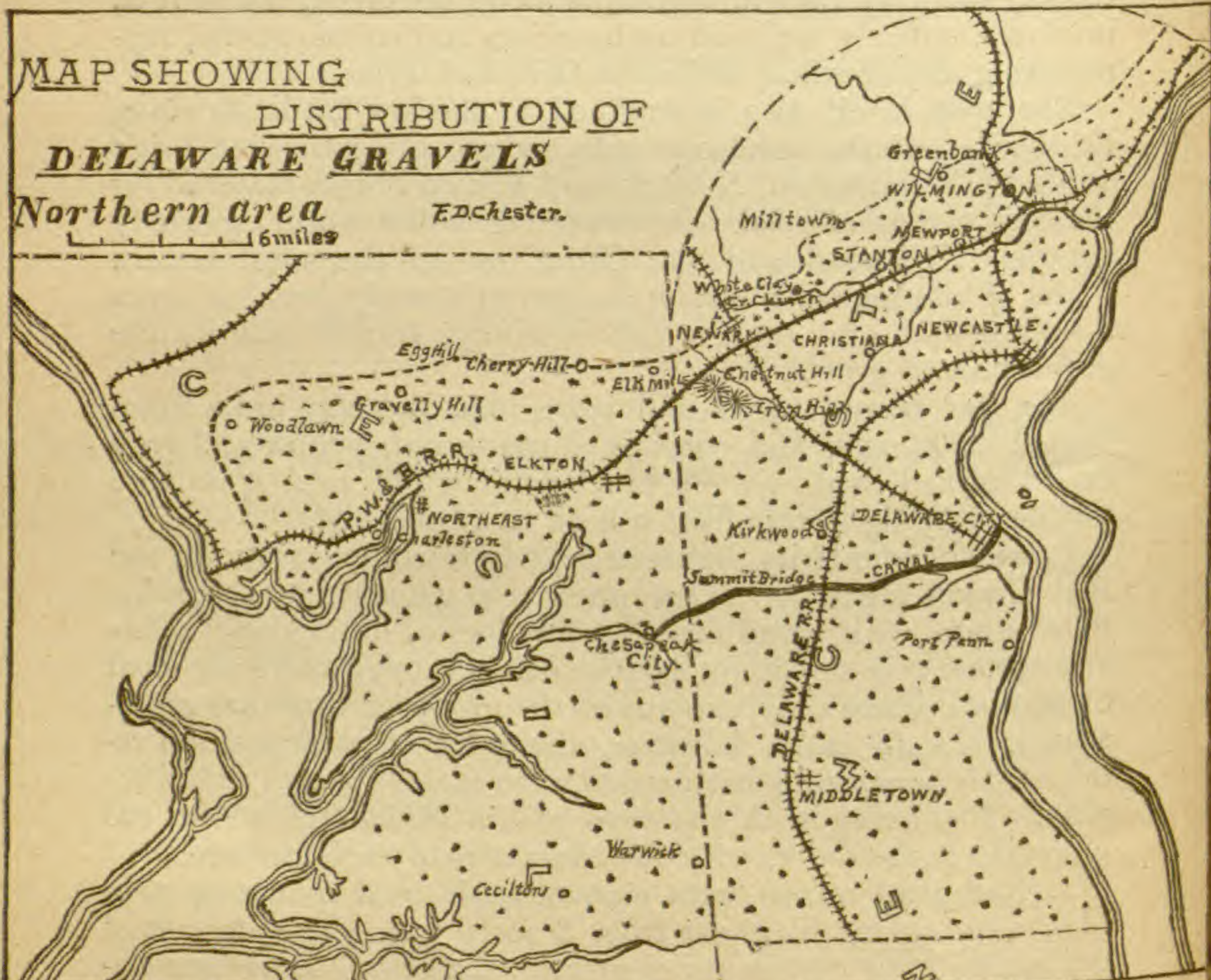
1. Red sand mixed with characteristic oval quartzose pebbles, varying in thickness from 3 to 10 feet. The amount of red argillaceous matter varies greatly, the gravel sometimes being clean, and again when wet forming a very disagreeable mud. It is generally free from, yet again, is entirely filled with fragments of mica and mica schist, becoming a red micaceous sand.

2. Alternate layers of pebbles, with coarse red, yellow, gray and black sand, *entirely free from argillaceous matter*, and showing excellent examples of irregular bedding, particularly oblique lamination, and flow-and-plunge structure. This stratum varies in thickness from 3 to 10 feet.

3. A fine, clean yellow sand showing very delicate examples of oblique lamination with flow-and-plunge structure.

The Red Gravel is abundantly exposed along all the roads and railroads traversing the region, whenever the talus slopes can be sufficiently removed to give perpendicular cuttings, yet it is only in the deeper gravel pits and cuttings of railroads that the deposit can be sufficiently exposed to give complete results.

It covers the whole region examined, and appears to maintain as great a thickness along the southern line of our present area as to the north, one well near Middletown failing to penetrate the red gravel at a depth of 35 feet.



From the identity of this gravel with the deposits described by Professor H. Carville Lewis* as found along the valley of the Delaware River both north and south of Philadelphia, it is evident that the same is a true river gravel and similar to all the deposits which our present streams lay down over the beds of the estuaries into which they empty.

From the universal coarseness of the gravel, also, together with the abundant evidences of flow-and-plunge structure, more particularly shown along the northern line, it is evident that the same must have been deposited by a swift current, and

* Geology of Philadelphia. Lecture before the Franklin Institute, Jan. 12, 1882.

yet from the vertical heights at which this gravel is found the current must have been deep as well as swift. A glance at the map will show that the northern limit of the Delaware Gravels runs approximately parallel to the river, where the same crosses the northern limits of the State. This river during the latter part or close of the Glacial period was, as we know, a swollen rushing flood, having a width of about ten miles and an average depth of over 200 feet. It emptied into the Delaware Estuary near Wilmington, and its current, urged on with a tremendous head, instead of bending to the south and southeast, as is indicated by the present flow of the river, must have continued in its same southwesterly course entirely across the State into Maryland, until it reached the head of the Chesapeake, where it was stopped by the high hills which rise above the level of the shore line. A belt of gravel thus stretched across the head of the estuary by the current of the river would be subsequently spread out by the waves as a broad sheet to the south.

During the entire time spent in systematic work in the field, the record of every section has been kept; between them all there is great similarity, hence it will only be necessary to give a few of those which show most clearly the range of variation. The new extension of the Baltimore and Ohio Railroad now in process of construction, and extending approximately along the entire length of the shore line has offered most valuable aid, especially as the sections there are freshly cut.

Section on Baltimore and Ohio R.R., Newark, Del.

	Feet.
1. Yellow brick clay, free from gravel	3
2. Red Sand, highly argillaceous, free from gravel	8
3. Rock undecomposed.	

Section in Gravel Pit, Newark, Del.

1. Yellow brick clay, free from gravel	3·5
2. Red micaceous sand, free from argillaceous matter with coarse gravel and sand in lower part	12
3. White fire clay. Cretaceous.	

One mile north of Newark, on Pa. R.R.

1. Yellow brick clay	3·5
2. Red sand, coarse, micaceous with oval quartzose pebbles	3
3. Alternate layers of gravel, with black and brownish sand, irregular bedding with flow-and-plunge structure	3·75
4. Fine yellow clean sand	2·5+

Two miles northeast of Stanton, Del., on Baltimore and Ohio R.R.

	Feet.
1. Loam and sandy clay	4
2. Red, yellow and black sand with alternate layers of pebbles, no argillaceous matter. Very fine examples of flow-and-plunge structure, and other varieties of irregular bedding	20+

Stanton, Del.

1. Yellow clay, sandy and micaceous	4
2. Red sand 3. Alternate layers of clean sand with coarse and fine gravel, with flow-and-plunge structure	14+

Newport, Del. (gravel pit.)

1. Yellow clay	2
2. Coarse red sand and gravel, compact and highly argillaceous	10
3. Yellow sand, delicate examples of flow-and-plunge structure	2+

Wilmington, Del. (gravel pit), altitude 264 *feet.*

1. Yellow clay	3
2. Red sand, compact and argillaceous with pebbles	6
3. Alternate layers of yellow and black sand with pebbles, flow-and-plunge structure	10+

Christiana, Del. (gravel pit.)

1. Yellow clay	8
2. Coarse clean sand and gravel irregularly bedded	6+

Delaware City, Del.

1. Yellow clay	2·5
2. Irregular layers of red sand and coarse gravel	4
3. Yellow and gray sand with fine oblique lamination	2+

Section 1·5 *miles south of Kirkwood, Del.*

1. Yellow, gravelly clay	3·5
2. Coarse red and black sand with gravel	4+

Gravelly Hill, Md., (altitude 388 *feet).*

1. Yellow clay	2·5
2. Red compact gravel, highly argillaceous	12+

(A well near this spot showed a depth of the gravel of 30–40 feet, with fine sand below.)

Middletown, Del.

1. Yellow clay	2·5
2. Red sand and coarse gravel	35+

The Shore line.—After having finished the tracing out of the shore line of the Delaware estuary, which is recorded upon the map, the measurements of the altitudes of the terrace at different points along its line were undertaken. All the heights were taken with a Gay-Lussac barometer, with vernier arrangement for measuring tenths of millimeters, making the usual allowances for temperature. Each measurement was accompanied by a duplicate, and only confirmatory results accepted. By this method much more accurate results were obtained than could be with the use of the aneroid.

All altitudes were calculated from tide water at Delaware City.

	Feet.		Feet.
Back of Wilmington	264	Newark, Del.	100
Green Bank, Del.	269	Elk Mills, Md.	166
Back of Newport	284	Brewster's Mill, Md.	216
Back of Stanton	249	Cherry Hill, Md.	255
Milltown, Del.	260	Back of New Leeds, Md.	360
Pike's Creek, Del.	192	Egg Hill, Md.	370
White Clay Creek Church, Del.	145	Gravelly Hill, Md.	388

From these figures it is seen that the shore line is by no means a level one, and to a person acquainted with the region the reason is obvious. The shore line rests throughout its whole length upon the slopes of the Archæan highlands; these slopes have since the final elevation of the land suffered great disintegration, whereby all definite traces of a terrace have been destroyed, and the author has found it to be generally true that wherever the gravels rose to great height, the underlying rock was hard and durable, and *vice versa.* At Newark the shore line rises only 80 to 100 feet above tide; here the rocks decompose rapidly, while between Stanton and Newport, along the hills, the gravel rises over 200 feet higher, and here the rock, a fine-grained quartzitic gneiss, is extremely durable. Also along the terrace between Gravelly and Egg Hills, the gravel rises to the greatest elevation along the line, while here again the rock, which is a dioritic trap, is even more durable than back of Stanton. We have then to regard the present limits of the gravels as the ragged remnants of what was once a level terrace due to the varying durability of the hills on whose flanks the shore line rested.

That this is true is shown by the finding of cobble stones and even bowlders in places at considerable distances above what is apparently the line of the terrace, mingled with the angular detritus of gneiss. In places in Cecil county, in traveling from the hills into the region of gravel, I have often thought I had reached the shore line by the piles of cobble stones on every hand, when a few steps beyond would bring me into a region of angular fragments again, while still further beyond, the unbroken expanse of gravel would be reached.

But the best evidence bearing upon this point is to be found near Newark. I have said that there the gravel only rises about 100 feet above tide, where the rock is a very friable mica schist and plagioclase gneiss, both of which are now decaying with great rapidity. Iron Hill, as will be seen by the map, is situated about three miles due south, and here I have found a few of the characteristic quartzose cobble stones within about 30 feet of the summit or at a height of about 225 feet above tide, instead of 100 as is the case at Newark. These facts are enough to convince us that the present shore line is not the original one, which would, in many cases, considering the topography, have to be several miles to the north. Taking the facts as a whole, however, the depth of the estuary waters, or depression of the land, must have been at least 350 feet, which depression would have sufficed to cover the whole peninsula with water, uniting the Delaware with the Chesapeake. This glacial arm of the sea we shall most fittingly call the *Delaware Estuary.*

The floor of the Estuary.—The base of the Delaware gravels, which is both the plastic clay of the Cretaceous, and the upturned edges of the gneiss, has everywhere suffered erosion. The red clay is generally a wavy irregular line, while the gneiss when not decomposed has been well worn. Clearly marked diluvial grooves have in several cases been seen running with the direction of the current, whenever the upper edges of the rocks happened to be freshly exposed, while again the edges have undergone a rough polishing as from the corrasive action of transported sand.

Bowlders.—Besides the Delaware gravels, a most characteristic feature of the region is its bowlders. By this we, more particularly, mean those isolated ones, which cover the surface of the clay, rather than those which form a part of the clay itself, although they are contemporaneous and have the same rock representatives. They are usually quartzose, including the glassy, flinty and quartzitic varieties, and vary in size from several hundred pounds to a ton or more in weight. Great piles of these have been collected from numerous fields. The quartzose varieties, even those of several hundred pounds weight, are all well rounded, evidently by water, and show no glacial scratches. Those made up of coarse constituents are more angular, and in some cases have shown obscure evidences of glacial markings, though as a general thing they show no such signs. Their glacial and iceberg origin is however certain, belonging to those bowlders borne upon the surface rather than ground beneath the glacier's base. The largest ones are scattered over the low ground or Cretaceous plain, yet often those weighing several hundred pounds are found as high as 250 feet above tide. Among the rock species found in bowlder examination, the following are the most prominent:

1. Fine grained red sandstone, certainly Potsdam.
2. Dioritic trap, similar to Triassic bedded trap, (one $3' \times 2\frac{1}{2}' \times 2'$).
3. Yellow friable-sandstone.
4. Hornblende rock in massive bowlders, (one $2' \times 1\frac{1}{4}' \times 1\frac{1}{2}'$.)
5. Black micaceous granite, foreign to the State, (one $2\frac{1}{2}' \times 2' \times 1'$.)
6. Gneiss far to the south, (one $2' \times 1\frac{1}{4}'$).
7. Compact gray limestone.
8. Quartzose, (one $3' \times 2'\ 9'' \times 2'$).

The evident fact that these larger bowlders are of iceberg origin, and their similarity with the smaller ones embedded in the Philadelphia clay, show that this deposit was contemporaneous with the final breaking up of the glacier. Even the unscientific eye cannot fail to be attracted to the great abundance of cobble stones which cover everywhere the surface of the country, and made to see the great part which icebergs play as agents of transportation and deposition.

Bowlders from Iron and Chestnut Hills.—The author has in a former paper (this Journal, Jan., 1883), called attention, under the title of *Bowlder Drift in Delaware*, to two hills lying to the south of Newark. These solitary elevations have for an indefinite time attracted the attention of local scientists, who I believe have been united in their statements as to the cause of their bowlder phenomena, which are thickly strewn over summit and flank. It would be unnecessary again to refer to this interesting case, except that several distinguished geologists unacquainted with all the facts, have been inclined to call the rounded trap rocks bowlders of disintegration, rather than of iceberg origin.

I have first to state, that since the writing of the paper above mentioned, there has been exposed an outcrop of serpentine rock, evidently eruptive, from the fact that the strike of the same is nearly at right angles with the Primary gneiss, following the trend of the hills. How wide this serpentine dike is we are unable to state, but it evidently forms the core or backbone of the elevations.

A glance at the map again will show that these hills lie directly across the current, which by checking its force and producing an eddying would have caused an unusual deposition of the gravel at that point. Icebergs, with their roots reaching deep into the water would further be stranded, and their large bowlders dropped. It is then easy not only to account for the great thickness of gravel which washes their bases, but also for the enormous rounded bowlders of trap which cover their faces. The height of Iron Hill as stated in the previous paper, and confirmed by a late measurement is 227 feet, or 275 feet above tide. This hill must have then been totally submerged. To those who still think that the trap bowlders are of dike origin, it will be best to present the following arguments:

1. At the northern foot of Iron Hill, there was found an immense pile of rounded and sub-angular bowlders piled on top of each other, like stone dumped from a cart. These were not rolled bowlders, for their size of many tons would preclude all idea of their being thus piled up. With these were associated large quartzose bowlders of undoubted iceberg origin.

2. Bowlders similar to those covering the hills are found to the northeast, and in fact as far off as Christiana and Stanton.

3. Bowlders are found lying upon the ground above the iron ore pits, while no signs of a similar rock are found in the cuttings either fresh or decomposed.

4. The trap bowlders of supposed dike origin are found associated with other rocks of which we have: one bowlder of red orthoclase granite, one bowlder of black micaceous gneiss, one bowlder of limestone, numerous bowlders of decomposed ferruginous quartz, and bowlders of a coarse ferruginous sandeston which have been found scattered quite widely over the area to the northeast. These latter rocks were found in such large quantities upon the hill that they were utilized as trimmings for the Presbyterian church of Newark.

With the main facts of the case thus briefly stated, it seems that there can be left no room for doubt as to the iceberg origin of the trap bowlders even in such isolated positions.

Morainic Phenomena.—We have already referred to the morainic character of the whole region of which we have been treating. These hummocky elevations are cut through by every road, whereby their internal nature is revealed. Sometimes they rise to a height of fifty feet, but have a general elevation of from ten to twenty. They are absent from no part of the region, and with the enclosed bowl-like depressions which separate them, the whole country assumes a rolling character. This is generally due merely to a swelling of both the clay and underlying gravel, but as the clay has but slight thickness compared with the height of the *moraines*, and as this thickness is usually uniform, the swelling becomes mainly confined to the underlying gravel. This gravel deposited in the troubled waters of the glacial and post-glacial estuary, with its strong currents, eddies, and waves, was therefore deposited unevenly over the estuary floor. Taking into further consideration the erosion which the gravel must have suffered during the deposition of the clay, with the comparatively slight erosion from surface washings and weathering, since the region became land, we can easily account for all the physical features of the surface.

But besides these mere swellings of the surface formations, there are occasionally found coarse gravel hills, which probably were shoal deposits. They rest upon the Philadelphia clay, with their bases ground into it. They are later in age than the latter deposit, belonging to the time when by the final elevation of the land, the waters of the estuary became more shallow and thus more efficient in piling up such shoal deposits. Between Newark and Elkton, a gravel hill rises to a height of 50 feet above the railroad. It is made up of coarse, clean, yellow sand, with pearly white quartzose pebbles. No stratification is visible and the gravel extends downward for the whole 50 feet before the true estuary deposit is reached.

Modern alluvium.—Following the river, from the northern to the southern limits of the region one notices a belt of marsh land upon the Delaware side, beyond which are the gentle swellings of the gravels. This marsh land has been made in very recent times, and consists of black mud, blue clays and river sand of great thickness. A boring made upon the Fort Delaware Island has penetrated through alluvium for a distance of 100 feet.

This alluvial formation has no particular geological interest, except that it indicates a greater width, but not necessarily a greater height of the river than at present.

Resumé.—In conclusion, the following are, in brief, the main events of the Delaware flood history as revealed by the observed facts. Toward the close of the Glacial period, the land of the peninsula became depressed to a distance of at least 350 feet. Into the Delaware estuary thus formed the river of the same name, fed by the melting glacier, poured its swollen rushing flood. Its current, urged by such a tremendous head, pushed its way across the States of Delaware and Maryland, to the head of the Chesapeake. By means of this current and the subsequent distributing action of the waves, the red gravel was deposited.

Later on, the extreme violence of the flood subsided, the land began to rise, and the glacier of the far north to break up. During this quieter period the Philadelphia clay was deposited, while the floating icebergs descending the river dropped over the estuary floor its bowlders. The land continued to rise, until the water became shallow, when the shoal gravels were piled up by the waves and tides, and the elevation still continuing, the river began more and more to assume its present channel, and the waters of the Delaware and Chesapeake were finally parted.

Delaware College, Jan. 1st, 1884.

Art. XXIV.—*On the identity of Scovillite with Rhabdophane;* by Geo. J. Brush and Samuel L. Penfield.

Last spring we described a hydrous phosphate of the cerium and yttrium earths from Salisbury, Conn., as a new mineral, giving it the name Scovillite.* Our attention has recently been called to the close resemblance of this mineral with rhabdophane, a mineral from Cornwall in England, originally described by W. G. Lettsom,† as essentially a phosphate of didymium and other cerium earths and supposed to be analogous to monazite in composition. A further investigation of rhabdophane by E. Bertrand‡ gave the composition as an *anhydrous* phosphate of cerium and yttrium earths closely related to phosphocerite and cryptolite. A more recent investigation by W. N. Hartley,§ however, proves the mineral to be a *hydrous* phosphate of these earths, of essentially the same composition as scovillite. Professor Hartley's analyses were published in advance of ours and we greatly regret his paper was not seen by us prior to the announcement of our results. Taken in connection with the description of the physical characters given by Lettsom, these analyses leave no doubt as to the essential identity of the two minerals, although there are variations in the relative amount of the constituent isomorphous earths. The American mineral contains no cerium oxide, and has a larger percentage of yttrium earths.

Our mineral contained 3·59 per cent of carbonic acid, which we stated might be considered as due to admixture with lanthanite $R_2(CO_3)_3$ $9H_2O$, or possibly it might be an undescribed carbonate of the composition $R_2(CO_3)_3$, $3H_2O$. In the former case the remaining scovillite would have the composition $R_2(PO_4)_2H_2O$, in the latter it would be $R_2(PO_4)_2$ $2H_2O$. The English rhabdophane is shown by Hartley to be free from carbonic acid, and the composition is $R_2(PO_4)_2+2H_2O$, consequently we must conclude that the American mineral (scovillite) is associated with a carbonate of the composition $R_2(CO_3)_3$, $3H_2O$. Assuming this to be true we have present in the analysis we have given 14·11 per cent of this carbonate with 85·72 per cent of $R_2(PO_4)_2$ $2H_2O$. If we may calculate the theoretical composition of this phosphate, assuming the relation of the yttrium to the cerium earths to be 1 : 4, we have P_2O_5 28·40, $(Y,Er)_2O_3$ 11·12, $(La, Di)_2O_3$ 53·28 H_2O 7·20 = 100. This is in close cor-

* This Journal, III, xxv, 459, June, 1883.

† Comptes Rendus, April 22, 1878. Communicated to the Academy by M. Lecoq de Boisbaudran.

‡ Bulletin de la Société Minéralogique, iii, 61.

§ Journal of Chemical Society, May, 1882, p. 210.

respondence with the results found by Hartley and ourselves, which calculated for comparison up to 100, are as follows:

	Rhabdophane.*	Scovillite.	Theory.
P_2O_5,	26·26	29·10	28·40
$(Y,E)_2O_3$	65·75	9·93	11·12
$(La, Di)_2O_3$		53·82	53·28
Fe_2O_3,		·29	
H_2O,	7·99	6·86	7·20
	100·00	100·00	100·00

Of the Cornish mineral it is stated that only four specimens are known, and these are from old collections made in Cornwall prior to 1820. It is a very interesting circumstance that this rare hydrous phosphate should be found in this country, although here also only a few specimens have thus far been obtained.

ART. XXV.—*The Sun Glows*; by HENRY A. HAZEN.

(Read Feb. 16th, before the Philosophical Society, Washington, D. C.)

THE recent brilliant lighting up of the skies after sunset and before sunrise have attracted universal attention, mingled in many instances with not a little superstitious dread. Physicists have taken the matter in hand and have advanced the most diverse hypotheses for an explanation. One of these is that immense volumes of volcanic gas were ejected on Aug. 26, 1883, into the atmosphere from the Straits of Sunda, and that these glows have been due to the diffusion of this gas, and furthermore that this gas has so enveloped the earth as to keep in its summer warmth, so that a mild winter has resulted.

Another theory, which seems to have gained the most adherents of any, is that the volcanic eruption mentioned above filled the air to a great height with ashes and that the upper currents have distributed these ashes over the earth, thus causing an ash canopy, reflection from which results in the glow. This is the theory so ably advocated by Mr. Lockyer in Nature, and more recently by Mr. Upton in Science.

The seemingly unusual nature of the phenomenon, calling for an extraordinary explanation, has induced some to advance the theory that the earth in its orbit has encountered a stream of minute meteors or a cloud of cosmic dust, and that the glow

* Hartley's analysis gave (Ce, La, Di, Yt.)$_2$O$_3$ 61·69, P_2O_5 24·64, Al_2O_3, Fe_2O_3, CaO, MgO with some P_2O_5 1·93, SiO_2 3·76, combined H_2O 7·50=99·52. The above excludes 5·69 impurities, *loc. cit.*, p. 214. Other analyses are given in the paper, in one of which 23·19 per cent. cerous oxide, and 2·09 yttrium oxide were obtained.

is due to reflection from these particles kept at a great height by electrical repulsion.

It is the purpose of this article to give:

1st. A general idea of the earliest appearances of the phenomenon. 2d. To describe what may be seen by an ordinary observer even to-day. 3d. To present the vapor theory and answer objections. 4th. To show why the "volcanic ashes" and "cosmic dust" hypotheses are untenable.

Remarkable sunset phenomena are reported as occurring on various dates at the following places.

Date.	Place.	Lat.	Long.
1883, Aug. 28.	Mauritius	20° S.	57° E.
30.	Maranham, Brazil	2 S.	44 W.
Sept. 1.	New Ireland	5 S.	152 E.
2.	Venezuela	10 N.	65 W.
5.	Hawaii	20 N.	156 W.
8.	Ceylon	7 N.	80 E.
15.	South Australia	38 S.	143 E.
20.	Cape of Good Hope	35 S.	20 E.
Oct. 8.	Florida	29 N.	82 W.
19.	Yuma, Cal.	33 N.	114 W.
Nov. 9.	England	52 N.	0
20.	Turkey.		
27.	British Columbia, Ala., Cal., Conn., Dak., Fla., Ga., Ills., Ind., Iowa, Kans., Me., Md., Mass., Mich., Mo., Neb., N. H., N. Y., N. C., Pa., Va., Wis., Germany, Italy, Spain, France, Sweden, England.		

Allowing for cloudiness, on certain days, it will be seen that before Sept. 8 a belt of the earth's surface 15° on either side of the equator was suddenly visited by the phenomenon. At first sight it might appear that there was a regular progression from the Indian Ocean westward, but on that supposition it would be hardly possible to explain why Venezuela should have seen the glow six days earlier than Ceylon, though somewhat farther north. The phenomenon might have been seen at Hawaii and even at Ceylon the last of August had it not been for cloudiness; and granting this it is plain that appearances might have been well nigh instantaneous over the regions near the equator. The glow was marked at Yuma on Oct. 19, 20 and 21, after which it ceased for a month. It was first seen in the eastern United States on Oct. 30, when the appearance was very brilliant; the same sight presented itself the next night, but after that it did not again appear as bright, though carefully looked for, until Nov. 27. On this night the spectacle in the southwest was grand and acknowledged by all as the finest even to the present time. The fire engines, at Poughkeepsie, N. Y., and at New Haven, Conn., were summoned to "quench the burning skies." On the succeeding night the scene was nearly the same. Since Nov. 28, the phenomenon has continued more or less brilliant, and with a few complete absences it has appeared down to the present.

A very remarkable fact is to be noted in connection with the display of Nov. 26 and 27, and that is, the sudden brightening over an immense region extending over half of Europe, over nearly the whole of the United States and British Columbia, though it had not been specially noted for about a month previous.

It may be interesting to note a few of the more detailed observations that have been made.

First. Just before and during the glow at night and after it in the morning, grayish, horizontally stratified, light clouds or striæ have appeared above the sun and have extended to right and left. These are invariably present with the glow, though the sky may be otherwise cloudless. On a careful examination, in the evening, these striæ will be usually found passing from a point 20 or 30 degrees to the left of the sun to the right and left and frequently overhead, reminding one forcibly of polar bands which are generally seen in eastern United States (where all these observations have been made) passing from S.W. to N.E.* In the morning in like manner striæ are seen passing above the sun and descending to the NE. or N. and SW. or S. Often the directions of these striæ are confused and marked by cloud layers somewhat nearer the earth.

What are these striæ? On Feb. 1 at 5 P. M. with the sun 10° high the striæ were the plainest yet seen, many of them passing overhead in continuous lines to the NE.

On the right of the sun they were more distinct than on the left, and the radiated structure was very plain, emanating from the N.E. point of the horizon. The next morning the sky was clear, it was even possible to separate ε Lyræ into its components, the striæ were not visible at the first blush of morning, but a careful examination finally revealed them though very faint and of limited extent. On February 2d the appearances were about the same as the previous evening. In the S. a plain cirrus cloud was seen at a great hight, its well-marked streaks dipped to S.E. and W.S.W., appearing as if at the outskirts of a great cloud system gradually advancing from S., though the actual motion of the cloud was from west to east. The streaks of cirrus while prominent did not have a sharp outline and were more or less broken up, while the striæ to the right were sharply defined and unbroken. At 5.30, the sun having set, the cirrus streaks overlapped the striæ and appeared plainly between them and the eye. At 5.35 the glow had begun in the horizon but was at a very low altitude, the striæ being unchanged, while a slight blush just tinged the cirrus

* The term "polar bands" is unfortunate as the striæ are parallel and the seeming polarity is due to perspective. The Germans use "Fallstreifen," and some such word might well be coined in English.

streaks. At 5.38 the former were unchanged, the latter had become a bright red. At 5.43 a slight rosy appearance was noted on the striæ, the color on the cirrus having slightly faded. At 5.44 the striæ were a clear rose color, while the cirrus was only bright near the sun, all color having disappeared from it at 50° to the left. At 5.48 the upper striæ near the sun were bright rose while nearer the horizon there was a deep red color, the cirrus were only seen as dark clouds against the bright red back-ground. The glow was very brilliant and lasted until 6.40. It is plain that the striæ are far above the cirrus clouds and appearances show that they are similar in formation. Whether these striæ are the cause of the glow or not is discussed later on.

Second. During the day with a cloudless sky the sun has appeared as if shining through a dense haze.

Third. On four occasions, January 4, 5, February 2 and 3, the moon was seen shining through seeming water vapor at a great height, the appearance being similar to that frequently noted at other times than the present. There was no halo in these cases, but a distinct ring uniformly bright about 30° in diameter.

Fourth. Several times when there was a plain cloud canopy, though rather light, and through openings in which the blue sky could be seen, the ordinary sunset phenomenon has been seen, upon this canopy, with glowing colors, and one-quarter or one-half hour afterward there has been the wonderful after-glow lasting till the end of twilight.

Fifth. Several times with a clear sky no glow has been seen, though it was quite prominent two or three evenings before and after. This intermittent nature of the phenomenon is regarded as one of its most important phases.

Sixth. The glow has not been quite as deep red in the morning as at night. On the morning of January 27, with a cloudless sky, a grand sight presented itself in the S.E. and E. At 5.50 a red glow first appeared, at 6.10, an intense red had extended to a height of 30°, though a rosy flush was seen even up to 50°, the whole eastern sky was lighted up. The striæ were confused by cloud layers near the observer. This first appearance faded away, but was followed at 6.45 by a still brighter glow. It is probable that this second glow was different from the regular sunrise appearance at 7.13. On February 3, at 6.15 A. M., the sky was very clear and the glow had already begun. At 6.25 the first glow was at its height, it then diminished until 6.35, when there was a very deep scarlet near the horizon. At 6.42 the red again developed rapidly, and at 6.47 the sight was fine, the lower deep red tapering to a rose at 25° altitude, and continuing up to 50°. At 6.55 only a faint rose color was left. Thus the morning appearances differ from those in the evening, in that they show distinctly this double phenomenon. The two are identical to the observer and the second can be seen even in a perfectly cloudless day.

Seventh. Faint stars and clusters, notably Præsepe, have been easily seen even near the horizon. On January 27, in the morning, while the sky appeared covered by several distinct layers of cloud directly above the sun, yet it was possible to easily find Antares shining through the haze till twenty minutes before sunrise.

Seeking now a probable cause for the glow, it is suggested that at least three conditions are necessary to show the best results.

First. The sky must be clear or nearly so.

Second. There must be an abundance of reflecting, diffracting or absorbing material, as is shown by the well nigh world-wide appearances.

Third. There must be some force to carry the material to a great height or sustain it for a long time against the action of gravity. The lateness of the hour after sunset at which the after-glow disappears indicates that the material may be at a great height, and the fact of the later long continuance of the phenomenon shows that some force must be acting to keep up the particles.

The second condition is abundantly satisfied by the presence of watery vapor, ice crystals or frozen water particles under a peculiar form which is assumed in a rare atmosphere and at a low temperature. It must be admitted that the fact that watery vapor is universally and somewhat uniformly distributed over the earth's surface, and has always been found in great abundance at the extreme limits reached by aeronauts, is a most important one in this discussion. As to the peculiar form of frozen moisture or frost particles at high altitudes, the following experience of the writer may be of interest:

On Dec. 15, 1883, an ascent of Graylock, in Adams, Mass., was undertaken. This peak rises almost abruptly 2,700 feet above a plain which is itself 780 feet above sea level. The summit was reached at 7.30, and here a severe gale, estimated at fifty miles per hour, was experienced. The temperature was 7°·1 below zero and the air was completely saturated with vapor, the wet bulb, after most careful manipulations, reading about half a degree *higher* than the dry. While there seemed to be a grayish cloud overhead, absolutely no ice spiculæ or frost particles could be seen or felt. The sensation was almost a weird one, apparently a dense shadow in broad daylight, with nothing to cast it. That there were minute, invisible, frozen moisture particles, was plain from the beautiful appearance of all trees and shrubs which made it seem as if one had stepped into an ocean of gigantic coral formations. The frost work was from ·50 to ·75 inch thick upon the branches and trunks of the trees. The frost work after a time formed on the coat of the observer as if accumulated by degrees. These frost particles were too minute to be seen directly, but could easily be recognized either by looking through a great depth or by the effect of the sun's light upon them.

It is not definitely known what causes the ordinary sunrise and sunset colorings, but it is certain that they may occur in all their magnificence in clear skies. The opinion generally held, that they are caused by the absorption of the rays at the blue end of the spectrum by moisture or dust particles, will not explain the present glows. It has been thought, however, that they may be explained if we consider them due to reflection from definite particles in the air. One difficulty in this is that we must assume that reflection and absorption would produce an effect precisely similar to the ordinary phenomenon. It may be said that the ordinary coloring may be caused by reflection, but it is a little singular that such an explanation has not before been suggested by meteorological authorities.

Under the third condition suggested above, some form of electrical action may be mentioned as amply sufficient to fulfill the requirements. We have no means of deciding the height at which frost particles are ordinarily sustained. Siemens has suggested that some form of vapor must be found at and beyond the limits of our atmosphere; however this may be, there must be some cause for so large an increase in the amount of frost particles in the upper regions of the atmosphere as to produce the present remarkable after-glows. That electrical action has been increased of late is evidenced by the behavior of electrical instruments in India immediately after the tremendous convulsion at Krakatoa. Also we note the recent increase in volcanic and earthquake phenomena over the earth, which it is well known is usually accompanied by electrical disturbances. The evidence from the sunspots also points in the same direction. The following table of mean monthly sunspot numbers is taken from "Science" for July 20, 1883. The observations have been made by Prof. D. P. Todd, of Amherst, Mass. I have added the observations since May, 1883, for comparison.

Table of mean sun spot numbers 1880–83.

Month.	No.	Residuals.	3d Order of Means.	Residuals.
1880, January,	11·5	−12·9		
February,	6·4	−18·0	5·8	−18·7
March,	2·1	−22·3	6·4	−18·1
April,	9·1	−15·3	9·8	−14·7
May,	11·7	−12·7	12·5	−12·0
June,	14·8	− 9·6	14·3	−10·2
July,	11·8	−13·6	19·1	− 5·4
August,	23·0	− 1·4	25·3	0·8
September,	33·4	9·0	25·4	0·9
October,	21·4	− 3·0	19·4	− 5·1
November,	15·6	− 8·8	14·8	− 9·7
December,	10·8	−13·6	15·4	− 9·1
1881, January,	18·5	− 5·9	19·8	− 4·7
February,	19·9	− 4·5	26·3	− 1·8
March,	31·9	7·5	30·6	6·1
April,	36·5	12·1	29·6	5·1
May,	20·4	− 4·0	29·4	4·9
June,	34·5	10·1	32·8	8·3
July,	34·4	10·0	33·9	9·4
August,	36·0	11·6	30·1	5·6
September,	25·7	1·3	24·6	0·1
October,	21·5	− 2·9	21·3	− 3·2
November,	19·8	− 4·6	20·1	− 4·4
December,	21·0	− 3·4	20·6	− 3·9
1882, January,	16·6	− 7·8	24·1	− 0·4
February,	32·1	7·7	30·8	6·3
March,	25·6	1·2	40·1	15·6
April,	57·1	32·7	43·4	18·9
May,	40·5	16·1	36·7	12·2
June,	29·3	4·9	28·2	3·7
July,	27·0	2·1	23·2	− 1·3
August,	16·0	− 8·4	23·0	− 1·5
September,	27·1	2·7	25·9	1·4
October,	27·4	3·0	25·7	1·2
November,	28·0	3·6	20·1	− 4·4
December,	12·4	−12·0	15·2	− 9·3
1883, January,	12·2	−12·2	15·4	− 9·1
February,	19·7	− 4·7	19·0	− 5·5
March,	15·0	− 9·4	22·4	− 2·1
April,	35·8	11·4	22·4	− 2·1
May,	7·4	−17·0	26·3	1·8
June,	34·6	10·2	35·2	10·7
July,	48·7	24·3	35·5	11·0
August,	24·0	− ·4	32·0	7·5
September,	31·1	6·7	34·6	10·1
October,	41·4	17·0	37·1	12·6
November,	35·5	11·1		
December,	35·3	10·9		

This table shows an increase of spottedness in April, 1882, when probably the maximum of the present 11 years cycle occurred and after that a marked fall followed since July, 1883, by almost a steady rise. This fluctuation is still more plainly indicated by the residuals in the third order of means. If, as is generally supposed, an increase of solar spots indicates an increase of magnetical and electrical influences, we may conclude that the latter have increased within a few months, not manifested however in their usual manner.

Lastly, the arrangement of the "striæ" in the so-called "polar bands," attributed by Professor Loomis to electrical action, also supports the view here presented.

The three conditions, above, enable us to explain all the facts thus far developed. *First:* They must all be existent for the best display. If either of the latter two gradually or suddenly increase or diminish, it would account for the intermittent action. *Second:* Granting the presence of "frost particles" in abundance, the appearances can be easily accounted for, as they are similar to those we recognize when water or frost particles are the cause, whether produced by diffraction or otherwise. *Third:* The transparent nature of the frost particles enables us to see faint stars, which certainly an opaque or semi-opaque envelope would not do. *Fourth:* The detailed descriptions of glows January 27th, February 2d and 3d, show that the striæ or grayish, cloud-like, stratified forms are the true cause of the glows, for if there were other clouds there would have been on the evening of February 3d three distinct appearances: *First*, on the high cirrus; *Second*, on these clouds; and *Third*, on the material causing the after-glow, whereas there were only two distinct appearances. The fact that these are hardly visible in the morning is remarkable and seems to show a change brought about possibly by the effect of the sun's rays impinging, through the day hours, upon the frost particles. *Fifth:* If a progression in many instances be insisted on, and some of the observations plainly indicate this, it is easy to see that the meteorological conditions might bring this about in a movement of the frost particles.

It has been objected that, "The persistence of the phenomenon and its great extent show that it is not due to aqueous vapor." It has been shown, I think, that these very facts are in favor of this theory. A writer in Europe, after noting two specially marked occurrences, and finding that one of them immediately followed a "high" while the other a "low," decided that watery vapor had nothing to do with the glow. It is evident that in order to come to such a conclusion, it must be shown that vapor can be present only in connection with either a "high" or a "low," and does not act with both or independently of either. As a matter of fact most of the more brilliant after-glows have been seen in front of a high area, but this, it is reasonable to suppose, is not due to an intimate connection between the two or the necessity of the presence of the "high" to show the glow, but simply to the clearing of the air in front of the "high," which gives a more favorable opportunity for observation. It is objected that there is a distinct interval between the ordinary sunset glow upon clouds or vapor comparatively near the earth and the later after-glow, whereas we should expect a continuous phenomenon if the vapor were uniformly distributed in depth. There is no evidence to show that the vapor is uniformly distributed; in fact Professor Vettin, of Berlin, has shown that the clouds have a tendency to arrange themselves in well defined layers at nearly constant heights. "Nature" for December 20th, 1883, gives the following table from his researches:—

Cloud.	Height in feet.
Lower	1600
Cumulus	3800
Cloudlets	7200
Under Cirrus	12800
Upper Cirrus	23000

The suggestion is also made that this indicates a geometrical progression in the heights, with a ratio of two. If such a ratio exists we can see that there might be a long interval between the highest and lower strata.

The most serious objection yet advanced however has been, that the rain-band spectroscope shows an entire absence of watery vapor. This objection is answered by the results of an investigation made by F. W. Cory of England, and recently presented to the London Meteorological Society. He found that a rainband as high as 70 per cent was followed by a *light* rain and one as low as 10 per cent was succeeded by a heavy snow, also that the spectrum is not affected previous to a snow fall except negatively, i. e. the rain-band diminished several days before a snow. He suggests that when vapor is transformed into snow crystals it does not cause a rain-band and that there is no doubt that when rain falls, after a low percentage of rain-band, it is due to either melted snow or hail. The report comes from Magdeburg that in the spectrum of the glow, uncommonly strong rain-bands were seen. This appearance was possibly due to a high temperature, prevailing at the time, which would fill the lower air stratum with water and not frost particles, and hence the spectrum, affected by this stratum, could reveal nothing as to the nature of the substance far beyond. The results of observations with the rain-band spectroscope are now called in question by many prominent meteorologists. In fact the unsatisfactory nature of the evidence may be easily shown to the satisfaction of any one possessing an instrument. If the spectroscope is first turned to the sky in any direction and afterward to a white wall fifty feet distant, it will be found impossible to distinguish between the appearance of the rain-band as shown by the whole atmosphere and by the layer fifty feet thick, and yet we find it insisted upon that the instrument must be turned to different points in the sky. However this may be it would seem that the presence of an abundance of frost particles would not affect the spectrum as would the same amount of aqueous vapor above a temperature of 32°.

A most singular hypothesis has been advanced to account for the material in the sky, namely, that the volcanic action at Krakatoa on Aug. 26th and 27th ejected, into the atmosphere, immense masses of ashes which have been distributed by air currents over the earth's surface. Vivid accounts of the terrific nature of this convulsion, whereby a mountain island 2000 feet in height was perceptibly lowered, have been published by eye witnesses. The position of the volcano was in lat. 6° 12′ S., long. 105° 28′ E. By comparing this position with the dates and positions of the first appearance of the after-glows as already given, it would seem as though there had been a natural progression, but it has been shown that an instantaneous appearance will account for the phenomena as easily. The following are advanced as a few of the objections to this theory.

1st. There must have been sufficient material ejected to cover more than 135,000,000 square miles (the earth's surface 45° both sides of the equator). The attempt to add to this quantity by instancing isolated and slightly active volcanoes thousands of miles away can be regarded only as an endeavor to support a weak cause.

2d. There must have been currents of nearly equal force acting in *opposite directions* at the same height in the atmosphere, an impossible condition. Meteorology has established that if anything there is a steady current in the upper regions from west to east.

3d. The upper currents must have had sufficient velocity to carry the ashes a distance of 12,000 miles in 150 hours or at a rate of 80 miles per hour toward the *west*. We know little of velocities of air-currents at great heights, but they are probably slight. The summer velocity on Mt. Washington, 6299 feet above sea, is less than 30 miles per hour, while on Pike's Peak, 14,134 feet in height, it is only 20 miles per hour. The conditions certainly are very diverse at the two stations and it is possible that the Mt. Washington velocities are 15 per cent too high, but, allowing for these, there seems to be a possibility of a gradual diminution in wind velocity at increasing heights above the earth's surface.

4th. That the ashes must have been mechanically distributed first along a belt near the equator, and afterward, without addition except possibly of a meager character, the currents must have been sufficiently uniform over the whole earth, to have borne them north and south to above latitude 45°. This is well nigh incredible. It seems probable that in a few radial lines from Krakatoa, ashes could have been carried 1500 or 2,000 miles, and some sporadic cases even greater distances. Professor Loomis in his Meteorology gives an instance in which volcanic ashes were carried 1200 miles in a single direction, nearly parallel to the equator, but it is more than likely that these were carried in comparatively narrow streams, and that almost the entire mass of matter ejected from a volcano returns to the earth within a few hundred miles. A good illustration of the nature of a stream of volcanic ashes is given by Mr. Whymper, in a recent number of "Nature." He gives a description of a cloud of ashes poured forth from the crater of a volcano, carried in a stream in one direction and afterward in another at right angles, but that there was no uniform distribution is plainly shown by the narrative.

Fifth. That the intermittent nature of the phenomenon precludes the idea of a dust envelope.

Sixth. That ashes are opaque while the appearances indicate great transparency.

The finding of a substance on the windows of a house in Holland, after a great wind and rain storm, which presented a similarity to volcanic ashes, is well known. This evidence must be accepted with caution, however, and it should be shown that it could not have come from the neighborhood, and besides it should all the more be found in other places. Similar substances have fallen at a locality in Spain, but the examiner of them candidly admits that they may have come from the region about.

The theory that the dust has come from space removes many of the objections before mentioned, and seems more satisfactory. The well nigh instantaneous appearance, the last of August and November, gives color to this hypothesis. The other appearances in September and October, at widely separated dates, seem fatal to it however, and besides it is difficult to consider that there were two clouds of dust into which the earth entered.

It is a matter of satisfaction that the phenomenon has attracted so much attention, and called out so many careful observations. These observations should be recorded, and especially any unusual development should be noted. A study of the cloud conditions as a whole, over the earth, will give an additional means of carrying on the discussion. The absence of auroral phenomena and magnetic disturbances at a time of sunspot activity is remarkable. The apparent surprising absence of all unusual appearances on Mount Washington and Pike's Peak demands an explanation. On the former peak a glow was noted December 2d.

While all explanations of the glows are more or less matters of conjecture, yet the field of conjecture is believed to be narrowing, and we may hope ultimately to reach a satisfactory conclusion.

February 3, 1883.

NOTE—February 6th.—"Nature" for January 17, 1884, contains striking corroboration of some of these views. From Honolulu comes a note, that during November the glow somewhat diminished, but since November 25, they have again increased in marked degree. A note from near Warsaw, Russia, gives November 30 as the date of an unusual brightening. Another observer in Freiburg, Baden, reports brilliant red glow, on the morning of January 10th. The morning of January 11th, with a clear sky, the display was confidently expected, but very surprisingly it did not appear at all, the sun rising after a twilight of pale yellow." In the evening clouds arose in the west, at first showing the red marginal coloring of ordinary sunsets, but later on there came again, distinctly higher than even the cirri, a very brilliant and lasting red luminosity.

ART. XXVI.—*Topaz and associated Minerals at Stoneham, Me.*; by GEORGE F. KUNZ.

[Read before the American Association for the Advancement of Science, at Minneapolis, August, 1883.]

THE topaz locality of Stoneham is situated on Harndon Hill, within one quarter of a mile of the Stow line, one and a half miles from Deer Hill, and two miles from the New Hampshire State line and the village of North Chatham. My attention was first drawn to Stoneham, Me., by an exhibition of minerals at the sale of the Mt. Mica Mining Company, September, 1882, where Mr. N. H. Perry had some minerals on exhibition, and for sale. Among these I observed a crystal that I recognized at once as topaz. Mr. Perry, on being informed what it was, instituted further search, resulting in the finding of the finest crystals, and about sixty kilograms of fragments of topaz, with other interesting minerals. A personal visit to the locality and some work there brought the rest to light. To Mr. Perry much credit is due for his keen perception in finding and his care in preserving the mineral specimens.

The minerals to be described in this paper were all found within a radius of fifty square feet in a coarse granite on the summit of Harndon Hill, which is 100 feet wide by about 250 feet long. For a brief mention of the locality, reference may be made to the Proceedings of the New York Academy of Sciences, November and December, 1882, and this Journal, February, 1883.

Topaz.—This locality is the first in New England that has furnished good, clear and distinct crystals of topaz, and thus far it has produced the best crystals found in the United States. Of these crystals, nearly all the finest were found in one pocket in cleavelandite (lamellar albite) at its junction with a vein of margarodite, and one was entirely surrounded by cleavelandite. The finest crystals vary in size from 10^{mm} to the largest which measures transversely 60^{mm} by 65^{mm} and vertically 56^{mm}. They are transparent in parts, and contain cavities of fluids, the nature of which has not yet been determined. A few small perfect gems (see Mining Statistics, 1883, p. 486) have been cut from the fragments of a large crystal that was broken.

The finest crystals are colorless or faintly tinted with green or blue. Some opaque crystals are as much as 300^{mm} across the largest part, and weigh from 10 to 20 kilograms each; they are not perfect in form, the faces are rough, and generally they were broken before they were taken from the rock. The color in these rough crystals is more decided than in the finer ones and is a light shade of either green, yellow or blue. The specific gravity of the transparent material is 3·54, and the hardness the same as that of the yellow topaz from Oura Preto (formerly Villa Rica), Brazil.

The following forms have been observed:

O, $i\text{-}\breve{\imath}$; prisms I, $i\text{-}\breve{\tfrac{3}{2}}$, $i\text{-}\breve{2}$, $i\text{-}\breve{3}$, $i\text{-}\breve{4}$; macrodomes $\tfrac{2}{3}\text{-}\bar{\imath}$, $2\text{-}\bar{\imath}$; brachydomes $2\text{-}\breve{\imath}$, $4\text{-}\breve{\imath}$; pyramids $\tfrac{1}{2}$, $\tfrac{1}{8}$, $\tfrac{2}{3}$, 1, 2; $\tfrac{4}{3}\text{-}\breve{2}$, $2\text{-}\breve{2}$.

Many of the crystals exhibit a pearly and at times an opalescent luster when viewed in the direction of the plane O, apart from the iridescence produced by fracture and cleavage.

A specimen of this topaz was sent to Professor J. W. Mallet for examination. In a letter to the writer, dated July 27, 1883, he says:

"Mr. C. M. Bradbury, of Petersburg, Va., has made what he himself believes to be a good and accurate analysis, and has obtained the following remarkable results:

Aluminum	27·14
Silicon	14·64
Fluorine	29·21
Oxygen	28·56
	99·55

counting the oxygen as the sum of that equivalent to the aluminum and silicon less one atom of oxygen for two of fluorine found. These figures lead to the usual formula for topaz, Al_2SiO_5, with oxygen partly replaced by fluorine, but presents the remarkable anomaly that, instead of *one-half* of the oxygen equivalent to silicon being thus replaced, we have *three-fourths* replaced. . . . .

I send you the results for what they are worth. This may be a new and interesting variety of topaz as regards chemical composition, but such a conclusion needs to be confirmed. The specific gravity of the mineral was found =3·54. . . ."

*Triplite.**—This mineral occurs scattered through the rock in masses that weigh from one gram to one kilogram, staining the topaz, quartz, cleavelandite and associated minerals. One mass that may have been a large rough crystal, that was broken to pieces in the blasting, furnished over 50 kilograms of the mineral of a very pure character, in color a light chocolate-brown and clove-brown, and usually with a black coating of oxide of manganese. The interior is streaked with a lighter colored variety of this same mineral that is translucent, but at times transparent in very small fragments. The quartz at its junction with it is often stained black as if the mineral had partly decomposed.

Triphylite.—Only one very imperfect crystal of this mineral was found.

Montmorillonite.—Occurs in masses that vary in color from a very delicate pink to a dark pink closely approximating red, filling the cavities and interstices in the cleavelandite. When the latter is broken, it falls out, and it so far retains the impressions of the spaces it has occupied as to lead one to infer that it has a crystalline form. It also occurs in botryoidal masses resembling rhodocrosite on crystals of cleavelandite. This mineral is evidently identical with that described by Professors Brush and Dana from the Branchville, Conn., locality.†

Columbite is scattered all through the cleavelandite, either on crystals of the latter in cavities, or else between the plates of this mineral. These crystals vary in length from 1 to 10^{mm}, and are not very perfect. In one curious occurrence a number of acicular crystals of this mineral are so bunched together as to have a fibrous appearance, yet each crystal is distinct. One pocket afforded 20 kilograms of pure material, and one mass, or rather a part of a large crystal weighing 8·5 kilograms, appear to have been originally one crystal or one group of crystals. [One very fine brilliant columbite crystal 6^{cm} long was found associated with the herderite.]

Autunite was observed in minute scales on the cleavelandite.

Beryl occurs in large crystals all through the rock, and at times in contact with the larger topaz which it strikingly re-

* Resembling zwieselite of Fuchs. See Dana's System of Mineralogy, 5th ed., p. 544.

† This Journal, III, xx, 283, 1880.

sembles. One vein in quartz with crystals nearly a meter long and one-third of a meter across, was traced for nearly forty feet, without, however, finding any fine crystals.

Zircon occurs in crystals from 1 to 15^{mm} in length scattered through the cleavelandite. The faces are all dull and the crystals are occasionally altered to malacon; those observed were *I*, *i-i* and 1.

Garnet occurs sparingly in poor crystals and is evidently a manganesian variety of the species; it resembles triplite in color.

Cleavelandite occurs by the ton in fine large masses of plates, in color snowy-white, or fading to this color from a dark brown after a short exposure to the sun. Beautiful crystals line the cavities or pockets, in which, as elsewhere, so many interesting minerals are found. The dark brown color is evidently a staining produced by the alteration of the triplite.

Quartz occurs in abundance, usually of a milky color. Masses weighing over 75 kilograms can be easily broken by dropping them, causing them to break asunder as if assisted by some internal force, at which they show an apparent cleavage. The bursting of the fluid cavities with which they are filled may assist the breaking. Some few irregular crystals and some small perfect ones were observed in the cavities. One smoky quartz crystal, or rather group of crystals, measured 80^{mm} by 75^{mm}.

Apatite, in small doubly terminated crystals, occurs in the cavities, often white in the center and blue or green at each end of the pyramid. In one fine group the crystals were white at the center and at the terminations almost sapphire-colored. The plane *O* is largely developed, also *I*, *i*-2 and 1. A massive variety also occurs, compact, vitreous green, the masses weighing 1 kilogram.

Fluorite fills small cavities in the cleavelandite; these masses were rarely over 10^{mm} across, and the color was a very deep purple. A number of very minute octahedrons, resembling blue topaz, were found.

Biotite in slender crystals occurs in the muscovite crystals. Very thin cleavages are dark brown by transmitted light. One crystal was found enclosed in muscovite.

Margarodite occurs here in abundance, of a light yellowish oil-green color. The form of this mineral is nearly radiated.

Muscovite occurs in large masses and hexagonal crystals that are from 2 to 6 inches across, also transparent through the prism, and in masses with a fibrous cleavage, in color brown, yellow and light green.

Damourite.—A curved mica occurs in large shells 4 inches across, saucer-like in shape.

In addition to the topaz and other minerals from Stoneham, Maine, the finding of two beryls, of exceptional beauty for this country, may be mentioned; they were found several miles apart and some distance from the topaz locality. They were discovered by chance, within the last two years, by farmers, in pastures in this township. The first is only one-half of the original crystal and has been roughly used by some one who possibly discarded it as worthless after breaking it, or may have broken it in taking it from the rock. It is 120^{mm} long and 54^{mm} wide, and was evidently at least 190^{mm} long and 75^{mm} wide. The color is a rich sea-green as viewed in the direction of the longer axis, and sea-blue of a very deep tint through the side of the crystal. The color and material in the crystal are the finest that have been found at any American locality, and if not broken, would be equal to the finest foreign specimens known. If cut, it will still furnish the finest colored large gem of this mineral found in the United States, (see United States Geological Mining Statistics, p. 487, 1883), weighing at least 20 carats, and a number of small ones weighing from one to six carats.

The other crystal referred to is doubly terminated, being 41^{mm} long and 15^{mm} in diameter. Over one half of it is transparent with a faint green color; the remainder is milky green and only translucent. At the junction of the two colors in the crystal there is the appearance of a flocculent precipitate, looking as if it had almost completely settled, leaving the upper half perfectly clear. The observed planes are: *O* largely developed, *I*, *i*-2, 1, 2-2, 3-$\frac{3}{2}$. The finding of these two crystals in such a manner can but lead one to think that rich material must be stored in the vicinity and would warrant further search.

[Since the above paper was read the locality has been worked to some extent, and a number of very fine crystals have been found by several parties; among these are several transparent pieces, yielding nearly as fine gems as the ones described, and also some remarkable translucent crystals; one of these measures 910^{mm} long and 110^{mm} in diameter and is of a very fair color. One fragment weighing 660 grams (now in the possession of Mr. Perry) that had originally been entirely transparent but was cracked by weathering, still has a very large clear space, and apparently is a part of the crystal described before. There have been found also some very curious penetrating and enclosed beryls. In one case, a crystal about three inches long and one and one-half inches wide, was penetrated by another crystal, which, as broken out, fits perfectly in the socket. One crystal six inches long had another running through the side, and still another entirely enveloped a smaller one.]

ART. XXVII.—*A Contribution to the Geology of Rhode Island;* by T. NELSON DALE. With a Map—Plate V.

IN a former paper on the Geology of Rhode Island* the writer gave a geological map of the southeast corner of the Island of Aquidneck and of the east shore of the eastern passage of Narraganset Bay from Fogland Point south to Seaconnet Point and West Island, also detailed sections of Easton's Point, the vicinity of Taggart's Ferry, Sachuest Neck, and "Paradise," together with a general section embracing the main features of a belt about two miles wide extending from the protogine bed of West Island to the carbonaceous schists of "The Cliffs" at Newport. The structure of Easton's Point was shown to be that of a simple anticlinal, consisting below of argillaceous schists, containing here and there iron pyrites and earthy chlorite, overlaid by a coarse conglomerate of pebbles of finely stratified, slightly micaceous quartzyte with traces of Lingulæ, possibly of Silurian age. It is uncertain whether the bed of conglomerate at present covers the schist entirely on the line of the section; toward the end of the point it has certainly been entirely eroded. At Taggart's Ferry a sharp anticlinal of this conglomerate is flanked on both sides by carbonaceous schists. At Sachuest Neck a siliceous argillyte, passing into an impure serpentine, and underlaid by a slaty conglomerate with an occasional pebble of red jasper, is conformably overlaid by a highly metamorphic, very coarse, blackish, quartzose sandstone (quartz and clay aggregate) containing in its upper part a few layers of black slate minutely veined with quartz and talc, and containing coal plants, one of which, *Annularia longifolia* Brgt., Lesquereux describes as very common in Pennsylvania, "especially in the lower strata above the Millstone Grit." At "Paradise" seven ridges, from 40 to 173 feet high, trend N.N.E. The two western ones, of quartzyte conglomerate, constitute a synclinal; the two eastern ones, of the same rock, form a ruptured anticlinal. Five beds of hornblende and chlorite schist, alternating with as many of mica schist, constitute the three intervening ridges, forming a monoclinal with a west-northwest dip. This series was probably thrown up in a fault, as suggested by Professor Shaler, although he supposes more faults to exist here than are necessary. The fact that these hornblende and mica schists measure as much as 950 feet in thickness and that they are not covered with the adjoining conglomerate lends some support to the theory that we have here to do with what was an island during the deposition of the

* Proceedings Boston Society of Natural History, vol. xxii, p. 179, Jan. 3, 1883.

conglomerates, and that subsequent flexure of both the hornblende and the abutting conglomerates brought them into their present relations. In the general section referred to, a synclinal and an anticlinal axis were supposed to exist in the chloritic argillytes between the line of West Island and Sachuest Neck, on account of the southeasterly dip of the nearest outcrops of these rocks farther north at Brown's and Church's Points on the Little Compton shore, also because of the W.N.W. dip of the beds at Sachuest Neck. Another synclinal was supposed to occur just east of Taggart's Ferry, and another west of it. Then come the ruptured anticlinal, the faulted hornblende, chlorite and mica schists, and the elevated synclinal of "Paradise;" still farther west is the anticlinal of Easton's Point followed by a gentle undulation, now eroded, along Easton's Beach.

The beds were arranged in the following chronological order: ·01. Granite and protogine; 1. Hornblende, chlorite and mica schist series, 950 feet; 2. Chloritic argillytes and micaceous argillytes, both with minute passages of calcite, 500–750 feet; 3. Slaty conglomerate with red jasper (Conglomerate I) and associated siliceous argillytes and impure serpentine, 500 feet; 4. Quartz and clay aggregate, 750 feet; 5. Argillaceous schists of Easton's Point, 600 feet; 6. Quartzyte conglomerate with a few layers of argillyte (Conglomerate II), 750 feet; 7 and 8. Carbonaceous schists with some conglomerate, associated with argillaceous schists, 1000 feet. (These last are followed by or form part of the Coal-measures proper). Total, 4950–5450 feet. The strata, especially those of Conglomerate II, were found to be fissured more or less vertically and at right angles to the axes of the folds, indicating possibly another system of uplifts with axes running W.N.W.–E.S.E., but less powerful in their effects as would be the case if the strata had been previously corrugated in the opposite direction or had already become rigid by metamorphism. The cleavage of the pebbles of the conglomerate, so often noticed, is probably due, first, to the pressure which made the adhesion of the cement equal to the cohesion of the pebbles, and, second, to the other pressure which fissured, because it could not flexe, the beds. Professor Wolcott Gibbs has suggested to the writer two theories to account for this fissuring: I, *Wave theory:* the conglomerate having been acted upon by a wave motion resulting in a succession of vertical breaks. II, *Contraction theory:* the bed having been heated and beginning to cool at its extremities would be fissured towards the middle by the resulting contraction.

This second paper covers the southwestern part of the island, or Newport Neck and the tract between Easton's Beach, Coddington Cove and the harbor, together with the southern half of Conanicut Island, the west shore of the west passage of Narraganset Bay from Plum Beach south to within 2½ miles of Point Judith, and the smaller islands and rocks between those bodies of land; politically the entire township of Newport and parts of Jamestown and North and South Kingstown. The two papers, together, thus describe a belt across the lands which border and divide the mouth of Narraganset Bay, and afford an entire section across the southern extremity of the New England Carboniferous Basin.

Newport Neck has been pretty fully described * and Jackson's map covers the entire tract. The highly metamorphic character of the rocks of the region, as well as their complex stratigraphical relations, and the fact that half the area is under water must account for the lack of clearness as well as the contradictions in some of the conclusions of the geologists who have studied it. Thus, Dr. Jackson regarded the granite of Newport Neck and Conanicut as intrusive and as having in both places altered the adjoining Carboniferous slates to siliceous and epidotic slates. The central portion of this neck, from Brenton's Cove to Coggeshall's Ledge, he maps as Archæan, the remainder of the neck on the west and a strip on the east, as "Metamorphic Slate," and the entire southern part of Conanicut and the west shore of the bay also as Archæan. Pres. E. Hitchcock also made the siliceous slate of the neck metamorphosed argillyte of Carboniferous age. The part west of a line running south from Brenton's Cove he calls Carboniferous, as he does the dolomite of Fort Adams, and "The Lime Rocks," and the various schists of "The Cliffs." But Professor C. H. Hitchcock regards the granite and protogine of these localities as either metamorphic or eruptive, and in any case as Post-Carboniferous. Older than this protogine but more recent than the Coal-measures he considers the siliceous and other slates of the central and western part of the neck, and also the jasper, serpentine and dolomite associated with them. Above the Coal-measures proper, but below these slates he puts the conglomerate of Coaster's Harbor Island and Miantonomah Hill. Professor Shaler calls the siliceous argillytes of the neck "Primordial Felsites." Professor Hunt is disposed to classify the magnesian rocks of the neck as Huronian and alludes to the granite as intrusive.

* Chas. T. Jackson, Geol. Survey, R. I., 1840, pages 40, 89–92. Ed. Hitchcock, Geol. of Mass., 1841, pages 537, 540, 550. 552. Ch. H. Hitchcock, Geol. of Island of Aquidneck, Proceedings American Association Advancement Science, 1860, pages 119, 121–126, 129–133, 136–7. N. S. Shaler, Geol. of Island of Aquidneck, etc., American Naturalist, vol. vi, 1872, pages 524–5, 616, 619, 752. T. Sterry Hunt, Proceedings Boston Soc. Nat. Hist., vol. xiv, 1869. For full titles and bibliography of R. I. Geology see first paper.

In order to rectify these contradictions and, if possible, determine the structural and chronological relations of these beds the following observations were taken.

Easton's Beach, the Cliffs, Newport City.—At 1 (see map), at east end Easton's Beach, alternating layers of conglomerate and dark gray argillyte dip 5°–10°–20° E.SE.* The nearest outcrop westward is at Bliss' Cave, 2, where similar rocks dip 30° W.N.W. At 3, west end of beach, alternating argillaceous and carbonaceous schists, grits and quartzyte conglomerates measure over 100 feet, dipping 45° W. At 4, corner of Gibbs avenue and Catherine street, 20 feet below the surface, pale greenish argillaceous schists with sparsely disseminated, minute, ferruginous nodules dip roughly W. As "The Cliffs" trend about N. 10° E., nearly with the strike, and as they advance and recede alternately the series is not easily made out.† The layers of conglomerate sometimes run out or fork. Many veins of milky quartz, large and small, traverse the rocks, sometimes starting abruptly from the junction of the conglomerate and slate and tapering upwards through the former, generally vertically and from E.–W. A little N. of 6 the dip is 90° and slickensides occur parallel with strata. At 6 the dip is 60° W. and slickensides are horizontal. At 5 and 6, among the shingle, quartzyte pebbles (possibly not from the outcropping conglomerate) containing *Lingulæ* with plumbaginous shells. The outjutting rocks opposite Narraganset avenue and the like-shaped mass south are due to the converse of the process which formed the chasm "Purgatory," the rock between two E.–W. fissures being left. while that on either side has been eroded. At 7, opposite Miss Wolfe's, about 25 feet of schist overlaid by about the same thickness of conglomerate dip W. At Mr. Lorillard's Breakwater, 8, the easternmost layers, grits and conglomerate, dip 65° E.S.E.; then about 20 feet of grits and dark gray schists dip 45°–50° W.N.W. crossed by slickensides, dipping about 75° W.N.W. Thence to Ochre Point, pale greenish, argillaceous schists with occasional layers of conglomerate, dip 35°–45° E.S.E., measuring perhaps 200 feet. The outlying line of rocks at Ochre Point indicates the direction of the strike and consists of the lowest conglomerate of the Ochre Point series, In passing westward the dip suddenly changes to 25°–30° S.S.W., the rocks being pale greenish, possibly hydro-micaceous schists with minute crystals of magnetite, in places reddish yellow, ochraceous schists, and traversed by several quartz veins. At 9, this bed seems to be underlaid by conglomerate and grit, dipping first 25° E.S.E. then 25°–30°

* These points are all given without allowance for variation.

† Notwithstanding this difficulty Professor Ch. Hitchcock gives a long series of measurements. Op. cit., p. 122–3.

S.S.W. Near 10 the ochraceous schists recur dipping under a large vein mass of milky quartz at 15°–20° S.S.W. South of 10 about 75 feet of finely laminated, carbonaceous slates dip 35°–40° W.N.W. At 11 these dip 45° W.N.W. and continue to Sheep Point and 12, 13. Professor C. H. Hitchcock gives 18 species of coal plants from this bed and two seams of anthracite, 6 inches and 12 inches thick, now probably concealed.* At 12, these schists dip 40° W.N.W. and contain ferruginous nodules several inches thick, minute veins made up of alternating laminæ of quartz and anthracite, and give rise to a ferruginous spring; at 13 they terminate with a high inclination. The next outcrop along shore (about 25 feet off) consists of a soft, decomposed, light gray, argillaceous or talcose schist dipping at high angle westerly, about 45 feet thick, passing into a harder, greenish, talcose schist which passes into a tough, dark gray, slightly purplish, coarsely schistose argillyte with minute veins of serpentine and passages of calcite. This rock forms the headland, 14, and, at 15, passes into an argillaceous serpentine with occasional layers of chloritic talcose schist, nodules and veins of epidote, passages of chlorite and both large and minute veins of quartz, dipping about N.N.W. The islet and rocks to the east seem to be of the same character, thus bringing the easternmost exposure of this bed on a line with Ochre Point. On the south it continues to 16, where it is in close contact with protogine, hand specimens showing both rocks together. This protogine forms the whole point and Coggeshall's Ledge, in places is characterized by large crystals of feldspar, according to Professor E. Hitchcock by faulted veins,† at one locality is traversed by a vein ? of yellowish serpentine, and at 17 near Bailey's Beach underlies the epidotic and chloritic schists again. These may be traced to 18 and 19. The contact occurs in this wise at 17: Lying immediately upon the protogine are layers of ferruginous chlorite dipping N. at a high angle, followed by layers of quartzyte with quartz pebbles and pyrites, measuring altogether about 17 feet, and followed by about 13 feet of protogine with large crystals of feldspar, upon which rest the epidotic and chloritic schists. North of Bailey's Beach the first outcrop is at 20, on the east side of Almy's Pond, where clay slates, like those associated with the conglomerate of "The Cliffs," dip 55° N.W., recurring at 21 and again at 22 near the corner of Spring and Perry sts. In digging for a sewer the rocks were recently exposed for the whole length of Levin street, pt. 23. They are gray argillaceous and perhaps micaceous schists, with thickly disseminated minute grains of a ferruginous mineral, and dipping about 25° W. Similarly speckled schists occur at 1, 2, 22, and were ex-

* Op. cit., p. 125. † Op. cit., p. 693.

posed on Bellevue avenue from Levin to Pelham streets. At 24, near corner of Clark and Mary streets, a 2-foot seam of coal was struck. At 25, near corner of Farewell and Marlborough streets some black slates were exposed several years ago with *Pecopteris arborescens* and *P. hemitaloides*, together with a new species which Lesquereux named *P. Clarkii**; at 26, Fort Greene, and the adjoining "Blue Rocks" dark gray argillaceous schists dip 30° N.W.

Miantonomah Hill, Coddington Cove.—At 27, in a ravine south of this hill, is an outcrop of more than 20 feet of light gray argillaceous schists associated with a conglomerate of small quartzyte pebbles dipping 20° N. At 28, west of the hill, quartzyte conglomerate and argillyte dip 40°–45° E. to N.E. The summit of the hill consists of a coarse conglomerate, like that of Easton's Point, 10–15 feet thick, overlying a siliceous, argillaceous grit, all dipping 15° S.E. to S.S.E.† These grits crop out again at 29. Schists, like those of 27, but of uncertain dip, are exposed by the railroad cutting at 30. At 31, Coddington Point earth works, dark gray argillytes dip 10°–15° S.W. At 32, the most easterly outcrop on Coddington Cove, is a 40 feet high cliff of more or less carbonaceous schists, slates and sandstones dipping 15°–20° S.W. At 33, the dip changes to 25°–30° W., a little north to 30°–35° N.W., the bend in the shore being just opposite to that in the strike. Some of the schist near 33 resembles that of Levin street, etc. Beyond, the strata strike N.–S. with a very high westerly dip and so continue to 34. At 35, 20°–25° W., and a little south the remains of a thick vertical quartz vein stand on the beach associated with the regular conglomerate but both vein and rock contain much chlorite.

Bishop Rock.—On the east side, argillaceous and carbonaceous schists, alternating with grit and quartzyte conglomerate, dip 30°–35° N. to N.N.W. The carbonaceous schists with ferruginous nodules on the W. and N. side dip 45°–50° N.

Coaster's Harbor Island and Rock, Gull Rocks.—At 36 slaty, chloritic argillyte with small passages of calcite, a rock similar to that at Brown's Point in Little Compton, dipping 25°–30° N.E. At Coaster's Harbor Rock, which lies due S., the same rock recurs, dipping 15° N., and also at the Gull Rocks, dipping 15°–20° N. with E.–W. vertical fissures. In the little

* See II Geol. Survey Pa., vol. P, text p. 261 and plate.

† Two bowlders from this vicinity are of extra-limital stratigraphical interest. One, found by Mr. Alexander Peckham SW. of 27, a reddish crinoid limestone with a Spirifer and Strophomena. The other, from the east base of Miantonomah Hill, a dark gray argillaceous schist with minute crystals of Ottrelite (Newportite) and an impression of a plant stem 14 inches long and 1 inch wide marked with longitudinal grooves 1⅗mm. apart. Bowlders and pebbles of Ottrelite schist abound about Newport, but I have failed to find any outcrop of it.

cove N.W. of 36, gray argillaceous schists, with minute nodules of some talcose mineral and ferruginous veinlets, dip 20°–25° N.E., reappearing on the W. side at 37, with a dip of 25°–30° N.E. The projection S. of 37 is "quartz and clay aggregate" like that of Sachuest Neck, with some carbonaceous slate. At 38, the conglomerate and associated beds commence, dipping a little farther north 35°–40° E.S.E. with N.N.W. fissures. The peculiar looseness of this conglomerate has been described by Prof. Ch. Hitchcock.* The pebbles increase in size northward, the largest about 8 × 10 inches; they are rather spherical, mainly quartzyte but sometimes argillyte. At 38, it contains pieces of carbonaceous slate and of the speckled slate of 36, 37. Near 39 a piece over 6 inches wide of alternating laminæ of anthracite and quartz, like the small veins near Sheep Point. This may have been a fragment from a seam of impure coal or, as seems quite as probable, from its adhesion to the rock, may have been formed at the time of the deposition of the conglomerate. This conglomerate occupies the remainder of the island, on the west side with schist and grit, at 39, dipping 25°–30° about S.S.E.; at 40, 30°–35′ E.S.E., on the northeast side, N.N.W. at high angle, and at 41 and 42, with carbonaceous, speckled slate, 20°–25° N.N.W.

Goat Island.—A boring recently made within the fort, after passing through 50 feet of alluvial gravel and clay, entered the chloritic argillytes with passages of calcite for about 150 feet.

Little Lime Rock (misleading in name).—Chloritic argillyte striking N.N.E.–S.S.W. and dipping almost vertically. At 43, and thence southward to the shore, these rocks recur, dip 15°–20° SE.

The Lime Rocks.—The western one is a light gray, inclining to bluish, dolomite, traversed by veinlets of quartz. A microscopic section shows nothing but the structure characteristic of limestones. On the south side are a series of joints or layers with a rough easterly dip. This grayish dolomite forms also the western half of the eastern rock, its other half being a yellowish, pinkish dolomite of the same character but containing dark purple and rarely green, slates. In one spot layers of purple slate alternate with 2-inch layers of dolomite; the dip uncertain. The small protruding rock south of these is dolomite but possibly a bowlder.

Newport Neck.—The line from 44 south to the west side of Bailey's Beach forms the eastern boundary of a bed of protogine. No contacts between it and the argillaceous and carbonaceous schists on the east have been found. From 44 west to 45, and thence north to near 47, the limit of the protogine is concealed and as the nearest outcrops north are at the Little Lime

*p. 130.

Rock and 22, there is about half a mile square here of uncertain age. At 47 and 48, the protogine is bordered by a narrow strip of highly inclined, siliceous argillyte; at 51, these rocks are seen in contact. The protogine becomes a compound of greenish feldspar and hyaline quartz, and the overlying rock is a stratified flint. From 51 to 50 there is a low cliff probably due to a fissure. From 57 to 58, the two rocks are again in contact and at 52 and 54 small insulated masses of siliceous argillyte overlie the protogine. At 46, distinct strata dip 40°–50° W.N.W. crossed by vertical fissures running E.S.E.–W.N.W.; and, at 53, this stratification is crossed by a system of joints dipping E.SE. At 49 are large veins of massive, bright pink feldspar and milky quartz. At 56, on Lily Pond Beach, the protogine is traversed by veins of flesh-colored, crypto-crystalline feldspar and quartz. The southernmost exposure is at Gooseberry Island. Lithologically, the rock varies from a compound of quartz and pinkish feldspar, or of these with chlorite, to one of all these with a greenish feldspar; and in a few places it is probably a true granite. Its area measures $1\frac{3}{8}\times\frac{7}{8}$ of a mile.

To the west of this tract is the "Flinty Slate" about $1\frac{7}{8}\times\frac{7}{8}$ of a mile in extent. The contact on the north, south and west is concealed or obscured by sea, marsh or beach. At 59, near the protogine, the dip is 50°–55° W.N.W.; at 60, 35°–40° W.N.W.; at 61, about the center, 35–40° N.W. From 62, on the south, northward to 63, the dips are: 62° N. 12° W. 70°, 65°–70°, 55°, 50°, all N.; a little west of 63, 35° E.S.E., a little north of it, 65° E.; on the south side of Price's Neck, at 66, 10°–15° E.N.E. In the northern part the dip is high and uncertain, but the strike in several places is clearly N.E.–S.W. The rock is a siliceous argillyte; in some places an impure serpentine, slaty or massive, varying in structure from finely granular to impalpable; at one locality it is an agglomeration of very small pebbles. The color is generally dark gray, sometimes with a greenish tinge owing to minute veins of serpentine. The point forming the east side of Brenton's Cove is a massive, dark purple, siliceous argillyte, with veinlets of pale green serpentine, enclosing, at one spot, amorphous calcite, and at 65, a bed of greenish gray talc several feet thick, which seems to recur at 64, where it is dark green and associated with asbestos and picrolite. Seams of serpentine are not infrequent in that vicinity and the schist is somewhat plicated, but the old locality of precious serpentine is now concealed.* Both on the north and south sides of the tract thin seams of black, siliceous argillyte occur. A little west of 63 the rock is very argil-

* A compass box made of this serpentine was so magnetic as to render the compass useless.

laceous and schistose; also at 62, 70 and 66. At 62 and 70, this appears to be exceptional, for on Price's Neck it is again more siliceous. At 66, it encloses fragments of chloritic argillyte. The adjoining rocks on the west are not dissimilar and dip 15°–20 N.E., as do the slates a little north, which belong to the siliceous argillytes. It is difficult to determine the precise boundary at this point. Perhaps it should be drawn at 67 where greenish-gray slates dip 10°–15°–20° E.S.E., and hold nodules of a decomposed ferruginous quartz.

The rest of the neck is mainly occupied by bluish green and dark purple, slaty, chloritic argillyte. At 71, it is decidedly chloritic, dipping 35° N. 12° W., containing passages of calcite, and underlaid by a ferruginous, siliceous chlorite schist,* resembling somewhat that at 17, Bailey's Beach, but, still more, certain layers in Church's Cove, Little Compton, at the base of the chloritic argillytes. Some disturbance has occurred here, for these ferruginous rocks protrude through the overlying argillytes and a thick quartz vein with chlorite traverses close by. At 72, these argillytes with calcite dip 15° N.E., at 73, 10°–25° N.E., at 74, alternating with dark purple ones, 10° N.E. A little west the purple and green run in stripes across the bedding and the layers seem somewhat talcose. At 75, Graves Point, veins of quartz with chlorite; a little west, Black Point, the dip is 10°–15° N.E., at 76, 10°–15° E.S.E. At 77, green and purple, very finely laminated and lustrous slates dip 15°–20°–25° N.N.W.; at 78, the purple ones, 5°–10° N.N.W. abounding in calcite. A little north the dip is 15°–20°–25 N.N.W. At Ragged Point, grits and purple slates, 15°–20° N.E., at 80, Ram's Head, 15°–25° N.E. with quartz veins containing chlorite and feldspar, and slickenside planes 25°–30° S.S.E. At 81 the slates dip 10°–20° E.S.E. On the west side of Castle Hill the argillytes abound in calcite. At 82 purple and green slates dip 25°–30° E.S.E. A recent excavation south of 82, brought to light green argillyte containing large nodules of limestone traversed by small veins of crystalline calcite. At 83, the dip is 35°–40° N.N.W., at 84, purple and green slates with calcite, dip 15°–20° E.S.E. From 84 to 85, grayish, greenish and purplish schists, here and there with calcite, dip 15°–35°–50° E.S.E. At 85, on Point of Frees Beach, plicated schists of alternating laminæ of quartz and slate crop out, dipping 20°–25° E.S.E. At 86, the chloritic argillytes dip E.S.E. and at 87, with calcite and pyrites, 10° E.S.E. From 87 southwest to 73, there are a number of outcrops. At 88, purple slates dip 30°–35° E.S.E.; at 89, purple and green, the former enclosing dark purple jasper, dip E.S.E., and continue in a ridge trending N.N.E. The small bowlders and pebbles of dark purple

* See Ch. H. Hitchcock, op. cit. p 126.

and red jasper on the beaches about Brenton's Point, probably originated here. At 90, which is 200 feet from the "Flinty Slate," the dip is 25°–30° E.S.E. The two protruding rocks in the northern part of the marsh dip toward the Flinty Slate in a general E.S.E. direction. At 91, near the artillery stables, the green slates dip 15°–20° E.S.E., and a lenticular mass of quartzyte, 15 feet thick by 40 feet long, is partly enclosed by them. Quartz veins abound hereabout. Returning to the west shore of the neck: from 85 to 92 there are dark purple schists passing into dark greenish ones, dipping 20°–25° E.S.E., and at 93, north of the redoubt, overlaid by the bluish green schists with a similar dip. At 94, opposite the harbor, are exposed at low tide green and purple slates containing nodules and pebbles of dolomite and red jasper, alternating with layers of a pinkish, yellowish, dolomite with veinlets of quartz like the dolomite in the eastern "Lime Rock" and enclosing pieces of slate. A microscopic section of it shows nothing but the structure characteristic of limestone. These beds strike N.E., and the dip, not clear now, Prof. C. H. Hitchcock found to be 40° S.E. Fragments of a bluish gray dolomite, like that of the western "Lime Rock," lie on the beach at 95, probably originating in the outcrop mentioned by him but now concealed.*

Rose Island.—The wider southern portion is entirely chloritic argillyte, dipping on the east and south sides 20°–25° N.E., on the west, 10°–20° N., and a little east of the lighthouse, traversed by veins of quartz, chlorite and feldspar, identical with those at point 80, Ram's Head. At 55, about 1000 feet from the northern end, these rocks are followed by the "quartz and clay aggregate" of Sachuest Neck, etc., dipping 35°–40° E., and followed at the end itself by carbonaceous argillytes with the same dip.

Conanicut.—The two parts of this island are united by the narrow strip of beach forming the head of Mackerel Cove. The northern part ends south in a hilly tract of protogine about 1 × ½ mile in area generally consisting of a pinkish and a greenish feldspar, quartz and chlorite At 101, this is traversed by one large and several small veins of milky quartz striking N.W.–S.E. and dipping N.E. Near 100, the pink feldspar occurs in large crystals, and at 100 the protogine is seen in contact with a siliceous argillyte, the two rocks being literally dovetailed into each other. This is due to faulting as may be seen from a four-foot long vein close by, which is faulted ten times. This siliceous argillyte passes shortly into a serpentine and epidote schist containing nodules of crystallized epidote and some quartz pebbles, resembling generally the schist at 15, at the end of "The

* Op. cit. p. 131; see also Jackson, pp. 34, 91, 246, and Ed. Hitchcock, pp. 537, 552.

Cliffs" in Newport. The dip is about easterly. There is a vein one foot thick of pink feldspar and quartz like those of 56, Lily Pond Beach. Near 99, this rock passes into a chlorite schist with a little mica and minute passages of calcite, and is identical with that of a portion of Ridge III, "Paradise." The "Dumpling" Islets seem to be of the same character, but the one S.E. of 100 is protogine. At 99, the chloritic and epidotic schists terminate. From 98 to 97 the protogine is bounded by the regular siliceous argillytes, like those at Newport and Sachuest Necks, which extend to 102, within half a mile of Jamestown Ferry; at the east end of Hamilton avenue, dipping 15°–20° E.; at 103, more highly inclined and striking N.N.W.–S.S.E. From 97 to 96 the protogine is bounded by a triangular mass of "quartz and clay aggregate," the last outcrop of which is at 104. At 96, on Mackerel Cove, these two rocks are seen in contact. The quartz of the protogine is dark colored, like that of the "aggregate" which lies upon it and which contains a few layers of dark gray slate. The dip is high and hardly determinable, but at 105, dark gray slates dip 10°–15° N.W., overlaid beyond, along the shore of the cove, by light colored, finely laminated, argillaceous slate dipping successively 20°–30° W.N.W., 30° N.N.W., 15°–20° N.N.W., and frequently striped across the bedding, enclosing siliceous-ferruginous matter like the slates at the southwest corner of Coasters' Harbor Island. North of Mackerel Cove, from 106 to 108, similar light and dark gray schists and slates recur, dipping successively 20°–25°, 45°, 25° and 30° W.N.W., with thickly disseminated, minute nodules of crystalline siderite, in some places striped across the bedding, and traversed by quartz veins with crystalline calcite which, from its color in weathering, must contain some carbonate of iron. No satisfactory outcrops exist east of the line just followed, but on the east side of the island at 102, beyond the northern termination of the siliceous argillytes, the argillaceous slates of the east side of Mackerel Cove recur, dipping at 107, 10° W., a little south of the ferry, 25° S.S.E., at the ferry W.S.W., and at Taylor's Point, 10°–20° S.W. to S.S.W.

The southern part of Conanicut consists entirely of the sideritic, argillaceous schists described, although in some places the siderite is wanting. The overlying rocks occur at Beaver Head. At 109, south of the Mackerel Cove beach, the schists dip 15° N.W., at 110, north of that beach, 25°–30° N.W.; at 111 they are dark colored as at 108; at 112 they dip 35°–40° N.N.W., becoming north somewhat ochraceous; and at 113 similar schists dip 40° S.S.E. to 90°. Between 113 and 114 there are no outcrops; but at 114 dark mica schists dip E. S.E. at high angle, and a little beyond stand erect, striking with the east shore of Dutch Island, much plicated, in folds several inches across, and veined with quartz. At 115 these mica schists are interstratified with conglomerate of flat pebbles of quartzyte, micaceous and argillaceous schist, dipping 20°–25° E.S.E. At 116 carbonaceous and argillaceous schists dip 45° E. S.E. The siderite schists on the west shore of Mackerel Cove, from 109 south to 120, dip successively, 15° E.S.E., 15° N.N.E., 10° N.E., 20°–25° N.E., 30° N.E., 25°–30° N.N.E., 20° N.N.E., 25°–30° E. by S.E., 15° E.N.E., 10° N.N.E.; at 121 in Hull's Cove, 15° N.N.E.; from the west side of Hull's Cove to Beaver Tail Light, successively; 10°, 30° N.N.W., 5° S.S.E., 5°–10° N. N.W., 10°–15° W.S.W., 10°–15 N.N.W., 15° N.N.W., 5 N.W. or N.N.W., 15° N.W., 10° W.S.W., 30° W.N.W.; from Beaver Tail Light north to Austin's Cove on the west side of the island: 30°, 35°, 40°–45°, all W.N.W.; at 124, 40° W.; at 125, 40° N.N.W.; at 126, 40°–45° N.W.; and at 127,—N.N.W. The following observations were made: From 109 to 120 the schist is often minutely plicated, one specimen showing 7 plications to the inch, and sometimes folded at high angles. At 117 is a sheet of schist, broken off from the adjoining outcrop, measuring about 5′×5′×6″ which is folded twice at right angles. At 119 occur veins of quartz, with chlorite and ferruginous, crystalline calcite like those between 106 and 108. The schists and slates are very finely laminated, greenish gray, waxy, possibly slightly talcoid or hydro-micaceous. The minute nodules of siderite vary in size and in distribution. Between 119 and 120 the schists are dark gray; at 120, striped light and dark across the bedding. Between 120 and 121 is a bed or vein 10 feet thick of a much decomposed, micaceous, siliceous and ferruginous rock. At 122, the dark gray slates recur with cubical pyrite, and continue to Lion's Head, with one vein of quartz and calcite. The dark gray schist passes both vertically and horizontally into the light colored. At Lion's Head, are striped schists. At 123 there is a vein 1 to 3 feet thick, running N.W.–S.E. at high angle, of argillaceous quartz with cubical pyrite and crystalline calcite. Near Beaver Tail Light, the beds are slightly ochraceous; on the west side, north of the Light, they are alternately light or dark or striped; at 124, a vein like that of 123. At 126 the oxidized nodules of siderite stand out on the weathered schist which is finely veined with quartz. The largest nodules measure 3–4 mm. in diameter. At 127, the summit of a 120 foot hill, is an outcrop, traceable for about 1200 feet, consisting at the south end of siderite schist which passes northward and horizontally into a micaceous schist.

[To be continued.]

ART. XXVIII.—*On the Crystalline Form of the supposed Herderite from Stoneham, Maine;* by EDWARD S. DANA.

IN the preceding number of this Journal (III, xxvii, 135), Messrs. Hidden and Mackintosh have described a mineral from Stoneham, Maine, which, as they show, is probably identical with Haidinger's herderite. The first notice of this mineral was given by Mr. Hidden in the January number (p. 73). Mr. Hidden has had the kindness to place in my hands the best of his specimens for crystallographic description, and I have also to thank Mr. George F. Kunz, of New York, for additional material furnished me for the same object. The study of these specimens has enabled me to make out the form of the mineral with reasonable accuracy.

The crystals examined were mostly quite small, varying from 1 or 2 to 3mm in diameter, though there were also a few larger crystals. A preliminary examination served to confirm the results of Mr. Hidden that the form of the Maine mineral approximated closely to that of the herderite from Saxony. The position in which the crystals are placed is consequently made to correspond with that of the herderite as given by Brooke and Miller (p. 490) and in Dana's System of Mineralogy (5th ed., p. 546).* The measurements and the optical examination go to prove that the crystals belong to the orthorhombic system.

The crystals are prismatically developed in the direction of the brachydiagonal axis, as shown in the figures (1, 2, 3), and they are ordinarily terminated at both extremities of this axis. The commoner forms are those of figures 1 and 2, the habit varying according to the development of the pinacoids *b* and *c*. Occasionally more complex forms, as that in figure 3, are seen, and in one or two cases the crystals were further modified by several minute planes not there represented; these are *l*, *n*, *q* (see below), and two or three others which could not be determined with certainty.

The observed planes are fifteen in number, viz:

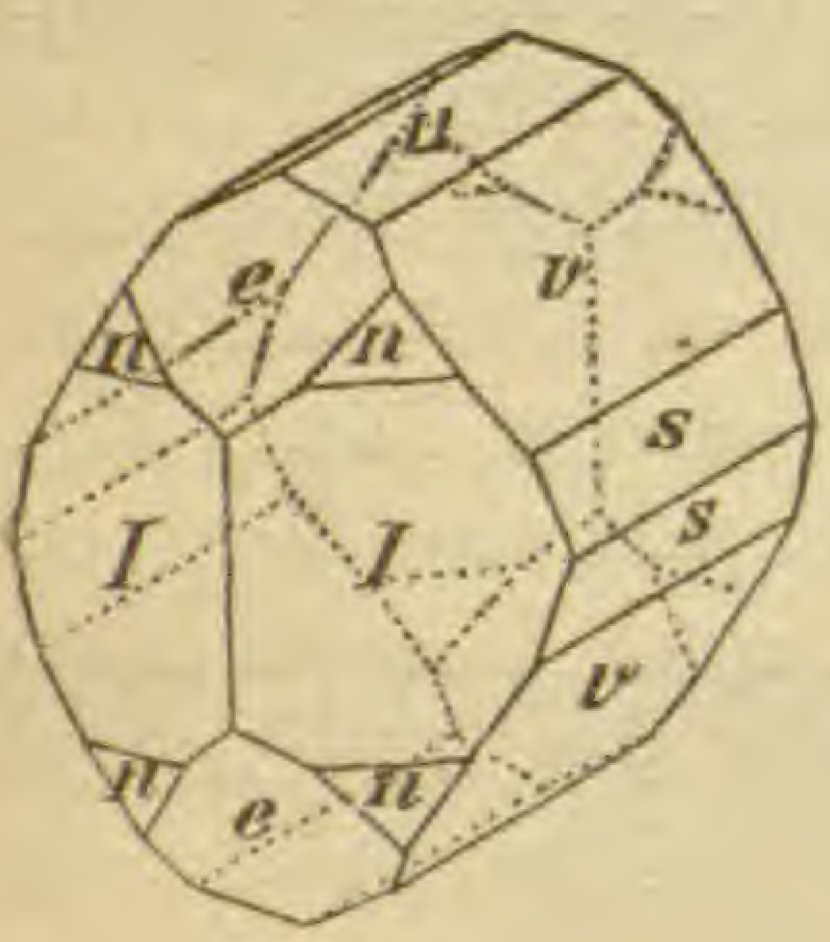
O (001, *c*), i-$\breve{i}$ (010, *b*); prisms I (110), i-$\breve{2}$ (120, *l*), i-$\breve{3}$ (130, *n*); macrodome $\frac{3}{2}$-$\bar{i}$ (302, *e*); brachydomes 1-$\breve{i}$ (011, *u*), $\frac{3}{2}$-$\breve{i}$ (032, *t*), 3-$\breve{i}$ (031, *v*), 6-$\breve{i}$ (061, *s*); pyramids 1 (111, *p*), $\frac{3}{2}$ (332, *q*), 3 (331, *n*); 3-$\breve{2}$ (362, *x*); 3-$\breve{3}$ (131, *y*).

Considerable difficulty was found in obtaining satisfactory fundamental angles, and a large number of measurements were

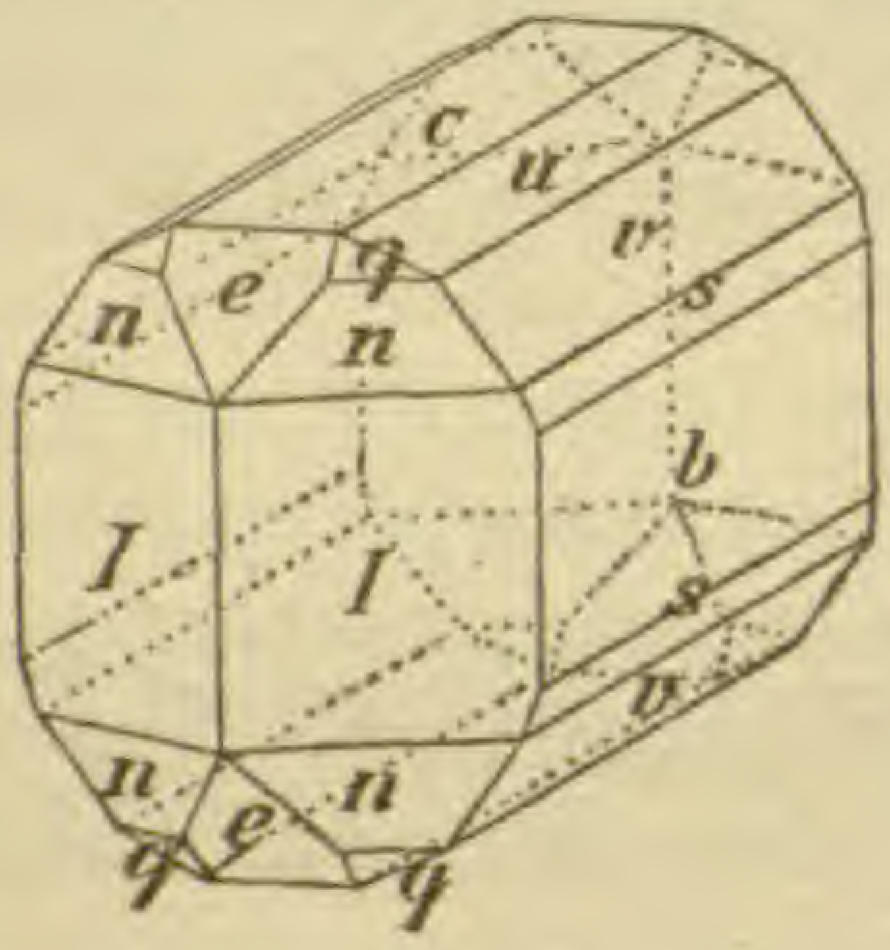
* By Haidinger, and after him Naumann, $t=i$-$\breve{\frac{3}{2}}$ (230), and $I=\frac{3}{2}$-$\breve{i}$ (032).

made before these could be settled upon. The reason for this is that the planes, though in most cases bright, seldom afford sharp well-defined reflections. Their surfaces are sometimes irregularly striated, again uneven as if broken, and still more

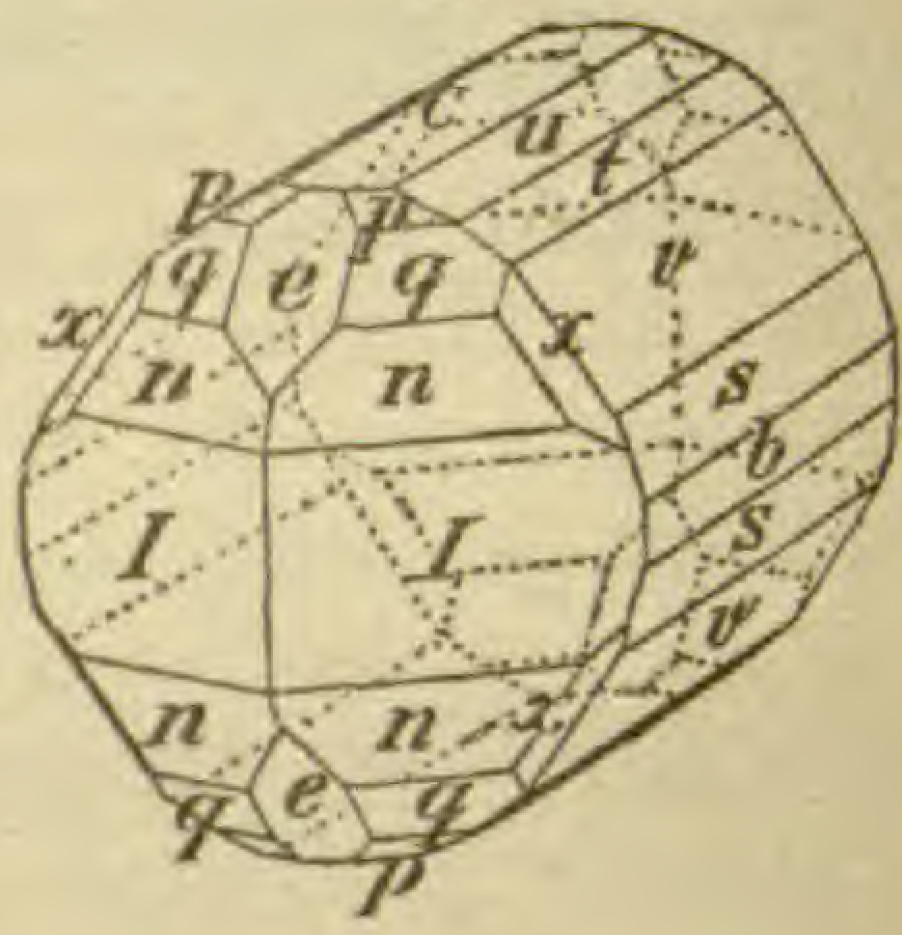
1.



2.



3.



frequently they are covered by minute pyramidal prominences. In the last case it was common to obtain two or more equally bright reflections, and these prominences mark the tendency of the crystallization to produce "vicinal" planes in the place of the simple plane whose position they so nearly occupy. Similar elevations have been observed on the surfaces of the crystals of many species (see the memoirs of Scharff, Sadebeck and others), and very recently Dr. Max Schuster has made a minute and careful study of them on the crystals of danburite from the Scopi (Min. Mitth., 1883, 397), and has discussed their significance in the development of the crystalline form. It is not considered necessary to go into the subject here, but it is evident that, in such cases as the above of multiple reflections, neither one gives the true position of the plane in question; in general it was found that the mean of the two measurements corresponded to it more closely.

The angles finally selected as the basis of calculation were those most nearly free from the irregularities named, the surfaces of the planes being smooth and the reflections tolerably sharp and well defined. These angles are:

1-ĭ ∧ 1-ĭ over *O*	(011 ∧ 0$\bar{1}$1)	=45° 54′
1-ĭ ∧ 3 adj.	(011 ∧ 331)	=57° 7′

The axial ratio calculated from these angles is

$$\breve{a} : \bar{b} : c = 1 : 1\cdot6114 : 0\cdot6823 \quad \text{or} \quad 0\cdot6206 : 1 : 0\cdot4234$$

and the following list gives the most important of the calculated angles.

$O \wedge$ 1-ĭ,	$001 \wedge 011 = 22°\ 57'$		$I \wedge I$ ov. i-ĭ,	$110 \wedge 1\bar{1}0 = 63°\ 39'$
$\wedge$ $\frac{3}{2}$-ĭ,	$\wedge 032 = 32\ \ 25$		i-2̆ $\wedge$ i-2̆ ov. i-ĭ,	$120 \wedge \bar{1}20 = 77\ \ 43$
$\wedge$ 3-ĭ,	$\wedge 031 = 51\ \ 47$		i-3̆ $\wedge$ i-3̆	$130 \wedge \bar{1}30 = 56\ \ 29$
$\wedge$ 6-ĭ,	$\wedge 061 = 68\ \ 31$		$\frac{3}{2}$-ī $\wedge$ $\frac{3}{2}$-ī ov. O,	$302 \wedge \bar{3}02 = 91\ \ 20$
$\wedge$ $\frac{3}{2}$-ī,	$\wedge 302 = 45\ \ 40$		1-ĭ $\wedge$ 1-ĭ	$011 \wedge 0\bar{1}1 = 45\ \ 54$*
$\wedge$ 1 ,	$\wedge 111 = 38\ \ 46$		$\frac{3}{2}$-ĭ $\wedge$ $\frac{3}{2}$-ĭ	$032 \wedge 0\bar{3}2 = 64\ \ 51$
$\wedge$ $\frac{3}{2}$,	$\wedge 332 = 50\ \ 18$		3-ĭ $\wedge$ 3-ĭ	$031 \wedge 0\bar{3}1 = 103\ \ 35$
$\wedge$ 3 ,	$\wedge 331 = 67\ \ 27$		6-ĭ $\wedge$ 6-ī	$061 \wedge 0\bar{6}1 = 137\ \ \ 2$
$\wedge$ 3-2̆,	$\wedge 362 = 58\ \ 30$			
$\wedge$ 3-3̆,	$\wedge 131 = 55\ \ 16$		1 $\wedge$ 1 ov. 1-ī,	$111 \wedge 1\bar{1}1 = 38\ \ 33$
			1 $\wedge$ 1 ov. 1-ĭ,	$111 \wedge \bar{1}11 = 64\ \ 18$
i-ĭ $\wedge$ I,	$010 \wedge 110 = 58\ \ 11$		1 $\wedge$ 1 ov. O,	$111 \wedge \bar{1}\bar{1}1 = 77\ \ 32$
$\wedge$ i-2̆,	$\wedge 120 = 38\ \ 51$			
$\wedge$ i-3̆,	$\wedge 130 = 28\ \ 14$			
$\wedge$ 1,	$\wedge 111 = 70\ \ 43$		3 $\wedge$ 3 ov. 3-ī,	$331 \wedge 3\bar{3}1 = 58\ \ 17$
$\wedge$ $\frac{3}{2}$,	$\wedge 332 = 66\ \ \ 4$		3 $\wedge$ 3 ov. 3-ĭ,	$331 \wedge \bar{3}31 = 103\ \ 24$
$\wedge$ 3,	$\wedge 331 = 60\ \ 51$		$\frac{3}{2}$-ī $\wedge$ 1-ĭ	$302 \wedge 011 = 49\ \ 57$
$\wedge$ 3-2̆,	$\wedge 131 = 43\ \ 37$		$\frac{3}{2}$-ī $\wedge$ 3	$302 \wedge 33\bar{1} = 72\ \ 56$
$\wedge$ 3-3̆,	$\wedge 362 = 48\ \ 24$		$\frac{3}{2}$-ī $\wedge$ 3	$302 \wedge 331 = 33\ \ 47$
			1-ī $\wedge$ 3	$011 \wedge 331 = 57\ \ \ 7$*

For comparison with the calculated angles the following results of measurement may be given, only the most reliable being taken.

		Measured.				Required.
$110 \wedge 1\bar{1}0$	=	63° 38′	63° 37′	63° 40′		63° 39′
$302 \wedge 30\bar{2}$	=	88 45	88 38	88 23	88° 27′	88 40
$011 \wedge 0\bar{1}1$	=	45 54*			45 50	45 54
$031 \wedge 0\bar{3}1$	=	103 39				103 35
$061 \wedge 0\bar{6}1$	=	137 $1\frac{1}{2}$				137 2
$331 \wedge 3\bar{3}1$	=	58 13			58 12	58 17
$331 \wedge 33\bar{1}$	=	44 52			44 42	45 5
$302 \wedge 011$	=	49 39			49 37	49 57
$302 \wedge 331$	=				33 53	33 47
$302 \wedge 33\bar{1}$	=	73 7				72 56

Comparison with herderite.—The only detailed account of the crystalline form of the original herderite is that of Haidinger already referred to. Figure 4 represents the form given by him, but redrawn so that the vertical prism is in its ordinary position (compare figure 454, p. 546 in Dana's Mineralogy). It will be seen that the habit does not correspond very closely with that of the Maine mineral. The planes given for herderite are O (001, *c*), i-ī (100, *a*), i-ĭ (010, *b*), I (110), $\frac{3}{2}$-ĭ (032, *t*), 6-ĭ (061, *s*), 1 (111, *p*), 3 (331, *n*), 4 (441, *o*). By comparing this list with that given above, it will be seen

4.

that all of these planes except the macropinacoid and the pyramid 4 occur on the Maine mineral, while with the latter there are eight not given for herderite. The axial ratio given for herderite is:

$$\breve{a} : \bar{b} : c = 1 : 1\cdot5971 : 0\cdot6783 \quad \text{or} \quad 0\cdot6261 : 1 : 0\cdot4247$$

The following list will show how far the angles correspond:

		Maine phosphate.	Herderite.
$I \wedge I$,	$110 \wedge 1\bar{1}0$,	63° 39′	64° 7′
$1\text{-}\breve{\imath} \wedge 1\text{-}\breve{\imath}$,	$011 \wedge 0\bar{1}1$,	45 54	46 2
$6\text{-}\breve{\imath} \wedge 6\text{-}\breve{\imath}$,	$061 \wedge 0\bar{6}1$,	137 2	137 8
$O \wedge 1$,	$001 \wedge 111$,	38 46	38 41
$O \wedge 3$,	$001 \wedge 331$,	67 27	67 25
$1\text{-}\bar{\imath} \wedge 1\text{-}\bar{\imath}$	$101 \wedge \bar{1}01$,	68 37	68 18

These angles are in the four principal zones and serve as well as a much larger number to show the relation of the two minerals. It will be seen that the angles in the brachydome series approximate very closely, as also those of the unit pyramids, while the macrodomes and vertical prisms vary somewhat. In other words the ratio (compare the axial ratios given) of the axes $\bar{b} : c$ is nearly the same, while those of $\breve{a} : c$ and $\breve{a} : \bar{b}$ differ slightly. This variation is a real one and not caused by error in the assumed fundamental angles; for example for herderite the angle of the macrodome is $302 \wedge 30\bar{2}$ $= 89° 0'$, while on the Maine phosphate the measured values of this angle varied in the extreme cases from 88° to 88° 45′, the most trustworthy angles being those given in the table above. What degree of dependence is to be placed on the original angles of Haidinger cannot be determined, but it may be mentioned in this connection that Groth (Min. Samml. Strassburg, p. 259) states that his measurements on an original specimen confirmed those of Haidinger. Neither the variation in habit nor in angle is, however, sufficient reason for separating the two minerals, but we must conclude that the results of the crystallographic study of the Maine phosphate serve to strengthen the probability of its identity with the Saxon mineral. The question, however, cannot be regarded as settled until something more definite is known about the chemical composition of the latter mineral. It is much to be hoped that one of the few existing authentic specimens will afford the means of at least determining whether it contains aluminum as suspected by Plattner, or beryllium like the mineral from Stoneham.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On a Relation between the Molecular weight of Liquids and their Velocity of Evaporation.*—On distilling successively in the same apparatus given volumes of benzene and of water, SCHALL found that, even when the boiling was maintained as nearly uniform as possible, very different weights of these two substances passed over in the same time. Even in a rough experiment, the quantity of benzene in the receiver was double that of the water. With a view to give the experiment greater exactness, the time of evaporation of equal volumes of these liquids was carefully determined. Knowing then the density of the liquids at the boiling point, their weights could be calculated and hence the exact time of evaporation of equal weights. On comparison, the values thus obtained appeared to be very nearly in the inverse ratio of the molecular weights of the liquids employed. Thus benzene, with a boiling point of 79·2° and a density of 0·8136, evaporated in 12·7, 12·95 and 12·3 minutes; while the same volume of chloroform, boiling point 61·5° and density 1·4048, evaporated in 14·3, 14·5 and 14·3 minutes. Or, reduced to equal weights, in 8·25, 8·4 and 8·28 minutes. Since $m : m' :: t' : t$, the first value gives for the molecular weight of chloroform 119·64, the second 120·25, and the third 115·88; the true value being 119·5. Benzene, when compared with carbon disulphide, boiling point 45·3° and density 1·2212, evaporated in 12·3 minutes, while the same volume of CS_2 required 19 minutes; or 12·66, reduced to equal weights. This gives a molecular weight of 75·79, in place of 76. Water, boiling point 99° and density 0·9596, evaporated in 64 minutes; or 54·26 minutes reduced to equal weights. This gives a molecular weight of 17·68 instead of 18. Moreover, the ratio of the volumes of two liquids evaporated in equal times is the ratio of their molecular volumes. Thus the ratio for benzene and chloroform above given, is 1·126 : 1; whence 1·126 : 1 : : 95·94 (the molecular volume of benzene) : 85·2 (the molecular volume of chloroform); Schiff obtained 84·65. The author has further observed that on comparing Regnault's values of the heat of vaporization of several liquids, these numbers decrease as the molecular weight increases. From which, of fifteen liquids whose heat-data are known, thirteen fall readily into five groups in which the product of the heat of vaporization into the molecular weight is approximately constant. Thus water gives $536·67 \times 18 = 9660·06$; while alcohol gives $214·3 \times 46 = 9857·8$. Acetone gives 7523·76, chloroform 7289·5 and carbon tetrachloride 7161. Ethyl oxide 6711·8, carbon disulphide 6361·2 and ethyl chloride 6128·79. Stannic chloride 11736·4, arsenous chloride 12292·99 and ethyl acetate 12820·72. Phosphorous chloride 8970·5 and ethyl iodide 8938·8.

The remaining two are amyl alcohol, which gives 17954·64 and bromine, 7963·2. These do not seem to belong to any of the above groups, unless the latter be placed in that containing acetone.—*Ber. Berl. Chem. Ges.*, xvi, 3011, Jan., 1884. G. F. B.

2. *On the use of Nitrogen iodide in Photometry.*—In experimenting with nitrogen iodide, prepared by the action of iodine upon an aqueous solution of ammonia, GUYARD has observed that this substance is immediately decomposed in sunlight, nitrogen gas being evolved with effervescence. The minimum action takes place in the violet, the maximum in the blue. In the red-orange the action is sensibly the same as in white light, and in the yellow it is somewhat superior to white. The result appears not to be an effect of heat, since it is the same when the containing vessel is immersed in water kept at a low temperature, or in an athermanous solution. When placed in pure water, and exposed to light, the nitrogen iodide decomposes at first tranquilly, then explodes violently. But immersed in a solution of ammonia of 22° Baumé, it decomposes quietly, no explosion taking place, the rapidity being proportional to the intensity of the light. This suggested the use of this reaction in photometry. But the result may be obtained more simply by acting with iodine upon ammonia at 22° B., the nitrogen evolved in a given time being measured. Nitrogen iodide is produced equally in the light and in the dark; being produced in the light more rapidly than it is decomposed. One-half the iodine forms nitrogen iodide the other half ammonium iodide; traces of ammonium iodate being also produced. For photometric purposes the nitrogen set free may be estimated either by weight or by measure, one gram of pure iodine being employed for 25 to 30 c.c. of ammonia at 22° B. The author gives the name *isophore* or *phosisotime* to the unit of luminous intensity represented by fourteen thousandths of a milligram of nitrogen evolved per hour. This is equivalent to 1·7 c.c. (containing aqueous vapor and ammonia) at 15° and 76 cm. in the photometric burette. The decomposition of the nitrogen iodide by the action of light is given thus: $(NH_2I)_2 = NH_4I_2 + N$; ammonium di-iodide and nitrogen, with a trace of iodate, being the sole products.—*Bull. Soc. Chim.*, II, xli, 12, Jan., 1884. G. F. B.

3. *On the Production of Hydroxylamine from Nitric acid.*—DIVERS has investigated the reducing action of various metals upon nitric acid, and finds that the action of tin, zinc, cadmium, magnesium and aluminum gives rise to the production of hydroxylamine, especially in presence of hydrochloric or sulphuric acid. The function of the second acid is to decompose the nitrate as fast as it is produced, and so (1) to hold the hydroxylamine in a more stable state, (2) to preserve it from the destructive action of nitrous acid by preventing the formation of this acid from the reaction of the metal on the nitrate, and (3) to determine the reduction of the nitric acid to hydroxylamine by supplying the hydrogen for reproducing it. Metals he divides into two classes according to their action on nitric acid. In the first class are

silver, copper, mercury and bismuth. These metals form nitrite, nitrate and water, and exert no further action, producing neither ammonia nor hydroxylamine. They decompose the nitric acid into hydroxyl and nitroxyl combining with these radicals to form hydrate and nitrite, which by secondary reactions become water, nitrous acid and metal nitrate. They therefore separate nitrogen from oxygen (hydroxyl) in decomposing nitric acid, and not hydrogen from oxygen. In the second class are tin, zinc, cadmium, magnesium, aluminum, lead, iron and the alkali metals. These form ammonia and generally hydroxylamine, but do not produce nitrous acid or nitrite with free nitric acid. On the other hand they readily form nitrite by acting on their own nitrate. Two actions are noted: 1st, upon seven molecules of acid separating as hydroxylamine, the hydrogen of six of them by forming nitrate and leaving the seventh converted to water and the said hydroxylamine; 2d, they combine with hydroxylamine to form metal-ammonium hydrate which decomposes with water into metal-hydrate and ammonia. The author considers that nitrites have a constitution indicated by the name "nitronates," the metal being directly united to their nitrogen. The radical is the same as that existing in nitrates $-NO_2-$, these being its metal-oxyl compounds.—*J. Chem. Soc.*, xliii, 443, Dec., 1883. G. F. B.

4. *On the Oxidation of Phosphorus at low temperatures.*—It having been asserted by Irving that phosphorous oxide, prepared by passing a current of dry air over melted phosphorus, is decomposed when exposed to sunlight into amorphous phosphorus and phosphoric oxide, COWPER and LEWES have repeated the experiments with a view to verify them. They obtained a perfectly white deposit in the farther chambers of the tube, and on scaling off two of these and exposing one to the light while the other was kept in darkness, they observed that the former became brown in a few hours, while the latter remained white. On examining the white mass with a lens, it was seen to be filled with minute crystals, and on shaking a portion into the air it at once took fire. Another portion of the white deposit treated with water and filtered left a residue of phosphorus on the filter which took fire on drying. On analysis the white deposit proved to be a mixture of phosphoric oxide 71·0, phosphorous oxide 9·6 and phosphorus (by difference) 19·3 per cent. The so-called phosphorous oxide of Irving is therefore essentially phosphoric oxide containing considerable free phosphorus.—*J. Chem. Soc.*, xlv, 10, Jan., 1884. G. F. B.

5. *On the Constitution of Benzene.*—About eighteen years ago KEKULÉ suggested the hypothesis that all aromatic compounds had as a nucleus six tetrad carbon atoms united in a closed ring. The marvelous fruitfulness of this hypothesis has well nigh re-created organic chemistry. In 1879, Gruber produced an acid by treating protocatechnic acid with nitrous acid, which he called carboxytartronic acid, to which he assigned the formula $C_4H_4O_7$,

or $OH-C\begin{cases}COOH.\\COOH.\\COOH.\end{cases}$ Barth, the following year, produced it from pyrocatechin by similar treatment, and maintained that its formation proved that in benzene one carbon atom must exist united to three others; contrary to the hypothesis of Kekulé. This latter chemist has now made an elaborate investigation of the so-called carboxytartronic acid, and has succeeded, 1st, in producing from it, by the action of reducing agents, tartronic, inactive tartaric and racemic acids; and 2d, in preparing it from tartaric acid. The insoluble characteristic sodium carboxytartronate prepared from tartaric acid, is identical with that obtained from pyrocatechin. It is therefore clear that carboxytartronic acid cannot have the constitution hitherto ascribed to it, and hence is wrongly named. It should not be called carboxytartronic acid nor oxymethin tricarbonic acid as proposed by v. Meyer; first because it does not possess the constitution expressed by these names; and second, because these names should be reserved for their proper acids. Although the exact formula is uncertain owing to the difficulty of obtaining the water of crystallization, yet no doubt exists that this acid stands in simple relation to tartaric acid and is dioxytartaric or tetroxysuccinic acid. Since, therefore, it contains no carbon atom united to three other carbon atoms, its formation from pyrocatechin is no argument against the benzene ring. Although this formation can be explained by either the hexagonal or the prismatic formula, the author believes that it is more easily explained by the former than by the latter.—*Liebig's Ann.*, cci, 230, Oct., 1883. G. F. B.

6. *Observations on Phosphoresence, and a new phosphorescent eye-piece.*—E. Lommel places in the plane of the cross hairs of an ordinary spectroscope a piece of microscopic slide glass, one portion of which is covered with a thin layer of Balmain's paint, or other phosphorescent material. In certain cases the phosphorescent substance is contained in a very fine powder between two such slides. It is found that the phenomenon can be observed through this layer as well as by observing it on the side which receives the light. The slit of the spectroscope is suitably modified and the solar spectrum is thrown upon the phosphorescent slide after it has been subjected to daylight or to any source of light. The phenomena described by H. Becquerel can then be readily studied. The dark bands in the ultra red are shown to be true absorption bands due to the phosphorescent substances employed. By passing the red rays of the spectrum through red glass the ultra red portion is made visible by a greenish-blue phosphorescent light. By allowing the spectrum to fall on one portion of the phosphorescent slide and extinguishing it on a lower portion one can study the light bands and the dark bands of phosphorescence together. The method of increasing the visibility of the ultra red is closely analogous to that of fluorescence by means of which the ultra violet is made visible. If the wave-

length of the D line is taken as 0·589 mikron, the first characteristic dark band in the phosphorescent spectrum lies between 0·942 and 0·861, and the second between the wave-lengths 0·804 and 0·715. A greenish-blue phosphorescing sulphide of calcium gives a more vivid spectrum than Balmain's paint. A plate covered with this substance and kept in the dark for four days will show the bright phosphorescent ultra red spectrum in a beautiful manner, while Balmain's preparation of sulphide of calcium scarcely shows it after being two days in darkness. Other preparations of sulphide of calcium were experimented with, including a sky-blue preparation, but these were all inferior to the greenish-blue preparation. It was found that the phosphorescent light is stronger during the action of the exciting rays than afterward, and the distribution is also different in the two cases.—*Ann. der. Physik und Chemie*, 1883, No. 12[b], pp. 847–860. J. T.

7. *Earth Currents.*—In reply to certain criticisms of M. Larroque, M. E. E. Blavier, who is engaged in studying electrical effects upon a line between Nancy and Paris, says, in substance: The potential of a point on the earth's surface is modified by many accidental circumstances, such as the discharge of a storm cloud, etc.; but this variation is infinitely short and equilibrium is soon re-established, and the slight changes give no trace upon a strip of photographic paper on which the space given to one hour is only $0^{m}\cdot01$. It is claimed by M. Larroque that sufficient attention has not been paid to polarization currents. The plates employed were masses of iron, which it is true gave a contrary electromotive force of about $\frac{1}{10}$ of a volt, while the earth currents observed were often 3 to 5 volts. The polarization is sensibly constant during a certain portion of the time of observation and can be taken into account in cases of registration. M. Larroque believes that the static potential of the earth at the two contacts should be taken into account. M. Blavier has not occupied himself with this question. In reply to the point that the resistance of the earth between the two stations varies with different conditions, it is replied that the resistance of the earth around an earth-plate in ordinary telegraph lines when communication is well established, does not exceed generally 40 ohms, while the experimental line adopted by M. Blavier had a resistance of 10,000 ohms. M. Larroque believes that uncovered aerial telegraphic lines are unsuitable for the study of earth currents; but M. Blavier finds no difference between an aerial line and a submarine cable. In reply to the points that it is necessary that the line should be formed of a wire of small resistance, non-magnetic, well insulated and absolutely free from humidity, M. Blavier states that it is necessary to employ a circuit of high resistance, that the magnetic properties of the iron have no effect, and that the insulation of an ordinary telegraphic iron gives the same result as a submarine cable. It was found that the battery earth of the telegraphic system of Paris did not affect the results appreciably, and that earth currents could be observed on short lengths of

line. The curves furnished on a line from Paris to Chalons were compared with those given by a line from Rue de Grenelle, in Paris, to the Porte de Flandres, and were found to exhibit the same variations, with only slight variations due to the lines not holding exactly the same direction.—*Comptes Rendus*, Dec. 31, 1883, pp. 1551–1553. J. T.

8. *Heat in iron due to periodically changing magnetic force.*—The heat noticed has been attributed by some investigators to the movements of the magnetic molecules, and hence has been called heat of magnetic friction. Other investigators think that this heat is due almost entirely to electro-magnetic induction in the mass of iron. E. WARBURG and L. HÖNIG have taken up the subject and their experiments lead them to believe that a large part of the heat is due to magnetic friction. The magnetizing coil and the entire apparatus were placed in a carefully constructed calorimeter with double walls filled with fine pieces of ice. The iron, generally in the shape of a bundle of iron wires, was enclosed in the bulb of what was practically an ether thermometer. The leading principle of the method adopted was to heat the iron by two cyclic processes. In the first cycle the magnetizing force varied from 0 to $+k$; in the second cycle from $-k$ to $+k$. k was 170 times the horizontal component of the earth's magnetism in Freiburg. If the heat produced depended only upon the electrical resistance of the iron, and if the coercitive-force of the iron was zero the authors maintain that the heat of the double cycle should be twice that of the single cycle. In one case, in which they used a thick bar of iron, this was so; in other cases the ratio of the heat produced in the double to that in the single cycle, was greater than two. The authors examined the sources of error that might arise from the change in character of the temporary and permanent magnetism due to change in direction of the magnetizing currents. They also examined how much heat was due to the application of Carnot's principle, pointed out by Thomson, namely, that a production or absorption of heat is produced according as the magnetizing function decreases or increases with the changing temperature. The general conclusion arrived at is that a large proportion of the heat observed, nearly 75 per cent, is due to magnetic friction.—*Ann. der Physik und Chemie*, No. 12^b, 1883, pp. 814–835. J. T.

9. *Principles of Theoretical Chemistry, with Special reference to the Constitution of Chemical Compounds;* by IRA REMSEN, Professor of Chemistry in the Johns Hopkins University. Second edition, thoroughly revised and enlarged. 8vo., pp. xii, 242. Philadelphia, 1883. Henry C. Lea's Son & Co.—This excellent little book of Professor Remsen's may fairly be considered a protest uttered against the now prevalent notion that the science of Chemistry lies chiefly in its formulas. Its key-note, stated on page 100, is as follows: "It cannot be denied that we are now in a period of Chemistry which may fairly be called one of *formula worship*. By weaker minds more value is attached to a formula

than to that which it is intended to represent. In consequence of this truth, it has happened that a large number of chemists have regarded the determination of a formula for a compound as the great object to be accomplished and forgotten that what we ought to know and what is of vastly greater importance for the science is the chemical conduct of the compound." Hence the author states in the preface: "I have endeavored to discuss in an impartial way, as objectively as possible, the principal hypotheses which at present play important parts in the science of chemistry. As, strictly speaking, we have no theory of chemistry, the hypotheses are more or less disconnected; and as there is no general theory to keep them in check, some of them have assumed a variety of forms." What, precisely, is meant by the term "constitution" on the title page, he tells us on page 232: "A study of the preceding chapters on constitution will show that no absolute meaning is to be attached to the word. Constitutional formulas are those which suggest certain reactions and recall analogies. The formula CH_3—OH does not mean that hydroxyl (OH) is necessarily present in the compound or that CH_3 is present, but that the different parts of the compound bear such relations to each other that when the compound is decomposed it acts as if the parts were united as the formula indicates. The formula suggests possibilities; it may not represent realities." The book is therefore a valuable contribution to the chemical literature of instruction; and particularly at this time when so strong a tendency exists to over-value chemical hypotheses and under-value chemical reactions. That in so few years a second edition has been called for indicates that many chemical teachers have been found ready to endorse its plan and to adopt its methods. In this edition a considerable proportion of the book has been rewritten, much new matter has been added and the whole has been brought up to date. We observe, however, that the somewhat cumbrous terms "hydroxide" and "anhydride" have been retained, in place of the simpler ones "hydrate" and "oxide," which seem more in harmony with chemical nomenclature generally. We earnestly commend this book to every student of chemistry. The high reputation of its author assures its accuracy in all matters of fact. And its judicious conservatism in matters of theory combined with the fullness with which, in a small compass, the present attitude of chemical science toward the constitution of its compounds is considered, gives it a value much beyond that accorded to the average text books of the day.

II. Geology and Natural History.

1. *Human foot-prints on sandstone near Managua, in Nicaragua;* by George H. Johnson, Professor of Mathematics and Engineering at Leon, Nicaragua. (From a letter dated College of Leon, Leon, Nicaragua, Central Am., Nov. 5, 1883, to Professor George H. Cook, of New Brunswick, N. J., and communicated

by the latter.)—Before coming to Leon we remained six weeks in Manaqua studying the language. While there I learned that foot-prints had been found on a sandstone at a quarry in the vicinity, and took the first opportunity for visiting the quarry. The quarry is situated southwest of the School of Arts and about a quarter of a mile west of the *Plaza.* Around the quarry were many blocks of sandstone about one cubic foot in size ; these had just been excavated and quite a number of them contained tracks which were undoubtedly human foot-prints. They looked exactly like the impressions of bare feet which may be seen at any time on the sandy beach of Lake Manaqua, which is only a few rods from the quarry. The bottom of the foot-print was generally about two-thirds of an inch below the even surface of the stone, and some of the impressions were quite distinct, showing the form of each toe. Most of the tracks were large enough for a man, but some of them were evidently made by a child. I found by inquiry that when the stratum of sandstone was exposed three parallel series of tracks were seen, all of them directed from the east toward the west. I examined the strata overlying the sandstone containing the tracks, and the vertical section (from the surface downward), as shown at the quarry is as follows:

Unsolidified volcanic conglomerate, 3 layers, 3½ feet.
Stratified sandstone, 2 layers, 2 feet.
Greenish-brown clay, 14 inches.
Sand, 1½ feet.
Yellowish-brown clay, 14 inches.
Brown clay, 6 inches.
Sandstone, 3 layers, 2·3 feet.

All the beds are approximately horizontal and of nearly uniform thickness. It will be seen from the section that the tracks are found about twelve feet below the surface. Some of the overlying beds contain numerous arrow-heads and other relics which are quite unknown among the Spanish-speaking Indians who now constitute the mass of the population.

All the western part of Nicaragua is highly volcanic and probably had its origin during the Quaternary period. There is some reason for supposing that Lake Manaqua, as well as the lake of Masaya, was formed by the sinking of a great volcano.

The beds overlying the tracks are undoubtedly either directly or indirectly of volcanic origin. That is, the beds may be composed of volcanic matter originally deposited in its present location and then partly solidified by pressure, or the matter may be disintegrated lava, etc., which was deposited in water. The latter hypothesis is supported by the fact that that part of the country has sometimes been inundated by great floods during the rainy season.

2. *On the relative ages of certain River-valleys in Lincolnshire ;* by A. J. Jukes-Browne. (Quart. Journ. Geol. Soc., xxxix, 4, 1883, 596.)—The author sustains the general theory of Jukes, that in a region of parallel escarpments the drainage (im-

plied consequent) comprises (1) cross-streams in the direction of dip (and implied slope), which are the older, and (2) longitudinal tributaries parallel with the escarpments and strike, which are the newer; but he assails the unessential though indubitable corallory that no longitudinal tributary can ever intercept and incorporate the lowest of the pre-existent cross-streams. Assuming a dip and slope not orthogonal to the escarpments—a condition incompatible with Jukes's theory in its simplest form—he argues (and demonstrates, from an ill-considered example adduced by Jukes), that the longitudinal stream flowing into the sea may so extend its course as to interrupt and absorb a number older cross-streams. Additional examples are described originally, and discussed at length. W. J. M.

3. K. J. V. STEENSTRUP *on the Glacier and Glacier-ice of North Greenland.* 84 pp. 8vo, with 7 plates and a colored geological map.—This memoir relates to the West Greenland region, between the parallels of 69° (near Jakobshavn) and 72° 30′ N., which includes the island of Disko. The fine map shows the limits of the inland or interior ice; the limits of the many glacier-streams that descend from the interior ice into the heads of the long fiords; other smaller glaciers descending from the high land within the coast region; the position of the Carboniferous beds along the northern and western coasts of Disko, on the peninsula of Nugsuaks next north, and on Upernavik and at other points farther north; the distribution of the trap, the chief surface rock apparently of Disko and other coast islands and peninsulas; the localities about Disko, and the peninsula north of it and elsewhere, of the nickeliferous (or meteorite-like) iron, part of the iron in place; and other points of interest. The plates are phototypes and highly instructive.

4. *Malesia*, auct. ODVARDO BECCARI.—The three earlier parts of this fine work were published in the years 1877–8, and were duly noticed in this Journal. The indefatigable author has now sent us the fourth part, which completes the first volume, a quarto of 304 pages, and with 28 excellent lithographic plates. The work is devoted, as we know, to the publication of the author's own botanical collections, observations and discoveries upon the plants of Indo-Malesia and Papua, during his travels in those regions in the years 1865–1876. In the part now issued Dr. Engler of Kiel has elaborated and illustrated the *Araceæ.* A. G.

5. *Thoughts upon Botanical Taxonomy. Pensées sur la Taxonomie Botanique;* par T. CARUEL.—A memoir by the most accomplished systematist in phænogamous botany in Italy, now professor in Florence, presented to the Lincean Academy in 1881, published the following year in its Scientific Transactions, in Italian, now re-edited by the author, in French, and published during the past year in Engler's Botanische Jahrbücher, the first portion in the fourth, the remainder in the fifth volume. The separate issue fills a little more than a hundred octavo pages. It is a treatise upon the classification of plants; which the author

well insists should remain upon a morphological basis, without mixture of other considerations. And his strength is mainly devoted to a natural arrangement of the families (orders of Jussieu) under more comprehensive orders, cohorts and classes, etc. Of course he begins the series of Phanerogamæ, class Angiospermæ with the Monocotyledones. We should all do that now, if we had to begin anew, and if we keep Gymnospermæ as a class, so as to give the latter its proper position between the higher Cryptogams and the Angiospermous Dicotyledones. Of course, also, the artificial divisions of *Polypetalæ*, *Gamopetalæ* and *Apetalæ* are thrown aside. M. Caruel replaces them with his cohorts Dichlamydanthæ, Monochlamydanthæ and Dimorphanthæ. The first includes Gamopetalous and Polypetalous orders generally; but the second has all the Candollean orders from Ranunculaceæ to Fumariaceæ, the Cactaceæ, Portulaccaceæ, Rhamnaceæ, etc., etc.; the third has Begoniaceæ, Euphorbiaceæ, Urticaceæ, etc., as well as the Amentaceous orders. A class, Anthospermæ, of equivalent weight to Angiospermæ and Gymnospermæ, is interposed between them, and consists only of the order Spermifloræ (Loranthaceæ and Viscaceæ). We need not present the new arrangement of what used to be called Cryptogamia. Looking only at the Phanerogamæ, our only remark need be that such essays are full of interest, perhaps of future promise; but that none of the recent schemes are in condition to replace the Jussiæan and Candollian arrangements with all their imperfections.

A. G.

6. *Necrologia Botanica.*—The annual record which was published in this Journal for many years has not appeared for the last three years; yet some biographical notices of deceased botanists have generally been given. From the ranks of American botanists the losses which we particularly recall to mind are the following. In the year 1880: COE F. AUSTIN, who died on the 18th of March, at the early age of 48. CHARLES C. FROST, an excellent Cryptogamist, died at Brattleboro, Vermont, March 16, at the age of 75. JOHN CAREY, whose active botanical career was in this country, in which the middle years of his long life were passed, died on the 26th of March, in his 83d year. DR. SAMUEL B. MEAD, of Augusta, Illinois, died November 11, at a good old age. In the year 1881, January 4, died Professor ALPHONSO WOOD in the 71st year of his age. In 1882, THOMAS POTTS JAMES, one of our few adepts in Bryology, died Feb. 22, in the 79th year of his age, leaving the venerable Lesquereux to complete the Manual of Mosses upon which these two veterans were engaged. ELIHU HALL, one of the best explorers of Colorado and of Oregon botany, died September 24, at the age of 60. Happily we have no name to add to this list for the year 1883.

In the Old World the full obituary record for the year 1880 would be a long one. It would commence with the name of the venerable J. S. TOMMASINI of Trieste, who died upon the last day of the year preceding. It includes the name of the distinguished Agrostologist, General William Munro, who died Jan. 29, at the age of 64; also of the two eminent Bryologists W. P. Schimper, March 20, æt. 72, and of Ernest Hampe, Nov. 23, æt. 85; of N. J. Anderson of Stockholm, who had been infirm for several years, but survived until March 20; and of Robert Fortune, who died April 13, at the age of 68.

In the year 1881, died Ludwig Rabenhorst, the Cryptogamist, April 24, at the age of 76; Matthias Jacob Schleiden, a foremost name forty years ago, but whose botanical career was brief, although he lived till June 23, and reached the age of 77 years; Michael Pakenham Edgeworth, a brother of Maria Edgeworth, and an adept in East Indian botany, July 30, æt. 69; Hewett Cottrell Watson, who so sedulously investigated the particular distribution of plants in Europe, July 27, æt. 77; Paul Gunther Lorentz, who was professor of botany at Cordoba, in the Argentine Republic, but who died at Concepcion in Uruguay, Oct. 6, æt. 52; and Otto Wilhelm Sonder of Hamburgh, who died November 21, æt. 70.

In the year 1882 we lost Joseph Decaisne, February 8, at the age of 75; George H. K. Thwaites, who died at Peradeniya, Ceylon, September 11, æt. 71; and here we may also add the name of Charles Darwin, who died April 19, æt. 73.

So far as we are now informed only three distinguished botanists have died during the year 1883, namely:

Vincenzo Cesati, until recently professor of Botany in the university, and director of the Botanic Garden at Naples, died there, February 13, 1883, in the 77th year of his age. He was born at Milan, of a noble Lombard family; and there most of his botanical work was done, all of a respectable but none of a very high order.

Hermann Mueller of Lippstadt, Botanist and Entomologist, the renowned investigator of the mutual relations of insects and flowers, as concerns the fertilization of the latter, and the adaptive modifications of the one to the other,—died on the 25th of August last, in the 54th year of his age. A brief notice of him and of his latest and most notable work was given in the October number of this Journal, p. 324; and a fuller memorial was published in Science, for Oct. 12, 1883.

Oswald Heer, the most distinguished paleontological botanist of our time, professor of botany in the University of Zurich, died, at Lausanne, September 27, at the age of 74. An appreciative biographical notice appeared in Science, for November 2, and one may be expected in this Journal.

At home we have sustained a loss in the death of Charles F. Parker, of Philadelphia, late curator of the Herbarium of the Academy of Natural Sciences, Philadelphia, an excellent local botanist, a kindly and most estimable man. He died September 7, at the age of 63. A just tribute to his memory was contributed by his associate, Mr. Martindale, to the Proceedings of the Academy of Natural Sciences, 1883, pp. 260–265. A. G.

7. Dr. George Engelmann.—Just as these pages were going to the press we are grieved to learn that our oldest associate and friend, the most venerable and eminent of our botanists, who had attained his 75th birthday on the second of February, died on the eleventh, at his home in St. Louis, after a short illness. Although his health became seriously impaired a year or two ago, yet it was of late so far restored that he was able to continue his botanical work with zeal and hopefulness, and the very last number of this Journal contained a notice of a recent publication which gave evidence of this. It must be left to a future number to place upon record some account of his life and of his many and important contributions to science. A. G.

III. Astronomy and Mathematics.

1. *Double Star observations made in* 1879 *and* 1880 *with the* 18½-*inch refractor of the Dearborn Observatory, Chicago ;* by S. W. Burnham.—This reprint from the memoirs of the Roy. Astr. Soc. contains Mr. Burnham's thirteenth catalogue of new double stars, and measures of 770 others.

The several catalogues of Burnham's new stars now contain 1013 numbers. In the appendix to this memoir the author gives the number of pairs of double stars in class I (distance 0″·0 to 1″·0), and in class II (distance 1″·0 to 2″·0), occurring in the principal original double star catalogues.

			Class I.	Class II.	Total.
Burnham, catalogue of	1000	stars,	266	254	520
O. Strue, "	547	"	154	63	217
Struve, "	2640	"	91	314	405
Herschel, I, "	812	"	12	24	36
Herschel, II, "	3429	"	2	20	22
Alvan G. Clark,			14	1	15
All other observers,			40	75	

Hence, he concludes that the known pairs having a distance under 2″ are less than 1400. The principal interest will in the future he believes belong to these close pairs. Double stars below the 8th magnitude and having a distance exceeding 5″ will rarely prove of much interest.

The Milky Way has furnished to Mr. Burnham a larger number of new doubles than the same area elsewhere. In magnitude of leading component the thousand stars are distributed as follows:

0″·0 to 1″·0,	2	3″·1 to 4″·0,	11	6″·1 to 7″·0,	173	9″·0+	69
1″·1 to 2″·0,	8	4″·1 to 5″·0,	29	7″·1 to 8″·0,	303		
2″·1 to 3″·0,	11	5″·1 to 6″·0,	94	8″·1 to 9″·0,	300	Total,	1000

Particular attention is called by Mr. Burnham to the close couple *O* Σ 535, (δ Equulei). The two close components of this triple star are so nearly equal in magnitude that several of the early measurements may be assumed to be 180° in error, and upon these suppositions Mr. Burnham assumes that it has an orbit whose period is 10·8 years. The distance is never more than 0″·40.

We would remark that the observations of Mr. Burnham in 1880, 1881 and 1882, together with nearly all the previous measurements of Struve and others, (corrected, if necessary, by 180°) can be satisfied by an apparent orbit of 11·6 years, the principal star central, the semimajor axis 0″·38, and semiminor 0″·10. The couple in 1883 was very close. The measures then taken are not, however, satisfied very well by this orbit. They indicate very clearly a rapid rotation.

This binary being visible to the naked eye and having probably the shortest period now known, will be watched hereafter with special interest. H. A. N.

2. *A Treatise on Projections;* by THOMAS CRAIG. 4to. Washington, 1882. — This treatise was prepared and published by the U. S. Coast and Geodetic Survey, primarily for its own use. In the several volumes of reports of the survey are very valuable papers on projections by Hunt, Schott, S. C. Peirce and others, the larger portion of them having some reference to the Polyconic projection. The present treatise is wider in scope, and treats of the whole subject of map projections. It consists of two separate portions, the first and larger one being devoted to the Mathematical Theory of Projections, and the second to the Construction of Projections.

The first section in the first part is given to the various kinds of perspective projections of a spherical surface on a plane. Then follow two sections on orthomorphic projections, or those in which figures on any one surface are represented upon any other surface in such manner that small parts in the one figure shall be similar to the corresponding parts in the other. The fourth section treats of projection by development, or, in effect, the representation in small portions of a spherical surface upon tangent cones or cylinders, which are then developed. Two chapters follow upon Zenithal and Equivalent Projections, and then three on the general Mathematical theory of the Orthomorphic, the Equivalent and the Development projections.

The second part is independent of the first, and is intended for practical use. It gives the methods of construction of the several projections, and is followed by thirty-one tables. H. A. N.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Distribution of the Magnetic Declination in the United States at the Epoch January*, 1885, with three isogonic charts and one plate. *Secular Variation of the Magnetic Declination in the United States and at some foreign stations.* (Fifth edition.) With four plates. — The above are titles of two important memoirs by Mr. CHARLES A. SCHOTT, published (as stated on p. 79 of this volume), as appendices to the report for 1882 of the U. S. Coast and Geodetic Survey, J. E. Hilgard, Superintendent. The last published isogonic chart for the United States, by J. E. Hilgard, was prepared for the epoch of 1875

(it was reproduced in this Journal, vol. xix, p. 173). The present chart is on a larger scale than the former, and being based upon a greater number of observations it differs from earlier charts in showing the local disturbances in the direction of the magnetic needle; in the case of the New England States and Missouri, for example, the minor irregularities in the distribution of the magnetism are given with considerable accuracy. The accompanying memoir gives a table, extending over upwards of forty pages, of magnetic declinations reduced to the epoch of January 1, 1885.

The memoir upon the secular variation of the magnetic declination, chiefly in the United States, the preceding 4th edition of which was published in June, 1881, gives a most valuable and interesting summary of the facts relating to the secular variation of the magnetic needle in this country, together with the enumeration of the long series of observations upon which the results are based. A special plate shows the position of the region in northeastern Maine and beyond, where the needle has reached its western elongation and become stationary; and also of that in the west, across Idaho, Nevada and Arizona, where the needle is also stationary, having reached its eastern elongation. The progressive motion of the secular change from east to west may be compared to a wave motion, and these two regions named are in opposition with respect to the phases of the phenomenon, the one corresponding to a crest, the other a trough, and the space between them representing half a wave-length. Another plate exhibits the more or less exactly known positions of the agonic line of the North Atlantic for the epochs of 1500, 1600, 1700, 1800, 1880 and 1900, and it is shown that the azimuthal motion of the isogonic system in the vicinity of this agonic line, as represented by this line, has been since 1600 in the direction of the hands of a watch.

2. *Maps issued by the Northern Trans-Continental Survey*, RAPHAEL PUMPELLY, Director.—The Northern Trans-Continental Survey, organized in 1881 in the interest of the principal railroads of the Northwestern Territories, has recently issued Map Bulletin No. 1, prepared by the Topographical Department, A. D. WILSON Chief Topographer, associated with R. W. Goode and Louis Nell. It includes the following maps: Yakima Region, W. T., in two sheets; Colville Region, W. T.; Judith Basin, Montana, in two sheets; Crazy Mountains, Montana. The maps have been excellently executed by Julius Bien, of New York.

OBITUARY.

ARNOLD HENRY GUYOT.—Professor Guyot, for many years occupying the chair of Geology and Physical Geography in the College of New Jersey, at Princeton, died on the 8th of February, in his 77th year. He was born near Neuchâtel, Switzerland, in 1807; studied at the universities of Stuttgart, Carlsruhe and Berlin, adding to theology, at the latter place, physical geography under Karl Ritter, and geology under Hoffmann; and ended his preparation for work by studies from 1835 to 1839 at Paris. In 1839 he was called to the Professorship of History and Physical Geography at Neuchâtel, where Agassiz, his early companion, and but four months his senior, had occupied, since 1832, the chair of Natural History.

Professor Guyot held this position at Neuchâtel for ten years, and in the interval he spent much of his time in carrying on investigations, previously begun, in the physics and structure of the Alps, and the phenomena of glaciers. He made out the laws of motion in the glacier, and diverged from Agassiz in the conclusion which he reached as to the movement, attributing it to "molecular displacement mainly under the action of gravity." He was the first to discover (in 1838), the laminated character of the glacier ice. He made a special study of the bowlders that are spread over Switzerland between the Alps and the Juras, and discovered that those of different kinds of rocks were largely in lines leading up to different Alpine peaks from which they were sent off, and, after laborious explorations and comparisons involving over 3000 barometric determinations of altitude, proved that the order of succession in the lines over the plains and on the Juras and other distant heights, corresponded with the geographical positions of the peaks. He thus determined the height of the Alpine sources and the limits of the drift over a region 300 miles long and 200 wide, and demonstrated the morainic character of the erratic material, and the identity between the laws of existing glaciers and those of the former great ice-mass that had covered all Switzerland. The specimens collected from all the lines of stones to the mountain tops are now arranged geographically in the Princeton Museum, which contains also the other gifts from him, its Curator, and evidence of his care everywhere, and which has recently been named the Guyot Museum.

The "*Système Glaciaire*," published in 1847, has for its full title, "Système Glaciaire, ou Recherches sur les Glaciers, leur mécanisme, leur ancienne extension, et le rôle qu'ils ont joué dans l'Histoire de la Terre, par MM. L. Agassiz, A. Guyot and E. Desor; Premiere Partie." This *first* part was the great work of Agassiz on glaciers. But although so valuable, it was unfortunate for science that the other parts failed of publication, owing to revolutionary movements in Switzerland which were destructive to the Neuchâtel University. Guyot's views appeared in brief in the Bulletin of the Neuchâtel Society of Natural Sciences, and are cited in the second volume of d'Archiac's "Histoire des progrès de la Géologie" (1848).

In 1848 Guyot came to this country, following the course of Agassiz who reached America two years before. Switzerland lost much in this removal of two of her ablest professors, but America gained vastly more. While Agassiz infused new ideas into the people and the schools and other educational institutions of the land as to the value of natural science and the methods of instruction, Guyot gave, with like effect, new methods and widened comprehension with regard to the relations of physical geography to man and history, and to the true objects of geograpical study. For six years Guyot was employed by the Massachusetts Board of Education as lecturer to the normal schools of the State on geography and the best ways of teaching it. The year after his arrival in the country he delivered in French a course of lectures in Boston, which were afterward translated by Professor Felton, of Harvard, and published under the title of "Earth and Man." The volume exhibits the broad philosophic views and exalted tone of mind and heart of its author, and commenced his period of influence over geographical education among us.

In 1850 he organized the system of meteorological observations put into action by the Smithsonian Institution, and advised as to the construction of instruments for the purpose. In 1851 to 1859 he prepared a volume of *Meteorological and Physical tables*, published by this Institution. He began at the same time a systematic study of the physical geography of the United States, especially as regards the features of its mountains and the heights of their peaks, from northern New England to South Carolina. The principal results up to 1861 are presented in one of the volumes of this Journal for that year, in a paper "on the Physical Structure of the Appalachian System." His last work of this character was carried on in the Catskill Mountains, during several summers between 1862 and 1879, the latter two years after he had passed his 70th birthday. It was a work of great difficulty on account of the pathless forests spreading over many of the summits, which were mostly featureless, and the necessity in some cases of climbing to the tops of the highest trees to gain a view of the neighboring summits for triangulation. He carried his survey through with wonderful precision, considering the difficulties, discovered heights among the peaks greater than had before been known, and has given an excellent map of the region. (This Journal, volume xix, 1880.)

Professor Guyot's theological and scientific training fitted him to make a judicious exposition of the first chapter of Genesis. A brief statement of his views on the subject has been before the country in the chapter on Cosmogony in Dana's Manual of Geology, derived orally from him. The closing labor of his life was the preparation of a volume of 200 pages on this subject, and the last proofs had been read just before his death.* Professor Guyot believed in the spiritual not less than in the material; in Nature's laws, and in the Infinite Lawgiver, the Author of Nature; and his life was throughout a manifestation of his Christian faith.

Professor Guyot received his professorship at Princeton, in 1855. He was one of the original members of the National Academy of Sciences. His excellent wife, who survives him, was the daughter of ex-Governor Haines, of New Jersey. J. D. D.

* Published by Scribner's Sons, New York, the publishers of his school geographies, atlases, and maps.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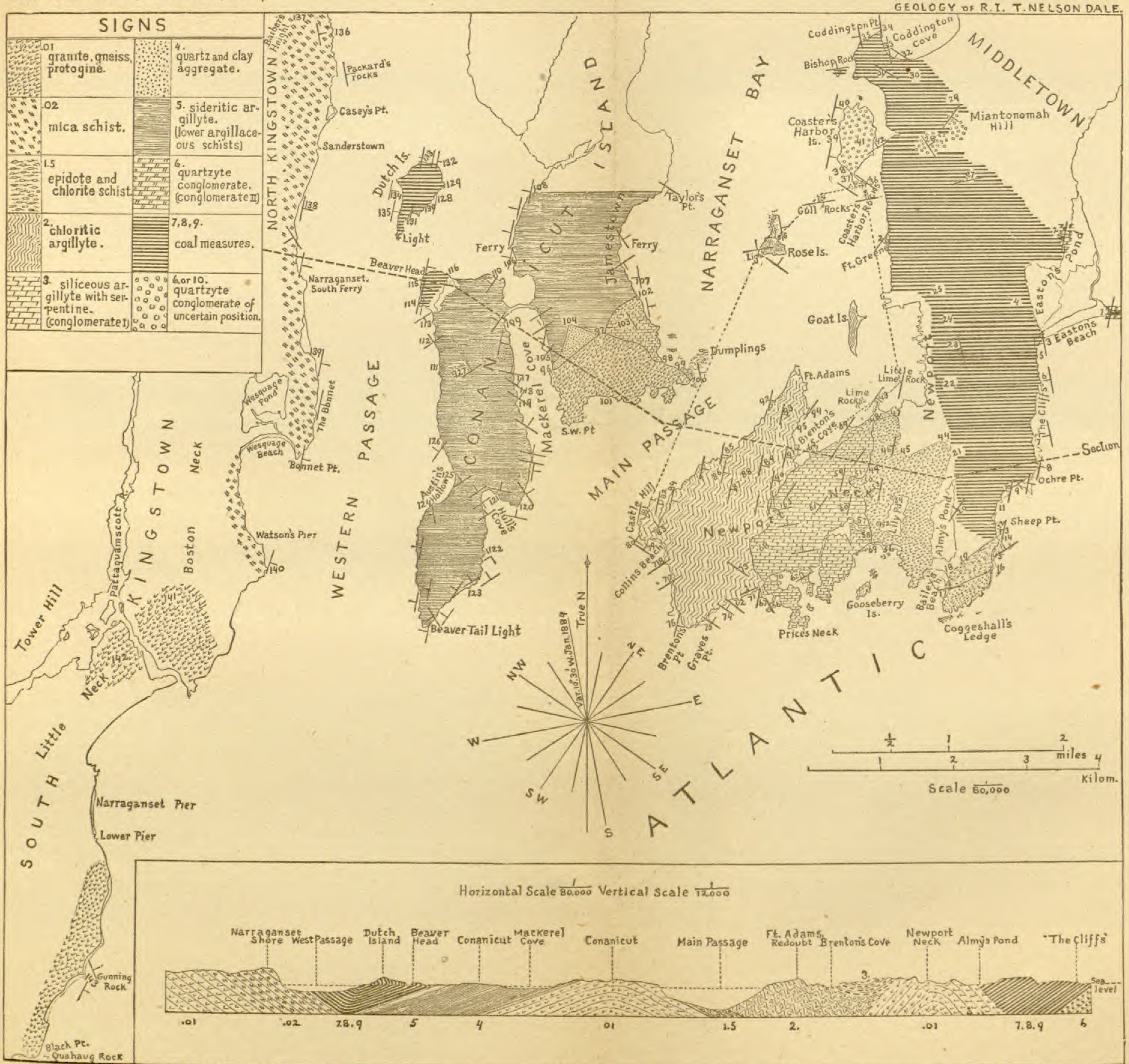
GEOLOGY of R.I. T. NELSON DALE.

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THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. XXIX. — *Recent Explorations in the Wappinger Valley Limestone of Dutchess County, New York;* by Prof. WILLIAM B. DWIGHT, Vassar College, Poughkeepsie, N. Y. With Plate VII.

No. 4.—DESCRIPTIONS OF CALCIFEROUS (?) FOSSILS.

IN a previous paper of this series, four years ago,* the writer made known his identification of Calciferous, as well as Trenton rocks, in the limestones of the Wappinger Valley. This determination was founded on the presence of the ordinary but very unsatisfactory fossils considered characteristic of the Calciferous in the United States.

One year later announcement was made, in a brief note,† of his further discoveries, in the same apparently Calciferous stratum, of fossils far more striking and important. These were stated to be gasteropods and one or two small brachiopods, accompanying orthoceratites lying crowded together, in some localities, and in much variety of structure and of size, reaching in some cases a length of 9 inches, and in others a width of 1½.

The long interval which has followed without the publication of the details in this series of papers has been unavoidably due to the extent of the problems, and of the work, thus suddenly and unexpectedly presented. The question of the true age of the stratum was at once re-opened; new, careful and extended exploration for all attainable facts was imperatively

* This Journal, January, 1880. † This Journal, January, 1881.

demanded. Under this exploration the stratigraphic relations of the adjacent slates and the two limestone formations, which at first seemed simple, proved exceedingly complicated; a large mass of fossils in a highly fragmentary and considerably metamorphosed condition has been collected, from which definite results in determination could be reached only by the most delicate and laborious manipulation, and the most painstaking collation of forms. This field work is not yet concluded, for every excursion, while contributing perhaps to the solution of previously unknown quantities, has brought forward new problems.

On account of the richness of this field in facts of paleontological and stratigraphical importance, it is now evident that justice cannot be done to the subject within the limits of these papers. The general facts, however, of both the stratigraphy and paleontology of this limestone belt will be presented here, leaving the more complete discussion of the subject for a monograph which the writer designs to prepare as soon as the work of investigation can be sufficiently completed. The Trenton limestone present has already furnished additional fossils, of which descriptions will hereafter be given.

The particular object of the present paper is to begin the descriptions of Calciferous (?) fossils. Before describing them, however, it will be proper to add a few very brief statements, sufficient for the present purpose, as to their occurrence and the probabilities as to their age.

What I am prepared to say at present in regard to their relative age may be stated as follows:

I. The rock containing them, both in its lithological character and its fossils, is quite distinct from the super-jacent limestone which is beyond question Trenton.

II. Its orthoceratites differ notably from any similar collection, taken as a whole, as far as I know, in either the Trenton or the Black River groups, in the facts that no species are found among them whose septa are more distant than about nine to the inch, most of them having septa standing much more closely; and the additional feature that with the rarest exceptions the siphons are lateral, if not marginal, with a tendency to be proportionally very large throughout the group.

III. Everywhere closely intermingled with the orthoceratites are various gasteropods appearing to be identical with those accounted characteristic of the Calciferous of the United States and of Canada. Notably there are admirable specimens of the *Ophileta compacta*, fortunately fully described and illustrated by Salter. (Geological Survey of Canada, Decade I, p. 16.) Except for the presence of these orthoceratites, there would be no hesitation is assigning this limestone to the so-called

Calciferous group. But the presence of these new fossils, to say nothing of existing doubts as to the true stratigraphic relations of much that has elsewhere been called Calciferous, suggests great caution in deciding upon the horizon.

On the other hand, these fossils as a whole, cannot at present be safely assigned to any other group with so much justification as to the Calciferous. They will be so assigned at this time, but with the understanding that it is a provisional arrangement.

A more full discussion of the age of this rock will be appropriate after the fossils have been more fully described, including the important gasteropods above mentioned.

This Calciferous formation, accompanied in many places by the Trenton in much smaller masses, displays its fossils for a number of miles above and below Poughkeepsie, in the Wappinger Valley. By far the richest locality, however, is at the hamlet of Rochdale; especially are the orthocerata the largest, and the most crowded together in a low ledge on a hill-side about 900 feet northwest of the woolen mills.

I am much indebted to the kindly and most valuable assistance of Mr. R. P. Whitfield in the difficult study of the specimens as well as in the drawing of some of the figures. Figures 1, 1*a*, 4 and 5 were outlined by him from the type specimens.

In my descriptions of Rochdale fossils, the richly fossiliferous ledge exposed for 200 or 300 feet each side of the cross-wall between the farms of H. Titus and W. Badgely, about 900 feet northwest of the woolen mill, will be named D. Another Calciferous locality, next to the one just mentioned in paleontological importance, designated F, consists of a series of outcrops barely above the surface of the ground in W. Badgely's field extending from the northerly extremity of ledge D, between two hills, to the Pleasant Valley turnpike, with which it is about on a level throughout. This locality is specially rich in small and neat annulated and other orthocerata, while the ledge D is filled with the larger Cephalopods.

CRUSTACEA.

Quite a number of fragments of trilobites have been collected at locality D. One which is a portion of a thickened margin of a cephalic shield, is 5^{cm} long and 13^{mm} wide. But the fragments which are sufficiently well preserved to admit of specific description are small, belonging to animals probably 5^{cm} or under in total length. The cephalic shields of the two species here described are not sufficiently complete to justify a satisfactory decision as to the genus. The courses of the facial sutures are especially incomplete. While they in many respects strongly resemble Bathyurus, they do not appear in all points to conform to that type. For the present, however, they will be provisionally classed under that genus.

Bathyurus taurifrons, n. sp.

Figs. 1, 1*a*, 2, 2*a*, 2*b* and 3.

Glabella very convex, much elevated, slightly conical, the sides of its posterior two-thirds being nearly parallel, while its anterior third is a little narrowed, and then rounded in front. Its greatest width is two-thirds of its length exclusive of the occipital ring. There is a slight, yet evident longitudinal line of angularity along the summit, and there are three pairs of very faint transverse furrows extending from the sides obliquely backward for about one-third of the width of the glabella. Certain traces may perhaps indicate a fourth pair situated more anteriorly. The three pair first mentioned are so situated that lines joining the outer ends of each pair would divide the surface nearly into quarters. With the above exceptions the glabella is entirely smooth.

The summit of the glabella is about its greatest width (and its anterior border about half the same), above the level of the anterior edge of the cephalic shield. In the specimens described this summit elevation is 7·5^{mm}. From the anterior dorsal furrow the surface of the cephalic shield descends in a steep sigmoid curve to its anterior margin which projects in a horizontal distance beyond the glabella about one-third of the maximum transverse diameter of the latter.

The dorsal furrow extends entirely around the glabella, but is not very deep. The anterior limb of the cephalic shield is about one-third wider than the glabella. The fixed cheeks are narrow; the palpebral lobes (not thoroughly preserved in the specimens), are small and opposite the center of the glabella. The occipital furrow is well marked and extends the entire glabellar width; the occipital ring has a longitudinal axis about one-sixth that of the glabella, and extends laterally a little beyond the dorsal furrows. Movable cheeks and thoracic segments not known.

Pygidium, anterior margin a gentle curve, posterior and lateral margin semicircular. The axial lobe well defined, in front one-third of entire width of pygidium, tapering considerably to the rounded posterior termination which does not quite attain the junction posteriorly of the lateral lobes; its length is two-thirds that of the entire pygidium. It is quite convex transversely, while it also curves rapidly down from front to rear. Its surface is without furrows and quite smooth, excepting a slight angularity along the median line of its summit, and two tubercles situated close together at its posterior terminus. The lateral lobes are less convex than the axial, and marked by three or four faint furrows, some of which may be traced across the margin by close inspection.

The depressed marginal band is rather wide, being about one-eighth of the greatest width of the pygidium; it is but little narrower at the extreme posterior portion.

The elevation of the anterior portion of the axial lobe above the marginal edge of the pygidium, is nearly equal to the greatest width of that lobe; about 4^{mm} in present specimens.

On account of the disappearance of all thoracic portions in specimens, the connection of the above described pygidium with the cephalic shield described, can only be inferred from their frequent occurrence intermingled in close proximity. These occurrences seem to justify the decision of the identity of the species. There is much general resemblance between this species and *Bathyurus extans* of the Trenton. Yet there are marked differences, such as the remarkable elevation of the glabella in the new species, while the pygidia vary in many features.

Locality—Calciferous, Ledge D, Rochdale.

Bathyurus? crotalifrons, n. sp.

Figs. 4, 4*a*, 5 and 6.

Glabella low, convex, strongly conical, its sides being somewhat concave a little anteriorly of the center. Its maximum width is very little less (about $\frac{1}{14}$) than its length exclusive of the occipital ring, and is found at about one-sixth of this length anteriorly to the occipital furrows. In the anterior third, the transverse diameter diminishes to two-thirds of the maximum and less. The front border and the posterior angles are well rounded. Surface of glabella is covered with tubercles; there are no glabellar furrows; dorsal furrows extend quite around, and are very deep; occipital furrow well-marked and extending across the entire breadth of the glabella; the tuberculated occipital ring has its longitudinal axis at least $\frac{1}{5}$th that of the glabella in front of it, while its width scarcely equals that of the glabella. Fixed cheeks of moderate width; these, and the palpebral lobes, depressed convex, the latter carrying a broad shallow groove at the exterior margin over the eye. The anterior margin of the cephalic shield projects in front of the glabella to a distance equaling about one-fifth of the length of the latter, exclusive of the occipital ring. The posterior limb of the cephalic shield extends out laterally at nearly right angles to the longitudinal axis.

Movable cheeks low convex, tuberculated, with a rounded lateral margin; ocular sinus moderate. General outline of cephalic shield not thoroughly defined in the specimens. Thorax and pygidium unknown.

Locality—Calciferous. Ledge D, Rochdale, N. Y. Fragments of half a dozen individuals found.

CEPHALOPODA.

Cyrtoceras Vassarina, n. sp.

Figs. 7, 7*a* and 8.

Shell stout, large and smooth, varying in the same individual from 1^{mm} to 2^{mm} in thickness; considerably curved in most specimens; the transverse-section is more or less distorted by compression in the best preserved specimens, but it appears to be broadly elliptical, the transverse axis being a little less than one-fifth shorter than the dorso-ventral axis. Taper gradual, about one part to nine near the chamber of habitation.

Septa from 10 to 15 or more to the inch, deeply concave, the concavity exceeding by one-half the depth of the interseptal spaces; their marginal sutures but slightly curved along the lateral margins, arching somewhat forward toward the concave ventral margin, and very strongly forward toward the convex dorsal margin. The extent of this forward deflection near the dorsal and siphuncular side, about equals three of the interseptal spaces, while that near the ventral side is somewhat less than one interseptal space. In several of the most marked specimens, the line joining in a cross-section, the points of maximum deflection to the front, on the opposite margins (shown by the dotted line in fig. 7*a*), would show a considerable angular deviation from the dorso-ventral line.

Siphuncle marginal, somewhat flattened, and of moderate proportional size, which is probably somewhat variable in different individuals of the species. In the specimen described in which it is best shown, fig. 8, its greatest diameter (parallel to the margin) is 4^{mm} and its transverse diameter about $\frac{1}{15}$ less, where the shell has a dorso-ventral diameter of 29^{mm}. In the other specimen (fig. 7) the siphuncle appears to have about the same proportion near the chamber of habitation, and nearer the apex it has a maximum diameter of 2^{mm} where that of the shell is two decimeters. In some specimens at least (as shown in fig. 7*a*) the siphuncle, which is dorsal, is situated considerably to one side of the dorso-ventral axis. It is slightly beaded, the gentle expansions occurring where it is met by the very oblique edges of the septa.

The chamber of habitation is capacious. Locality—Calciferous, Rochdale, N. Y., throughout the fossiliferous layers, but especially at Ledge D.

This is one of the most prominent and abundant of the orthoceratites in the Wappinger Creek valley; it occurs mostly in small fragments, sometimes closely crowded together; the largest known specimens have an incomplete length of five or six inches, implying a complete one of eight or nine inches. Several orthocerata of the latter length have been collected which are probably referable to this species, but lack of evidence as to the septa and siphuncle leaves the question at present in doubt. Although the specimens here described, and many similar ones, appear to belong under "Cyrtoceras," yet there is reason for doubt on this point. This arises from the presence of quite a number of orthoceratites closely resembling these, as far as can be judged in their imperfect state, but which are nearly or quite straight. It is possible that this latter group on further examination may disclose a specific difference in the shape of the cross-section, and especially in the rate of increase in the diameter of the shell which seems to differ from the taper above described. A local name has been assigned in honor of the college in whose vicinity these specimens occur.

Cyrtoceras? dactyloides, n. sp.

Figs. 9 and 9*a*.

Shell small, slender, tapering about $\frac{1}{8}$th to the inch; gently curved; surface not known, except so far as it appears smooth in vertical section; transverse section (of which only about three-fourths is evident) apparently elliptical, with the proportions of six to five for the two axes.

Septa about seventeen to the inch, considerably concave, the concavity equaling the depth of the interseptal spaces; their sutures horizontal at the lateral margins and very slightly curving forward at the dorsal margin; they are not preserved in the specimen at the ventral margin, but the partial obliquity in the position of the septa shown in the longitudinal section (upper half of fig. 9) indicates more arching forward on the ventral than on the dorsal side.

Siphuncle marginal, very nearly circular, there being a barely perceptible flattening parallel to the margin: it is on the convex dorsal side, and is proportionally large for a *Cyrtoceras;* its gain in size is apparently more rapid than that of the shell, for at the smaller end its diameter is slightly more than 2^{mm}, or one-fourth the diameter of the shell at that point, while at the larger end, its diameter is $3{\cdot}75^{mm}$ or about one-third the whole diameter of that portion. This species bears considerable resemblance to *Orthoceras sordidum* Billings (Can. Nat. and Geol., vol. iv, Calciferous group), yet the Canadian fossil, the type specimen of which, by the kindness of

Mr. J. F. Whiteaves, I have been able to examine, differs in several points, as lack of curvature, less proportional size of siphuncle, different shape of cross-section, stronger forward arching of the septa near the siphuncle, and other features. Locality—Calciferous, Ledge D, Rochdale, N. Y.

Cyrtoceras microscopicum, n. sp.
Fig. 11.

Shell very small and with exceedingly thin, delicate walls. It is known only in the exhibition of a longitudinal section of a single specimen. It is much curved on the inner margin, and very moderately on the outer one; its taper is apparently very rapid, but as some of this appearance may be due to possible obliquity of the section, no definite rate can be stated. Septa extremely delicate and crowded together at the rate of about 96 to the inch, with a gentle concavity, and meeting the dorsal and ventral margins at the same level. Neither the siphuncle nor the cross-section are known. The only specimen collected has a length of $6{\cdot}5^{mm}$, while the transverse diameters at the extremities are respectively 5^{mm} and 3^{mm}.

Locality—F, Calciferous, Rochdale, N. Y.

Orthoceras spissiseptum, n. sp.
Fig. 12.

Shell quite small, slightly curved, thin, and apparently nearly cylindrical. As the only specimen collected presents merely a plane longitudinal section, more or less oblique, the rate of taper cannot be stated more exactly. Septa delicate and exceedingly close together, at the rate of about 95 to the inch; their concavity is considerable, after making all possible allowance for obliquity of the section; their junctions with the shell are evidently considerably higher on one side than on the other. Transverse section, and siphuncle unknown. The fragment of the only specimen collected is $10{\cdot}5^{mm}$ long, and about 6^{mm} in transverse diameter.

Locality—Calciferous, Ledge D, Rochdale, N. Y.

Orthoceras Henrietta n. sp.
Figs. 13, 14 and 14*a*.

Shell small and tapering gently, at an approximate rate of one to ten, annulated, with generally from eight to ten rings to the inch (in some instances only six); these annulations are always formed more or less by undulations of the entire body of the shell, which is quite variable in thickness in different places; but frequently the rings are increased by a thickening of the shell where they occur. Chamber of habitation long;

it is apparently contracted anteriorly in several specimens, all of which are longitudinal sections made by natural weathering. This apparent contraction may be due to obliquity of the sections, or to curvature. No specimen has yet been collected that gives any other view of the fossil than a sectional one. Septa delicate and frequent, usually from twenty to thirty to the inch, though some have more; they are gently concave, and some of the natural sections exhibit them in positions where they indicate some obliquity of suture.

The imperfect transverse section, fig. 14*a*, exhibits an elliptical outline; a more complete one, since obtained, reveals an ellipticity of three to one, much greater than that indicated in this figure.

Siphuncle lateral, but probably not marginal, circular, with a diameter of a little less than a millimeter ($\frac{1}{32}$ inch), where the shell has a diameter of 6·3^{mm}. Locality—Calciferous, one or two specimens at Ledge D, but chiefly at locality F, Rochdale, N. Y.

I have thought it proper to give these graceful orthocerata a specific name in honor of Mrs. Henrietta Manning of New York City, since her generous contributions toward the expenses of developing this field of paleontological research have much facilitated the work and have constituted her a patron of science.

Oncoceras vasiforme, n. sp.

Figs. 10 and 10*a*.

The description of this fossil is derived from a single specimen which is half imbedded, longitudinally, and the other half is lost by abrasion. There is thus exhibited only a plane median vertical section, nearly, but not quite, at right angles with the dorso-ventral axis. Shell small and delicate (4^{cm} in length and 9^{mm} maximum width), amount of curvature unknown, ventricose at the upper parts of the septate portion, and the lower part of the chamber of habitation, very narrow in the lower septate portion; chamber of habitation large, its length being more than one-third of the estimated length of the shell. Its maximum transverse diameter is anterior to the last septum at a distance of about one-fourth the diameter of the latter. Anteriorly, it then narrows to the aperture (whose diameter is about one-fourth of the maximum), rather evenly and gently; one margin in the vertical section exhibited, is convex externally throughout to the aperture, the other margin is convex for about one-half the distance and then gradually changes into a gentle concave line, showing a special but slight constriction on that side near the front.

From the above mentioned position of maximum ventricosity in the chamber of habitation, the shell diminishes with a rapid taper posteriorly to the apex. At the distance, however, of eight or nine septa from the first one, the rate of taper, which up to that point has been as one to three, diminishes a little for the remaining apical portion, causing a slight concavity in the outline in that vicinity.

A cut made across this fossil 4^{mm} anterior to its posterior termination, reveals one (dorsal ?) half of the transverse section, and shows that the complete section must be a little elliptical (if not ovate). The siphuncle, which is shown in this section near the end of the longer axis of this semi-ellipse, is very small, with a diameter of $\cdot 65^{mm}$ where the shell has a diameter of 6^{mm}; it is circular and quite close to the shell, though not actually in contact. The septa are frequent, about twenty-three to the inch, two or three nearest the chamber of habitation standing much closer together. They are very gently curved, and seem slightly oblique in this section. Locality—Calciferous, ledges in field F, Rochdale, N. Y.

This fossil sufficiently resembles *O. mummiforme* Whitfield (Geol. Wis., vol. iv, p. 232), to have induced for awhile its assignment to that species. A critical comparison however has made this assignment doubtful, and the recent evidence obtained in the cross-cut of the position of the siphon removes all doubt that it is a distinct species. It is certainly no nearer to *O. constrictum* Hall, and appears to be new.

EXPLANATION OF PLATE VII.—WAPPINGER VALLEY FOSSILS.

All the specimens here illustrated are from the Calciferous (?) at Rochdale, N. Y., and are represented in their natural size.

BATHYURUS (?) TAURIFRONS.

Fig. 1. Glabella and fixed cheeks, the former showing the furrows and median angular line. The furrows appear much too conspicuous in the cut.
Fig. 1*a*. Profile view of the same specimen.
Fig. 2. A pygidium found in close proximity to the above, probably of the same species, if not of the same individual.
Fig. 2*a*. Vertical transverse section of the same, showing the elevation and transverse contour of the anterior limb.
Fig. 2*b*. Profile view of same pygidium.
Fig. 3. Pygidium of another individual of same species, showing distinctly the two posterior tubercles on the axis.

BATHYURUS (?) CROTALIFRONS.

Fig. 4. View of a gutta percha cast taken from a natural mould, showing the glabella and fixed cheeks.

Fig. 4*a*. Profile view of same.

Fig. 5. View of gutta percha cast of natural mould of the right movable cheek of a larger specimen of the same species, showing the ocular sinus.

Fig. 6. View of glabella and a small portion of fixed cheeks of another individual. The parts represented on the right side of the glabella, especially the arcuated line, are doubtful, belonging perhaps to some other individual.

ORTHOCERAS VASSARINA.

Fig. 7. Lateral view of an internal cast, carrying portions of the smooth shell, showing clearly the chamber of habitation, septal sutures, and curvature of the septa. The smooth surface to the right below, has been polished to show the siphuncle which appears in the figure.

Fig. 7*a*. Transverse section of upper portion of same, showing the position of the siphuncle (not seen in that part of fig. 7) considerably to one side of the dorso-ventral axis. The upper part of this section shows a distortion by flattening. The broken straight line connects the points of maximum forward deflection of the septal sutures.

Fig. 8. Dorsal view of internal mould (with portion of shell) of another individual, showing the upward arching of the septa, and the marginal siphuncle a little expanded at its points of junction with the septa.

CYRTOCERAS DACTYLOIDES.

Fig. 9. A well defined specimen, the lower third of which is the cylindrica internal mould, showing the sutures, while the upper two-thirds is an abraded and polished vertical plane section of the same, showing the large marginal siphon, and the curvature of the septa.

Fig. 9*a*. A transverse section at the lower end, showing the size of the siphuncle at that point.

ONCOCERAS VASIFORME.

Fig. 10. A natural vertical median plane section, not quite rectangular to the dorso-ventral axis.

Fig. 10*a*. An artificial transverse section of the specimen, 4^{mm} from the lower end, showing the position of the siphuncle.

CYRTOCERAS MICROSCOPICUM.

Fig. 11. A polished vertical median plane section passing probably nearly in the plane of the dorso-ventral axis.

ORTHOCERAS SPISSISEPTUM.

Fig. 12. A natural longitudinal section, showing a few of the septa.

ORTHOCERAS HENRIETTA.

Fig. 13. A polished vertical section showing the chamber of habitation, and some of the septate portion.

Fig. 14. A similar, somewhat oblique section of another individual, showing the siphuncle at lower end.

Fig. 14*a*. A polished transverse section of the lower end of the same showing the position of the siphuncle.

ART. XXX.—*Upon the Kettle-Holes near Wood's Holl, Mass.;* by Professor B. F. KOONS.

IN the study of the glacial phenomena about Wood's Holl, Mass., I have gathered many facts concerning the Kettle-Holes of the region as to depth, size, direction of the longer axis, their groupings, and other points, which may throw light upon their origin. No special study of them as regards some of these points had been made, and, therefore, without previous convictions as to what conclusion the facts would lead, I determined during the last summer to give them a careful examination as far as my work in connection with the United States Fish Commission at Wood's Holl would allow. Professor Warren Upham, who has made many observations on the terminal moraine along southern New England and the adjoining islands, regards the deposits as a part of that terminal moraine, and others hold the same opinion. There is perhaps no more remarkable region on the whole line than the vicinity of Wood's Holl, both over the point of the main-land, and on the adjoining eastern islands, Uncatina, Nonamesset, and Naushon, of the Elizabeth group, which extend southwestward between Buzzard's Bay on the north and Vineyard Sound and the ocean on the south. The trend of this group of islands is north 60° east.

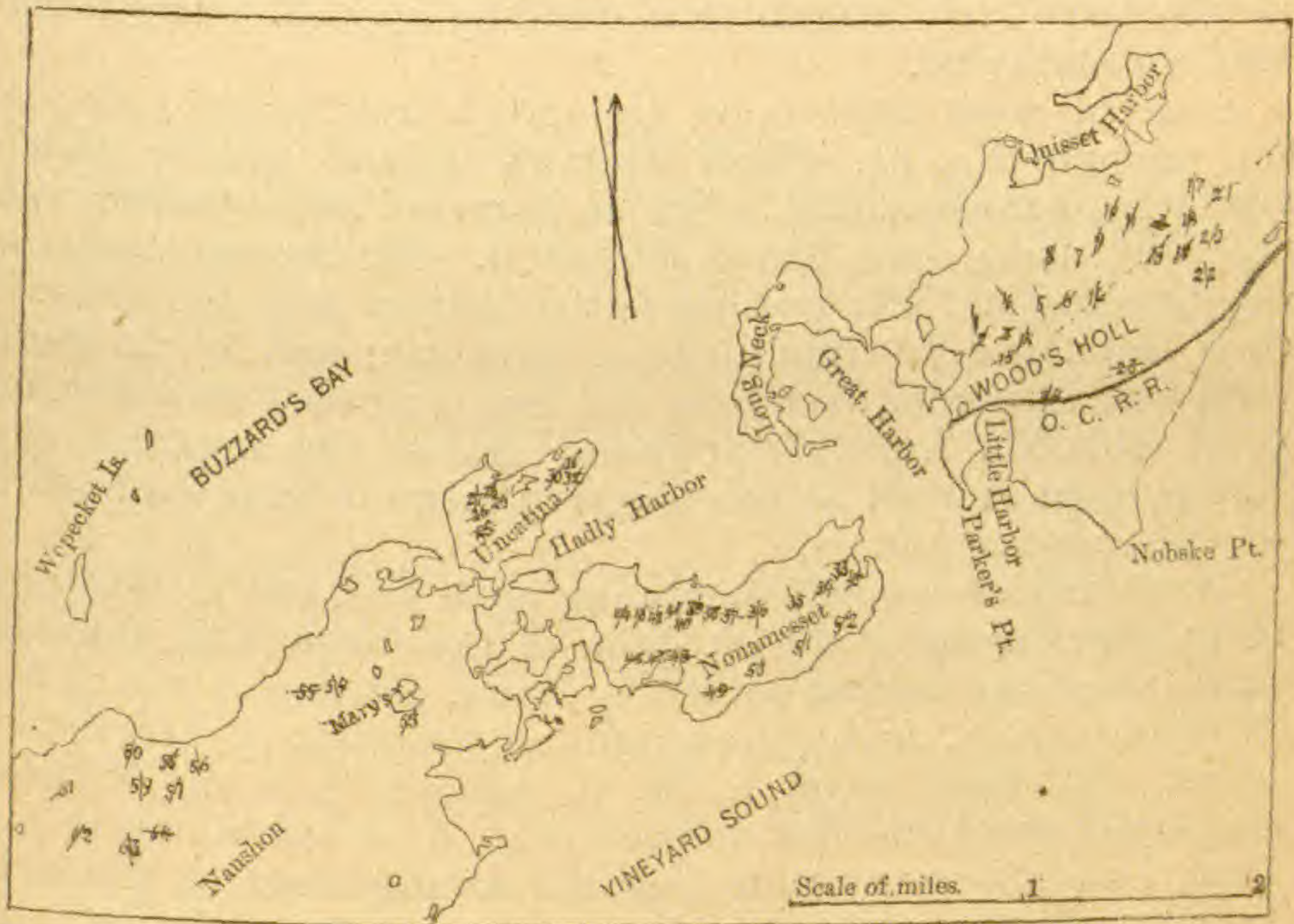
The hills are masses of earth, sand, gravel and bowlders tumbled together in the greatest confusion. In places the surface is well covered with granite and gneiss bowlders, some of gigantic size, as will be seen by reference to table No. 2.

The theory that this is a part of the terminal moraine, seems plausible when the country is viewed from some of the high hills a mile or two to the east of Wood's Holl. To the southwest stretches away the long line of islands; and to the northeast almost as far as Falmouth, it appears as though the glacier had pushed its front down to the sea and there unloaded its vast amount of rock and earth to form this line of abrupt hills. To the northeast of Falmouth, these hills recede from the coast, leaving a level plain between them and the sea. For a number of miles the railroad runs along the base of these hills, leaving the level tract of country to the southeast of it; while to the northwest are the high and rugged hills of unstratified material.

Upon the tops of some of these hills (of the peninsula of the main-land) one hundred or more feet above the level of the sea where cuts for roads have been made, *stratified* material, consisting of sand and gravel is found. This occurs between Buzzard's Bay and Vineyard Sound, where the land is not more than three-fourths of a mile wide. One of these localities of stratified material is directly on the north side of a kettle-hole

(No. 18 on the map below) upon the steep border, seventy-three feet above the bottom.

At another place, upon a similar deposit several feet thick, lies a bowlder weighing several tons. On the island of Naushon, opposite Tarpaulin Cove, upon the summit of a hill over 200 feet above the sea-level and where the island is not more than two-thirds of a mile wide, there is a stratified deposit which has been partly cut away by the winds and thus its character made known. It has at top a bed of fine yellow sand ten inches thick; beneath this a layer of white or smoky white sand, then again a black layer, and beneath this a ferruginous layer two inches thick, all very similar to those of Gay Head at the west end of Martha's Vineyard. And within a few rods of this stratified deposit the surface over a considerable area is completely covered with bowlders, two of which, Nos. 7 and 8 of table No. 2, are of unusual size.



Map of the vicinity of Wood's Holl and the neighboring Elizabeth Islands, showing positions and direction of the larger diameter of the Kettle-Holes.

In my study of this region I kept a record generally of only the largest kettle-holes—passing by some of great size because they are so very numerous. It seemed important to obtain measurements of a representative number, and these sufficiently distributed to give the general character of the whole. I doubt not that if the region studied, extending from Tarpaulin Cove on the south side of Naushon to Falmouth, a distance of twelve miles, were carefully examined, more than a thousand kettle-holes could be mapped.

Many of these depressions have water in them forming a small pond or lake. The depth of the ponds could only be estimated, except for No. 53 of table No. 1, which has considerable size, and is called "Mary's Lake." I learned from the owner of the land that its depth is eighteen feet. The map here given, shows with approximate correctness, the distribution of the kettle-holes, and also the direction of the longer axes. By a glance at the map it will be seen that the general trend of the longer axes is nearly that of the terminal moraine.

Some few kettle-holes were found with circular depressions and these were omitted, but all with the longer diameter transverse to the general trend were measured and recorded.

Over the hilly region to the northeast of Wood's Holl, many of the gulleys or ravines run northeast and southwest, about in line with the trend of the Elizabeth Island; the hills also have largely this direction. The small bays among the islands usually have their longest axis trending approximately northeast and southwest.

Some of these kettle-holes are upon a truly grand scale; as for example No. 61, which contains several smaller within the large depression, and is like an immense amphitheater with the hills rising upon every side of it. Its highest border is one hundred and fifty feet above the bottom and the outlet is forty feet above the small lake at its center; and on the south side, near its border, but upon still higher ground, bowlder No. 6, of table No. 2, stands projected against the southern sky like a huge sentinel as the observer views it from the bottom of this immense pit.

It occurred to me before entering upon this study, that possibly observations on the direction of the longer axis, the side upon which the highest border is found, position of the outlet, distribution, etc., might throw light on the origin of these kettle-holes. But there seems to be no uniformity in any of these characters except the first and second. After examining all the facts, I am led to conclude that the arrangement of this axis supports the theory that the depressions were made by ice. In many cases it appears as if a long, narrow block of ice, broken from the front of the glacier, had lodged against the material which was in front of it, and then had become covered up by other materials; finally on melting it left the long kettle-hole with a high southern border. A couple of these are found just at the edge of the village of Wood's Holl, while in many others the appearance suggests that the ice mass was covered by material from the northwest, and the result was a kettle-hole with a high steep northwest border. Many of the kettle-holes having either a high border on the southeast or northwest, or approximating these points, seem to sustain this view. In the study of the geological characters of the eastern part of Connecticut, I have found numerous kettle-holes in the middle of wide level plains, of terrace origin, where it seemed that no known cause of the present, except stranded ice, could make them. It was my intention to have given further study to the kettle-holes of Naushon, in order to ascertain whether the kettle-holes are more numerous on the northern or the southern slope of the island. I could command time for only one day's work upon this island, and in it was assisted by Professor Edwin Linton, of Washington College, Penn.; and I did not carry the investigation far enough to decide with certainty upon the point. As to those upon Nonamesset, the mainland, and those examined on Naushon, the facts indicate with a good deal of certainty that they are much more numerous and generally larger upon the northern slope than upon the southern.

The observed facts pertaining to the kettle-holes are given in table No. 1; and those as to some large bowlders in table No. 2.

No. 1.

On the Mainland.

No.	Direction of long axis.	Length of long axis.*	Length of short axis.*	Height of outlet.	Highest border.	Position of highest border.	Depth of water.
1	N. 10° W.	12 rods.	6 rods.	10 ft.	25 ft.	N.E.	8 ft.
2	N. 40° E.	8	6	4	25	S.	5
3	N. 50° E.	7	5	5	24	E.	3
4	N. 40° W.	10	6	5	30	E.	5
5	N. 10° W.	6	3	5	21	E. by N.	--
6	N. 50° E.	40	25	45	75	N.E.	6
7	N. 20° W.	30	12	18	40	----	6
8	N. 20° E.	10	4	12	25	----	--
9	N. 15° E.	10	4	3	15	----	--
10	N. 20° E.	7	4	5	20	----	--
11	N. 25° E.	40	12	50	76	N.E.	--
12	N. 30° E.	15	8	25	50	N.E.	--
13	N. 5° E.	25	10	40	68	S.W.	--
14	N. 35° E.	12	10	7	25	S.E.	--
15	N. 60° E.	8	5	5	25	S. by E.	--
16	N. 5° E.	25	8	45	66	N.W. & S.E.	--
17	N.	20	10	25	60	S.W.	--
18	N. 40° E.	60	43	42	73	N.W.	--
19	N. 35° E.	35	7	15	30	N.N.W.	5
20	N. 20° E.	30	10	6	40	S.W.	--
21	N. 35° E.	30	12	25	95	S.S.E.	--
22	N. 10° W.	16	9	13	50	S.W.	--
23	N. 80° E.	50	40	25	--	----	swamp.
24	N. 10° E.	10	6	18	38	E.S.E.	3 ft.
			On the Island of Uncatina.				
25	N. 70° E.	25	10	8	18	N.W.	--
26	N. 60° E.	18	7	5	20	N.E.	--
27	N.	8	6	4	25	N.N.S.	--
28	N. 20° E.	16	12	12	22	N.	--
29	N. 28° E.	38	20	12	25	S.E.	--
30	N. 30° E.	16	12	7	17	S.	--
31	N. 30° E.	11	5	3	25	S.	--
32	N. 30° E.	7	6	5	23	W. by N.	--

* At the level of the outlet.

On the Island of Nonamesset.

No.	Direction of long axis.	Length of long axis.*	Length of short axis.*	Height of outlet.	Highest border.	Position of highest border.	Depth of water.
33	N. 25° E.	12 rods.	6 rods.	7 ft.	30 ft.	S.	4 ft.
34	N. 40° E.	10	5	5	35	N.	5
35	N. 20° W.	14	9	10	35	W.	--
36	N.	20	12	5	40	N.	5
37	N. 60° E.	12	7	8	28	N.W.	--
38	N. 40° E.	6	4	2	28	N.	--
39	N. 20° E.	6	4	5	20	E.	-
40	N. 55° E.	20	10	16	28	W. by S.	--
41	N. 40° E.	8	4	12	20	W.	--
42	N. 50° E.	7	4	10	25	S.S.W.	--
43	N. 25° E.	13	5	10	25	W. by S.	--
44	N. 20° E.	16	9	12	30	N.W.	--
45	N. 35° E.	8	5	5	25	S.E.	5
46	N. 50° E.	8	3	5	18	N.W.	--
47	N. 60° E.	18	8	7	20	E.	--
48	N. 70° E.	18	6	14	23	S.	--
49	N. 80°	18	3	8	50	S.	3
50	N. 30° E.	8	4	4	25	N. by E.	--
51	N. 10° E.	20	12	5	25	N.N.W.	--
52	N. 28° E.	60	25	15	30	N.	6

On the Island of Naushon.

No.	Direction of long axis.	Length of long axis.*	Length of short axis.*	Height of outlet.	Highest border.	Position of highest border.	Depth of water.
53	N. 25° E.	60	40	18	50	N.E.	Mary's Lake. 18
54	N.	20	8	10	25	N.	swamp
55	N. 80° E.	20	8	5	35	----	--
56	N.	18	12	4	35	----	--
57	N. 20° E.	20	5	8	40	----	--
58	N. 30° E.	30	4	6	50	----	--
59	N.	6	4	5	25	----	--
60	N. 15° E.	40	6	20	45	W.	--
61	N. 40° E.	75	40	40	150	S.W.	5 ft.
62	N. 30° E.	80	10	25	100	S. by W.	5
63	N. 10° W.	10	5	12	55	S.W.	5

* At the level of the outlet.

No. 2.

Dimensions of Bowlders.

	Greatest length.	Greatest width.	Greatest height above surface of ground.	Locality, etc.
1	24 ft.	10 ft.	9 ft.	Center of Nonamesset.
2	24	10	4	Center of Nonamesset, and buried very deep in ground.
3	18	18	7	Center of Nonamesset, and buried very deep in ground.
4	10	11	6	Near Mary's Lake, very deep.
5	12	9	6	Near Mary's Lake, very deep.
6	12	10	5	Near Mary's Lake, very deep.
7	24	15	12	Near No. 61, slightly buried.
8	27	18	4	Near stratified deposit upon Naushon, and very deep.
9	27	15	16	Near stratified deposit upon Naushon, and on surface.

ART. XXXI.—*Examination of Mr. Alfred R. Wallace's Modification of the Physical Theory of Secular Changes of Climate;* by JAMES CROLL, LL.D., F.R.S.

[Continued from page 93.]

IN the examination of Mr. Wallace's main argument, I shall consider it, first, in relation to physical principles, and, secondly, in relation to geological and paleontological facts.

I. *Physics in relation to Mr. Wallace's Modification of the Theory.*

The grand modification, that during the height of the glacial epoch the snow and ice would not disappear when precession brought the winter solstice round to perihelion, I have already given in Mr. Wallace's own words. As the reasons which he assigns for this modification are very briefly stated by him, I may here give them also in his words.

After describing the state of Northeastern America and the North Atlantic, to which I have already alluded, he says:

"But when such was the state of the North Atlantic (and, however caused, such *must* have been its state during the height of the glacial epoch), can we suppose that the mere change from the distant sun in winter and near sun in summer, to the reverse, could bring about any important alteration—*the physical and geographical causes of glaciation remaining unchanged?* For, certainly, the less powerful sun of summer, even though lasting somewhat longer, could not do more than the much more powerful sun did during the phase of summer in *perihelion*, while during the less severe winters the sun would have far less power than when it was equally near and at a very much greater altitude in summer. It seems to me, therefore, quite certain that whenever *extreme* glaciation has been brought about by high eccentricity combined with favorable geographical and physical causes (and without this combination it is doubtful whether *extreme* glaciation would ever occur), then the ice-sheet will *not* be removed during the alternate phases of precession, so long as these geographical and physical causes remain unaltered. It is true that the warm and cold oceanic currents, which are the most important agents in increasing or diminishing glaciation, depend for their strength and efficiency upon the comparative extents of the northern and southern ice-sheets; but these ice-sheets cannot, I believe, increase or diminish to any important extent unless some geographical or physical change first occurs."—p. 150.

Again,—"It is quite evident that during the height of the glacial epoch there was a combination of causes at work which led to a large portion of Northwestern Europe and Eastern America being buried in ice to a greater extent even than Greenland. Among these causes we must reckon a diminution of the force of the Gulf-Stream, or its being diverted from the northwestern coasts of Europe; and what we have to consider is, whether the alteration from a long cold winter and short hot summer, to a short mild winter and long cool summer would greatly affect the amount of ice *if the ocean-currents remained the same.* The force of these currents are, it is true, by our hypothesis modified by the increase or diminution of the ice in the two hemispheres alternately, and they then react upon climate; but they cannot be thus changed till after the ice-accumulation has been considerably affected by other causes."—p. 148.

There are some further reasons assigned, which will be considered as we proceed.

From what has already been shown, it will be seen that the causes which led to the Glacial epoch may be classed under three distinct groups:—(1) the astronomical, (2) the physical, and (3) the geographical. This threefold division is distinctly recognized by Mr. Wallace in the above quotations, as well as in all his reasoning on the subject of geological climate.

In the astronomical group the main elements are the two following:—1st. A high state of eccentricity producing, on the hemisphere whose winter solstice happens to be in aphelion, a long and cold winter with a short and hot summer, and on the other hemisphere, whose winter solstice, of course, at the time is in perihelion, a short and mild winter with a long and cool summer. 2d. Precession, transferring these conditions from the one hemisphere to the other alternately every 10,000 or 12,000 years. The physical elements are, of course, the influence of snow and ice, ocean currents, aqueous vapor, clouds, fogs, and a host of other things which have already been discussed at length;* while the geographical consist of the particular distribution of land and water, elevations or depressions in the sea-bottom, contour of the sea-coast, and other geographical conditions influencing the flow of ocean-currents.

It is to the influence of physical agencies, however, that the Glacial epoch is more directly due. The main function of the astronomical agents is to set and keep the physical agencies in operation, and also to *determine* the character of their operations. For example, the position of the winter solstice in relation to the aphelion or to the perihelion, during a high state of eccentricity, determines whether the physical agencies will produce on a given hemisphere a glacial or a warm condition of climate; while precession determines which of the two hemispheres shall be the glaciated and which the warm. In one respect we may say that the astronomical causes produce glaciation by means of the physical agencies.

* 'Climate and Time,' chap. iv; American Journal of Science, Oct., 1883; Phil. Mag. Oct., 1883.

The geographical conditions, however, cannot properly be considered to be causes in the sense in which the astronomical and physical are. They are more properly *conditions* to the production of a glacial epoch than *causes.* They cannot be said to *act* in the production of glaciation. They are rather permanent and passive conditions enabling the active causes to produce their required effects. Had the Glacial epoch resulted from elevation of the land, as some geologists suppose, then this *elevation* might properly be said to have been the cause of the Glacial epoch; but the Glacial epoch was produced by no such means, nor by any *change* in the physical geography of the globe. A certain geographical condition of things was, of course, requisite in order to the effective operation of the astronomical and physical causes. This condition existed at the time of the glacial epoch; and it is only in this sense that that epoch can be referred to any thing geographical.

It is true that a cause, as Sir William Hamilton states, may be defined as "all that without which the effect would not happen;" but this is far too general an expression of cause for practical purposes. We therefore fix on the particular antecedent or antecedents, through the activity of which the event is mainly brought about, and term them the causes of the event, and the others the necessary conditions.

I cannot help thinking that the way in which geographical conditions are spoken of as causes of the Glacial epoch has tended to confusion.

During the Glacial epoch there were frequent submergences and elevations of the land, or rather oscillations of sea-level, and these, it is true, would produce a change in the relative extent of sea and land. But whether we suppose it to have been the sea which rose and fell in relation to the land, or the land in relation to the sea, it equally follows that the geographical change resulting therefrom could not possibly have been a cause of the glacial epoch. It is now a well-established fact that submergence accompanied glaciation; the glaciation may have been that which led to the submergence; but it could not possibly have been the submergence which led to the glaciation. An elevation of the land would have favored glaciation, but submergence would not. Its tendency would rather be in the opposite direction. It is now also established, that during the continental period, or period of elevation, the climate was warm and equable; for it was then, as has been remarked, that this country was invaded by tropical and subtropical animals. Now it is equally plain that the elevation could not have been the cause of the heat. Elevation of the land might produce cold, but it could not have been a cause of the heat. It follows therefore that the geographical change resulting from submergence or elevation of the land cannot be regarded as a cause of the glacial epoch; for its effect on climate, if it had any, was in opposition to that of the astronomical and physical agencies. It would prove a hindrance not a help.

Referring now to Mr. Wallace's argument. When glacial conditions in the North Atlantic attained their maximum development, "Can we suppose," he asks, "that the mere change from the distant sun in winter, and near sun in summer to the reverse, could bring about any important alteration—the physical and geographical causes of glaciation remaining unchanged?" Here, to begin with, we have an impossible state of things assumed. It is assumed in this question that it is possible for the winter solstice to pass from aphelion to perihelion, and the *physical* causes to remain unchanged. It is assumed as possible that the astronomical conditions might be reversed without a reversal of the physical.

When the winter solstice is in aphelion it sets in operation many physical causes, the tendency of which is to produce an accumulation of snow and ice; but when the solstice-point moves round to the perihelion, the tendency of these causes is reversed, and they then undo what they had previously done—melt the snow and ice which they had just produced. Now, what Mr. Wallace asks is this: When, owing to the winter solstice being in aphelion during a high state of eccentricity, a glacial condition of things is produced, will the fact of the solstice-point being moved round to perihelion remove the glacial condition, if *the physical causes remain unchanged in their mode of operation?* My reply is, it certainly would not. Here it is assumed that the physical causes are working in opposition to the astronomical; that when the solstice is in perihelion the action of the physical causes, instead of being reversed, as it should be according to theory, still continues to produce and maintain a glacial state of things, the same as it did when the solstice-point was in aphelion; and he asks, will the astronomical causes in this struggle manage to overpower the physical and produce a melting of the ice? I unhesitatingly reply, no; for the physical causes are far more powerful than the astronomical. The astronomical causes, as we have seen, are perfectly unable to produce a glacial state of things without the *aid* of the physical. How, then, could we expect that they could remove this glacial state if the physical causes were actually working against them.

In thus setting the physical causes against the astronomical, Mr. Wallace is basing his argument for the non-disappearance of the snow and ice on a state of things which cannot possibly under the circumstances exist. His question, to have consistency, should be this:—When glacial conditions were at their height, &c., "can we suppose that the mere change from the distant sun in winter and the near sun in summer, to the reverse, could bring about any important alteration—the *geographical* causes of glaciation remaining unchanged?" If the question is put thus, and it is the only form in which it can be put to be consistent with the theory which Mr. Wallace himself advocates, then my reply is, that the change from the distant sun in winter and near sun in summer to the near sun in winter and distant sun in summer, aided by the change in the physical causes which this would necessarily bring about, would certainly be sufficient to cause the snow and ice to disappear without any change in the geographical condition of things. The combined influence of the astronomical and physical causes, when the winter solstice is in perihelion, is perfectly sufficient to undo all that they had previously done when the solstice was in aphelion. When the action of the causes is reversed, the effects will be reversed.

Had the Glacial epoch been produced by geographical causes, then it is probable that the ice would not have disappeared till these causes were changed. Had the ice, for example, been simply due to an elevation of the land, as some have argued, then it would not likely have disappeared till the land became lowered. But it was the result of no such cause. It was due, not to an elevation of the land, but to a number of physical causes, brought into operation by a high state of eccentricity. This Mr. Wallace fully admits and maintains. A certain geographical state of things was, of course, necessary to enable the astronomical and physical causes to produce the required effect; and this was really all that geographical conditions had to do in the matter. Let this be observed, however, that the *same geographical condition of things* which favors the accumulation of ice when the winter solstice is in aphelion, favors its disappearance when the solstice is in perihelion. This is obvious, because the same combination of physical agencies which makes the hemisphere in aphelion cold, makes the one in perihelion warm. The heating of the one is, to a large extent, the result of the cooling of the other. It is the *transference* of heat by ocean-currents from the hemisphere in aphelion to the one in perihelion which is a main reason why the former is cold and the latter warm. Hence a change in geographical conditions is unnecessary for the disappearance of the ice on the hemisphere with the perihelion winter, whether that hemisphere be the northern or the southern.

The tendency of the combined influence of all the causes—astronomical, physical, and geographical—is to cool the one hemisphere and to warm the other, to accumulate the ice on the one and remove it from the other. Consequently the same total combination of causes which will produce an accumulation of ice on either hemisphere when the winter solstice is in aphelion will produce a melting of that ice when the solstice moves round the perihelion.

Another impossible condition assumed.— "What we have to consider," says Mr. Wallace, "is whether the alteration from a long cold winter and short hot summer, to a short mild winter and long cool summer, would greatly affect the amount of ice *if the ocean-currents remained the same.*" Here, again, we have an impossible state of things assumed. It is assumed that, notwithstanding the change from an aphelion to a perihelion winter, the ocean-currents would still remain the same. And it is asked, would the astronomical causes in this case remove the glaciation. I would be disposd to say that they would not.

"The force of these currents," he adds, "are, it is true, by our hypothesis modified by the increase or diminution of the ice in the two hemispheres alternately (they depend for their strength and efficiency upon the comparative extent of the northern and southern ice-sheets), and they then react upon climate; but they cannot be thus changed till after the ice-accumulation has been considerably affected by other causes."

What, then, are the other causes which affect the ice-accumulation and thus lead to a change in the ocean currents? "These ice sheets cannot, I believe," says Mr. Wallace, "increase or diminish to any important extent unless some *geographical* or *physical* change first occurs." The first thing required to affect the ice-accumulation is thus a geographical or a physical change. But we have just seen that the character of the physical causes depends upon the astronomical. A change from a long cold winter and short hot summer to a short mild winter and long cool summer would reverse the operations of the physical causes and lead to a melting of the ice. The physical causes therefore offer no barrier. What more do we still require? This we have in the following foot-note at page 150:— "The ocean-currents are mainly due to the difference of temperature of the polar and equatorial areas combined with the peculiar form and position of the continents, and some one or more of these factors must be altered *before* the ocean-currents towards the North Pole can be increased."

One of these factors—change in the form and position of the continents—may be left out of consideration for we have no evidence of any such change during the Glacial epoch, except one which, as has been already proved, could have had no effect. We must therefore look to a change in "the difference of temperature of the polar and equatorial areas" for any increase in the currents towards the North Pole. And in order to bring about this change, "the only available factor," Mr. Wallace states, "is the antarctic ice; if this were largely increased, the northward-flowing currents might be so increased as to melt some of the arctic ice. But without some geographical change the antarctic ice could not materially diminish during its winter *perihelion*, nor increase to any important extent during the opposite phase. We therefore seem to have no available agency by which to get rid of the ice over a glaciated country, so long as the *geographical conditions* remained unchanged and the eccentricity continued high."

According to Mr. Wallace, the *only* available factor to produce a difference of temperature between the south-polar area and the equator, so as to increase the north-flowing currents and thus melt the arctic ice, would be an increase of the antarctic ice; but this he considers impossible without some *geographical change.* Without such a change, the antarctic ice, he maintains, would neither be increased nor diminished. Hence it follows that without this change there is, according to Mr. Wallace's theory, no possibility of getting quit of our northern ice during interglacial periods.

This sweeping conclusion seems to be based on two assumptions, both of which appear to me to be erroneous. *First*, that the "only" factor available is the antarctic ice: and, *secondly*, that the antarctic ice can neither be increased nor diminished without some geographical change.

A Geographical change not necessary in order to remove the Antarctic Ice.—In reference to the first, that the antarctic ice is the "only" available factor, I shall presently show that there are other causes affecting the northward-flowing currents as powerfully as the antarctic ice. As to the second, that the antarctic ice can neither be increased nor diminished materially without some geographical change, this is an assumption based, no doubt, on the opinion which he holds that the antarctic ice is due to the elevated nature of that continent. Of course if this opinion be correct, then, without a lowering of the land, the ice can never disappear or be greatly changed in amount by astronomical or physical causes. But from what has already been stated in a former article* in reference to the condition of the antarctic continent, I think it is likely that it consists of low dismembered land or of groups of flat islands little elevated above sea-level, but all fused together by one continuous sheet of ice. In fact, it seems highly probable that a very large portion of the ice rests on a surface which is under the sea-level.

* "The Ice of Greenland and the Antarctic Continent not due to Elevation of the Land," Phil. Mag. November, 1883.

If this be the case, the antarctic ice is just in the condition admitting of its being easily modified by warm currents from equatorial regions. In fact at the very present day, as Dr. Neumayer has shown, the slight southward deflections of the warm westerly drift-current caused by the projecting land-masses of Australia, Africa, and South America, cut notches in the ice-cap. When the southern winter solstice was in perihelion during the glacial epoch, it is probable the greater part of the ice then disappeared.

In fact this is a result which would be even still more likely to occur were the views held by Sir Joseph Dalton Hooker and some others as to the nature of the antarctic ice proved to be correct. Sir Joseph thinks that much of the Antarctic ice-sheet, thousands of feet in thickness as it is, was formed by the successive accumulations of snow year by year on pack-ice. The snow fall in the Antarctic regions he believes to be enormous during both summer and winter; and as but a very small portion of it melts, the accumulated snow is perfectly sufficient to form such a sheet. He does not consider that there is land enough in the south-polar area to supply the astounding number and gigantic size of the icebergs that infest the ocean between lat. 50° and 70°. If this theory of Sir Joseph's be correct, and that immense masses of the ice be really afloat, we can easily understand how the whole might, during a southern interglacial period, be broken up, dispersed, and melted by an inflow of equatorial water.

I think, however, that the whole of that enormous sheet from which the icebergs are derived must be resting on the ground, although it is very likely, as has been shown on a former occasion,* that a very large portion of it may be on the sea-bottom. The weight of evidence seems to be in favor of the opinion that there is much to favor the assumption that there are large areas within the antarctic circle consisting of low flat groups of islands separated by broad and shallow seas which have all become filled with solid ice. It is quite possible that the ice filling these seas may have originated in pack-ice, which ultimately became converted into a solid and continuous sheet by long ages of successive snowfalls. As layer after layer, converted into ice, was being heaped upon it year by year, the mass would gradually sink till it rested on the sea-bottom.†

* Phil. Mag., November, 1883, p. 357.

† In this opinion I am glad to find that Sir Joseph to a certain extent concurs, for in a letter to me on the subject he says:—"I cannot doubt but that the icebergs have originated from the ice of the great southern barrier; and what I suspect is that much of this barrier-ice originated in pack-ice over very shallow bays, increased by successive snowfalls. The quantity of snow that falls in summer is enormous south of latitude 50°–60.° Certainly it fell on half the days of each summer month during the three seasons we spent in those seas, and I think

After this it would assume all the characteristics of continental ice. In fact we have a condition of things exactly similar in the North Sea during the height of the glacial epoch (see 'Climate and Time,' p. 449).

If such be the condition of the antarctic ice, we can readily understand how it might all soon disappear under the influence which would be brought to bear upon it were the eccentricity high and the southern winter solstice in perihelion. The warm and equable conditions of climate which would then prevail, and the enormous quantity of intertropical water carried into the Southern Ocean, would soon produce a melting of the ice. Layer after layer would disappear off the surface, and as soon as the weight of the sheet became less than that of the water which it had displaced, the sheet would float. After this it would no doubt shortly break up and become dispersed.

Other causes than Antarctic Ice affecting the Northward-flowing Currents.—If we consider the effect which the present amount of eccentricity, small as it is, has on the climatic condition of some parts of the southern hemisphere, we shall readily understand how, during the glacial epoch, the warm water of this hemisphere may have been impelled northward, even independently of the influence of the antarctic ice. In order to show the present effect of eccentricity on climate I cannot do better than quote Mr. Wallace's own words on the subject. Referring to its effects on south temperate America, he says:

"Those persons, who still doubt the effect of winter in *aphelion* with a high degree of eccentricity in producing glaciation, should consider how the condition of south temperate America at the present day is explicable if they reject this agency. The line of perpetual snow in the southern Andes is so low as 6000 feet in the same latitude as the Pyrenees; in the latitude of the Swiss Alps, mountains only 6200 feet high produce immense glaciers which descend to the sea-level; while in the latitude of Cumberland, mountains only from 3000 to 4000 feet high have every valley filled with streams of ice descending to the sea-coast and giving off abundance of huge icebergs. Here we have exactly the condition of things to which England and Western Europe were subjected during the latter portion of the glacial epoch, when every valley in Wales, Cumberland, and Scotland had its glacier; and to what can this state of things be imputed, if not to the fact that

in one month snow fell *every day*. There is no summer melting of snow and ice in the Antarctic as there is in the Arctic regions. It is the only region known to me where there is perpetual snow on land at sea-level."

Now if the snow which falls in the Antarctic regions at the sea-level does not all melt, but some of it remains year by year, then permanent ice formed at the sea-level, whether it be on frozen pack or on the ground, must be a necessary consequence. If this be so, it cannot be true, as Mr. Wallace affirms, that there is no permanent ice formed but on high land.

there is now a moderate amount of eccentricity and the winter of the southern hemisphere is in *aphelion?* The mere geographical position of the southern extremity of America does not seem especially favorable to the production of such a state of glaciation. The land narrows from the tropics southward, and terminates altogether in about the latitude of Edinburgh; the mountains are of moderate height; while during summer the sun is three millions of miles nearer, and the heat received from it is equivalent to a rise of 20° F. as compared with the same season in the northern hemisphere."—P. 142.

In a similar glacial condition are the islands of South Georgia, South Shetland, Graham Land, Enderby Land, Sandwich Land. There can be little doubt that the present extension of ice in the antarctic regions is to a considerable extent due also to the influence of eccentricity.

Let us now glance for a moment at the influence which this state of things has at present on northward-flowing currents. One result is that the southeast trades are stronger than the northeast, and as a consequence blow over on the northern hemisphere ten or fifteen degrees beyond the equator. This has the effect, as has been shown ('Climate and Time,' chapters v and xiii, and other places), of impelling the warm surface-water of the southern intertropical regions over on the northern hemisphere. It is possible that the greater strength of the south-east trades may to some extent be due to the preponderance of ocean on the southern hemisphere; but there can be little doubt that it is mainly the effect of eccentricity.

The result of this transference of water from the southern to the northern hemisphere is that the intertropical waters of the northern hemisphere are between three and four degrees warmer than those of the southern. Another result which follows, as has also been shown, is that the great equatorial currents are made to lie at some distance to the north of the equator; hence when they are impelled against the American and the Asiatic continents, and become deflected northwards and southwards, the larger portion of the water goes to the north, and thus raises the temperature of the northern hemisphere. Now if all this results as a consequence from the present small amount of eccentricity, how much greater must have been the effect during the glacial epoch, when the eccentricity was more than three times its present value and the southern winter also, as now, in aphelion! All those effects which we have just been considering would then have been magnified far more than threefold.

Climatic conditions of the two Hemispheres the reverse 10,000 or 12,000 years ago: Argument from.—Ten or twelve thousand years ago, when our northern winter solstice was last in aphelion, the climatic conditions were in all probability the reverse of what they are at present. There appears to be pretty good geological evidence that such was the case. This, under the present small amount of eccentricity, shows not only to what an extent climate is affected by eccentricity, but also (and with this we are at present more particularly concerned) that its tendency is to cool the one hemisphere and warm the other, to accumulate the snow and ice on the one and melt them on the other. And this result, to a large extent, is doubtless brought about by its influence on ocean-currents.

There are good reasons for concluding, as Prof. J. Geikie has fully shown,* that at a very recent date (during the time of the formation of the 40-feet raised beach and the deposition of the Carse-clays) the climate was much colder than it is at present. The seas surrounding our Island appear to have had a lower temperature than they have at present; and our Highland valleys seem to have been occupied by local glaciers.†

The Carse-clays of Scotland are best developed in the valleys of the Tay, the Earn, and the Forth. These deposits consist of finely laminated clays and silt. "Now and again," says Prof. J. Geikie, "the deposits consist of tough tenacious brick-clay, which does not differ in appearance from similar brick-clays of glacial age." The clay is usually free from stones, but occasionally blocks of six inches or a foot in diameter are found in it; and Prof. J. Geikie mentions having seen one four feet in thickness. Stones of this size in a fine laminated clay evidently indicate the presence of floating ice. But, as Prof. Geikie remarks, "it is rather the general character of the clays themselves than the presence of erratics which indicates colder climatic conditions. The fine tenacious brick-clays are not like the dark sludge and silt which now gather upon the estuarine bed of the Tay, but resemble and in some cases are identical in character with the laminated clays of true glacial age with arctic shells." These Carse-clays, as he further remarks, appear in a large measure to be made up of the fine "flour of rock" derived from the grinding action of glaciers which then occupied the Highland valleys, and from which muddy waters escaped in large quantities in summer owing to the melting of the snow and ice. In short, these Carse-clays appear to coincide with the most recent period of local glaciers.

During that period some of the glaciers, as Professor J. Geikie has shown, appear to have even reached the sea-level.

* 'Prehistoric Europe.'

† In a paper "On the Obliquity of the Ecliptic," read before the Geological Society of Glasgow in 1867, I concluded that at the time of the deposition of the Carse-clays the mean winter temperature was probably 10° or 15° lower than at present, and the Gulf-stream considerably reduced. See also 'Climate and Time,' pp. 403–410.

For example, at the mouth of Glen Brora, in Sutherland, there is a well-marked moraine with large blocks resting upon, and apparently of the same age as, the deposits of the raised beach.* Mr. Robert Chambers also observed moraine matter resting upon the 30-feet beach at the opening of Glen Iorsa, in Arran. In many of the Highland sea-lochs, says Professor J. Geikie, glaciers appear to have come down to the sea and calved their icebergs there. This, he thinks, is probably the reason why the 40–50-feet beach is not often well seen at the heads of such sea-lochs. The glaciers seem in many cases to have flowed on for some distance into the sea, and thus prevented the formation of a beach and cliff-line.

The greater magnitude and torrential character of the rivers of that period were no doubt due to the melting during summer of great masses of snow and ice. The presence of the large Greenland whale, found frequently in the Carse deposits, would seem to indicate a somewhat colder sea than now surrounds our island. A decrease of temperature of the sea is what would necessarily occur from a slight diminution in the volume of the Gulf-stream, arising from the greater deflection of equatorial water into the southern hemisphere.

Another circumstance deserves notice here, as it seems to indicate that the climatic conditions of the two hemispheres were at the period of the Carse clays the reverse of what they are at present. During that period the sea stood higher in relation to the land than it does at the present time. To this circumstance alone no great importance can be attached; but when we consider in addition that submergence has almost invariably accompanied glaciation, we may regard it as highly probable that the submergence at the period in question was the result of a greater amount of ice on the northern hemisphere and a less amount on the southern, than now. This probability is further increased by the fact that during the growth of the ancient Forest, which immediately underlies the Carse-clays, and indicates a condition of climate even more warm and equable than the present,† the sea stood not only higher in relation to the land than it did during the time of the deposition of the Carse-clays, but somewhat higher than it does at present. The buried Forest doubtless belongs to the period 10,000 or 12,000 years prior to that of the Carse-clays,‡ when the winter solstice was in perihelion; and at this time, owing to a somewhat greater amount of eccentricity than at

* 'Prehistoric Europe,' p. 411.

† Those who doubt the equable and warmer character of the climate of the submarine Forest-bed period should study the mass of evidence on this point given in 'Prehistoric Europe.'

‡ For the probable dates of the Carse-clays and the submarine Forest-beds see Appendix.

present, the quantity of ice on the southern hemisphere might be expected to be greater and that on the northern less than now.

Thus when the northern winters were last in aphelion there was a *rise* of sea-level, resulting doubtless from a preponderance of ice on the northern hemisphere; but when the buried Forest flourished 10,000 or 12,000 years prior, the winters were in perihelion, and there was a *fall* of sea-level, due in all likelihood to the preponderance of ice on the southern hemisphere. But this is not all: the strata which underlie the buried Forest bear witness to another *rise* of sea-level.

These changes of climatic conditions and oscillations of sea-level, which took place during the latter part of the Postglacial period, are just what should have taken place on the supposition that they were the result of those astronomical and physical agents which we have been considering. Thus, immediately preceding the Present period we have that of the 25- and 40-feet* raised beaches and the Carse deposits, which indicate that the climate was then more severe and the sea somewhat colder and standing at a higher level than at present. Now during this Recent period our northern winter solstice was in aphelion, and the condition of things is exactly what, according to theory, we ought to expect.

Preceding the period of the Carse-clays comes that of the buried Forest, when the climate was even more genial and equable than at the present day, the Gulf-stream larger and the sea at a lower level than now. Now during this period the winter solstice was in perihelion and the eccentricity somewhat greater than at present; and here again we have exactly that condition of things which, according to theory, we ought to expect. It would be very singular indeed were there no physical connection between these conditions and the causes to which I have been attributing them. It would certainly be singular were all these coincidences purely accidental. These changes have all been so recent, geologically speaking, and so general and widespread in their character, that they cannot reasonably be attributed to any known geographical changes. If we admit, then, that they were the result of those astronomical and physical agents to which I have referred them, we must also admit that those agents were as efficient in producing a warm and equable climate as in producing a cold and severe one. We must further admit that, with a very small amount of eccentricity, widely marked differences of cli-

* At one time I thought ('Climate and Time,' p. 409) that the 40-feet beach might belong to a period 50,000 years prior to the Carse-clays; but I am now satisfied that the two beaches both belong to the period of the Carse-clays, as Professor J. Geikie has shown.

matic conditions are brought about on the two hemispheres; that, when the winters are in perihelion, the melting of the snow and ice and the increase of the Gulf-stream and other northward-flowing currents are as necessary a result as were the formation of the snow and ice and the decrease of the Gulf-stream and those currents when the winters were in aphelion. And if this holds true in reference to recent and postglacial times, when the eccentricity was small, it must, for reasons which will presently be stated, hold true in a higher degree in reference to the glacial epoch, when the eccentricity was more than three times its present value.

The Mutual Reaction of the Physical Agents in relation to the Melting of the Ice.—When the winter solstice is in aphelion it sets in operation, according to theory, as has been shown, a host of physical causes, the tendency of which is to produce an accumulation of snow and ice; but when the solstice-point moves round to perihelion the tendency of these causes is reversed, and they then undo what they had previously done—they melt the snow and ice which they had just produced. The action of the causes being reversed, the effects are reversed. But it must be observed that the greater the amount of the eccentricity, the greater will be the effect resulting from the combination of these physical agents, whether that effect be the production of snow and ice on the cold hemisphere, or the melting of them on the warm—whether it be their production when the winter solstice of a hemisphere is in aphelion, or their melting when that solstice is in perihelion.

We have, however, to take into account not merely the action of the physical agents, but their mutual reactions on one another. The effect of this mutual reaction is very striking. Not only do the physical agents, in their actions, all lead to one result, viz: an accumulation of snow and ice when the winters are in aphelion, but their efficiency in bringing about this result is actually strengthened by their mutual reactions on one another. To illustrate this effect I quote the following from a former article:

'To begin with, we have a high state of eccentricity. This leads to long and cold winters. The cold leads to snow, and although heat is given out in the formation of the snow, yet the final result is that the snow intensifies the cold; it cools the air and leads to still more snow. The cold and snow bring a third agent into play—*fogs*, which act still in the same direction. The fogs intercept the sun's rays, this interception of the rays diminishes the melting-power of the sun, and so increases the accumulation. As the snow and ice continue to accumulate, more and more of the rays are cut off; and on the other hand, as the rays continue to be cut off, the *rate* of accumulation increases, because the quantity of snow and ice melted becomes thus annually less and less. In addition, the loss of the rays cut off by the fogs lowers the temperature of the air and leads to more snow being formed, while again the snow thus formed chills the air still more and increases the fogs. Again, during the winters of a glacial epoch, the earth would be radiating its heat into space. Had this loss of heat simply lowered the temperature, the lowering of the temperature would have tended to diminish the rate of loss; but the result is the formation of snow rather than the lowering of the temperature.

'Further, as snow and ice accumulate on the one hemisphere they diminish on the other. This increases the strength of the trade-winds on the cold hemisphere and weakens those on the warm. The effect of this is to impel the warm water of the tropics more to the warm hemisphere than to the cold. Supposing the northern hemisphere to be the cold one, then, as the snow and ice begin gradually to accumulate, the ocean-currents of that hemisphere, more particularly the Gulf-stream, begin to decrease in volume, while those on the southern or warm hemisphere begin *pari passu* to increase. This withdrawal of heat from the northern hemisphere favors the accumulation of snow and ice, and as the snow and ice accumulate the ocean-currents decrease. On the other hand, as the ocean-currents diminish, the snow and ice still more accumulate. Thus the two effects, in so far as the accumulation of snow and ice is concerned, mutually strengthen each other.'

With all this Mr. Wallace seems fully to agree; for at pp. 137–140 ('Island Life') he gives a very clear statement of the effect of these mutual reactions in the production of glaciation, and says that were it not for them it is probable the astronomical and other causes would not in our latitudes have been sufficient to produce glaciation. In short, he concludes that these reactions "produce a maximum of effect which, without their aid, would be altogether unattainable." Mr. Wallace thus does full justice to these mutual reactions in so far as the production of glaciation is concerned; but I am convinced that he must have underestimated their importance as regards the removal of the glaciation. He, however, recognizes the fact that these mutual reactions produce an opposite effect on the warm atmosphere whose winters are in perihelion. "These agencies," he says, "are at the same time acting in a reverse way in the southern hemisphere, diminishing the supply of the moisture carried by the anti-trades, and increasing the temperature by means of more powerful southward ocean-currents; and all this again reacts on the northern hemisphere, increasing yet further the supply of moisture by the more powerful southwesterly winds, while still further lowering the temperature by the southward diversion of the Gulf-stream."

Now if, during the glaciation of the northern hemisphere, these mutual reactions produce the opposite effect on the southern hemisphere, it is evident that they must produce this same opposite effect on the northern hemisphere when its winter solstice is in perihelion. Their effect then would be to increase the temperature and melt the ice. When the winter solstice is moving towards the aphelion, the physical agents begin to act and also to react on one another, and this action and reaction goes on increasing in intensity till the solstice-point reaches the aphelion ; but an exactly similar thing is going on in the other hemisphere, only the effects are the reverse. While the actions and reactions leading to an accumulation of ice are increasing in intensity, we shall suppose, on the northern hemisphere, the same increase is taking place on the southern hemisphere ; but the result is a melting, not an accumulation of the ice. The same process is undoing on the southern hemisphere what it is doing on the northern. Similarly, of course, when the northern winter solstice begins to move towards the perihelion, the mutual reactions of these physical causes will be reversed and will go on with increasing intensity till the perihelion is reached, melting the very ice which they had previously produced.

We have already seen that the greater the extent of the eccentricity, the greater is the effect resulting from the *actions* of the physical causes, whether this effect be the production of ice on the cold hemisphere, or its removal from the warm. It is evident that the same thing must necessarily hold true in regard to the mutual *reactions* of the physical causes. Consequently if the mutual actions and reactions of the physical causes, brought into operation during a high state of eccentricity, led at the glacial epoch to the great accumulation of ice when the winters were in aphelion, they must have led to an equally great melting and dispersal of that ice when precession brought the winters round to perihelion. These causes would be as efficient in the removal of the ice as they were in its production. In so far as the physical and astronomical causes were concerned, the greater the amount of ice formed during the cold periods the greater would be the amount melted during the warm interglacial periods.

Another reason assigned why the ice does not melt.—Mr. Wallace assigns the following as an additional reason why the ice does not disappear during the interglacial periods when the eccentricity is high :

"When a country is largely covered with ice, we may look upon it as possessing the accumulated or stored-up cold of a long series of preceding winters; and however much heat is poured upon it, its temperature cannot be raised above the freezing-point till that store of cold is got rid of—that is, till the ice is all melted. But the ice itself, when extensive, tends to its own preservation, even under the influence of heat; for the chilled atmosphere becomes filled with fog, and this keeps off the sun-heat, and then snow falls even during summer, and the stored-up cold does not diminish during the year. When, however, only a small portion of the surface is covered with ice, the exposed earth becomes heated by the hot sun, this warms the air, and the warm air melts the adjacent ice. It follows that, towards the equatorial limits of a glaciated country, alternations of climate may occur during a period of high eccentricity, while nearer the pole, where the whole country is completely ice-clad, no amelioration may take place." —P. 154.

For the past nineteen years I have been maintaining that, when a country is covered with ice, it becomes a permanent source of cold; and however much heat may be received from the sun, the temperature of the surface can never be raised above the freezing-point while the ice remains; and, again, that such an ice covering tends to its own preservation, because it chills the air and increases the snow fall. In short I have all along maintained this to have been one of the chief causes which led to the country being so deeply covered with ice. In fact, had it not been for some such conservative power in the ice, a glacial epoch resulting from the causes which I have been advocating would not have been possible. This conservative tendency certainly renders it more difficult for the physical agencies to get rid of the ice during interglacial periods; but we evidently have no grounds for assuming that it will defy their melting-powers.

I shall next consider Geological and Paleontological facts in relation to Mr. Wallace's modification.

ART. XXXII.—*A Contribution to the Geology of Rhode Island*; by T. NELSON DALE.

[Continued from page 228.]

Dutch Island.—The mica schist and conglomerate of 115, Beaver Head, recur here at 128; the conglomerate, measuring two feet, reappears at 129; the mica schist is garnetiferous, plicated and folded. These plications characterize the whole east side of the island. A remarkably fine section of them is exposed at a small recess between the upper and lower docks, 130, where, in a cliff fifteen feet high, the schists are folded two or three times, the last fold being directly over the first, and the strike N.N.E. At one place a fold has ruptured and a fault ensued. Portable and most instructive specimens of plicated schist can here be obtained. One such, measuring now $5\frac{1}{2}'' \times 10'' \times \frac{3}{4}$ inches, when each bend is measured, gives $8\frac{1}{2}'' \times 10'' \times \frac{3}{4}$ inches for its original size. It has three folds lengthwise, each forming an angle of 60°, but two of the folds die out toward one end where it has the shape of a flat-bottomed trough. Between 128 and 129, and north of the upper wharf, the edges of about ten feet of mica schists are exposed on the beach, dipping 60° N.N.W., their upper portions having been there eroded, but in the adjoining bank they are seen to fold over upon themselves, dipping 25° S.S.W. At 131, south of the lower wharf, ten feet of micaceous conglomerate and grit dip 60° E.S.E., above and below which are mica schists which continue to the light-house, there highly inclined or vertical. Near 132, at the north end, the mica schist dips 50° N.W. to vertical. Between 132 and 133 the dip is first southeastward, then vertical, then slightly N.W., the strike being N.E. to N.N.E. The rocks are garnetiferous mica schist with some small layers of micaceous, garnetiferous grit and conglomerate. Small pebbles of opalescent quartz occur in the grits. The pebbles of the conglomerate are uniformly flat and either quartzyte or mica schist. The mica schist is very different from that of "Paradise," being much more micaceous and brilliant, always garnetiferous and sometimes minutely crumpled in one or even in two directions. Among these layers occur several small layers of dark argillyte containing garnets and radiated crystal of hornblende or chlorite, which rock sometimes passes into a garnetiferous hornblende or chlorite schist. Quartz veins, either milky or hyaline, abound and contain some crystals of feldspar. Between 133 and 134 are no outcrops. At 134, two beds of highly carbonaceous and graphitic schist, separated by a layer of light colored mica schist and conglomerate, dip 45° E.S.E. It is quite possible that these pass horizontally into the regular graphitic coal. In proximity to them at 134 is a layer of carbonaceous, garnetiferous argillyte. At 135 the mica schist dips 70° E.S.E.

Packard's Rocks, Bonnet Point, Narraganset Pier.—At 136, on the mainland, West Passage, alternating dark and light mica schists, without garnets, dip 35°–40° E., the difference between them lying in the relative proportion of black mica. These schists extend north to Plum Beach and N.W. to 137 and beyond, and recur south at Packard's Rocks with the same dip. There the light colored layers are a highly metamorphosed grit with some large quartz pebbles. At 138, one and one-quarter mile south, these rocks dip 25°–35° E.S.E., then 25°–30° W.S.W., and are crossed by a granite vein. North of the "South Ferry" the dip is E.S.E., and a vein eight feet thick of cream-colored granite crosses E.S.E.–W.N.W. about vertically. The mica schists recur just south of the ferry, and, at 139, are disturbed by a vein mass of cream-colored granite, 25′–50′ thick, with large crystals of feldspar and mica and large masses of uncrystallized feldspar and quartz. A little south of 139 the schist contains nodules of feldspar and quartz and dips 25°–45° E.S.E. It makes up the whole of the cliff, here sixty feet high, "the Bonnet," dipping as high as 60° but averaging 45° E.S.E., and crossed by veins of granite. On the other side of Wesquage Beach the light and dark mica schists recur and southward to Watson's Pier and 140; dip 55°–75° E. 10° S. Numerous granite veins, from ¼″ to 3′ thick, occur among and parallel with the strata, and in everything but crystalline arrangement, which is across the veins, resemble layers. At 141, on Boston Neck, a light cream-colored granite crops out. Between 141 and Pattaquamscott River, and also at 142, on the other side, occurs a fine grained, light colored granite or gneiss. The next outcrop south is just below Narraganset (lower) Pier where a fine-grained, pinkish protogine and granite, in places probably gneiss, of pinkish feldspar, black mica or chlorite and quartz, is traversed by veins of coarse granite with reddish feldspar. This rock forms the shore for two miles; at 143, Gunning Rock, dips S.E. by E. and also E. by N., crossed by E.S.E.–W.N.W. joints. Southward it becomes finer grained and its feldspar lighter colored until near Quohog Rock it differs considerably from that of Narraganset Pier. Between 144 and Point Judith Light, two and one-half miles south, there are no outcrops. Near a bridge across the "Narrow River," a continuation of the Pattaquamscott, about one and one-half miles S.W. of South Ferry, a bed of fine-grained plumbago, said to measure about two feet was met in digging a well. Half a mile west of that place granite or gneiss ledges occur. Jackson, on his map, indicates plumbago in granite two miles west of Bonnet Point, and the range of Tower Hill back of the river he has down as granite and gneiss.

CONCLUSIONS.

Stratigraphical.—From the stratification at 46, 53, 17, on Newport Neck, and at 143, near Narraganset Pier, it is evident that the protogine masses of that neck are not intrusive, and it is therefore improbable that that of Conanicut is so. As protogine occurs also at West Island, and thus on both sides of the Carboniferous basin, it seems highly probable that all these masses of protogine belong to the same metamorphic bed or series of beds, and that these isolated masses in the center were thrown up either before or after the deposition of the Carboniferous strata or partially at both times. No eastward dips have been observed in the eastern half of the main protogine tract of Newport Neck, but for convenience such have been assumed. If the dip is uniformly W.N.W., a fault must be assumed at Almy's Pond between the protogine and the Carboniferous beds, or an original unconformity must be supposed to have been subsequently changed to a conformity in direction, but not in angle of dip; for the metamorphism of a bed overlying carbonaceous, fossiliferous beds into protogine is highly improbable and intrusion has been shown to be out of the question.

In intimate contact with these isolated masses of protogine we find, at the Dumplings and Bailey's Beach, certain epidotic and chloritic schists, some parts of which closely resemble the chlorite schist of "Paradise," which, therefore, on lithological grounds, would, together with its associated mica schists, seem to be perhaps synchronous with the former.

The chloritic argillytes with calcite, forming the western part of Newport Neck, evidently correspond to the similar rocks of Brown's and Church's Points in Little Compton, and accordingly underlie the coal measures; and at Coaster's Harbor and Rose Islands we find them below the "Quartz and Clay Aggregate." The dotted line on the map, from Castle Hill to Rose Island, the Gull Rocks, Coaster's Harbor Island, Little Lime Rock and Brenton's Cove, bounds the probable submarine extension of these rocks near Newport. But the western boundary of this tract almost touches the chloritic and epidotic schists of the Dumplings, which dip about easterly; and the chloritic argillytes of the northern half of Newport Neck dip E.S.E.; therefore, probably, the latter overlie the former. Again, the chloritic argillytes at 71, west of Price's Neck, are underlaid by a layer of ferruginous chlorite, which occurs also in Church's Cove, Little Compton, at the base of these argillytes and near the protogine; and a ferruginous chlorite of slightly different appearance occurs near the top of the protogine at Bailey's Beach; and it is natural that rocks abounding in chlorite should be followed by some a little less chloritic. For all these reasons the normal position of the chloritic argillytes would seem to be above the chloritic and epidotic schists of 15 and 17 and the chlorite and hornblende schists of "Paradise."

The dolomite at 94 and the Lime Rocks is associated with purple slate, and these slates belong to the chloritic argillytes, and so the dolomite. These two outcrops, as stated by Prof. Ch. Hitchcock, seem to be parts of the same bed on opposite sides of a synclinal axis. This axis may be traced northward through Coaster's Harbor Island and southward in the western part of the "Flinty Slate." The gentle S.E. dip at 43 would then represent a minor fold, and the easterly dipping lines at the Lime Rocks would be joints.

The siliceous argillyte of the middle portion of Newport Neck corresponds to that at Conanicut and Sachuest Neck, where it is associated with "Conglomerate I" and underlies the lowest distinctively Carboniferous bed. Its relation to the older rocks is not so clear. From Jackson's observations and mine it is evident that the series of (what may be provisionally termed) Pre-Carboniferous rocks is but incompletely represented at any one point. Thus at Rose Island the Carboniferous rocks rest on the chloritic argillytes, at Sachuest Neck on the siliceous argillytes, but in Conanicut directly upon the protogine. On Newport Neck the siliceous argillytes lie upon the protogine, but in Little Compton apparently the chloritic argillytes take that place. On Newport Neck the siliceous are juxtaposed to the chloritic argillytes, but their relative age is not clear. The following indications, however, throw some light on the question. The Conglomerate I associated with the siliceous argillyte at Sachuest Neck contains pieces of red jasper, and that occurs in this vicinity only in connection with the dark purple slates and dolomite of the chloritic argillyte series. At 66 the siliceous argillyte contains fragments of chloritic argillyte. The conflicting flexures throughout the region diminish the value of dip indications; but it is noticeable that the dip of the chloritic argillytes on Newport Neck is almost uniformly toward the siliceous argillytes, and that as the former nowhere come up again to complete the synclinal it may be supposed that they come up under the latter and thin out before reaching the exposed portion of the protogine on the neck. From the relative strike of the siliceous argillytes at Sachuest Neck and that of the chloritic argillytes of Little

Compton it seems probable that the former overlie the latter unless we suppose the protogine to recur under water on the east side of Sachuest Neck. Serpentine in layers and minute veins is characteristic of the siliceous argillytes, and Jackson found that in the northern part of the State chlorite and hornblende slate are followed by dolomite or serpentine, i. e. the chloritic rocks underlie the serpentines. From these data it seems somewhat probable that the true position of the siliceous argillytes with serpentine is above the chloritic argillytes with dolomite.

The lowest rocks of certain Carboniferous age, the quartz and clay aggregates of Sachuest Neck, recur at Rose, Coaster's Harbor and Conanicut Islands. Lying upon them in Mackerel Cove, and also probably at Coaster's Harbor Island, are the argillaceous schists with siderite and pyrites, in all probability belonging to the same horizon as the Easton's Point argillytes with pyrites (lower argillytes of first paper) which there underlie conglomerate II, and which, on account of their relation to Sachuest Neck, were represented in the general section as overlying the quartz and clay aggregate. At Beaver Head the great bed of quartzyte conglomerate is wanting and the coal-measures immediately follow the sideritic argillyte. Indeed, on the west side of Easton's Point, the conglomerate seems to thin out and there is some uncertainty as to where, in the vicinity of Easton's Beach, the boundary between that conglomerate and the overlying argillytes, conglomerates and carbonaceous schists should be drawn. At Coaster's Harbor Island a slightly metamorphic conglomerate occurs in close proximity to the sideritic and chloritic argillytes, which Prof. Ch. Hitchcock estimates at 50′ and places above the coal beds. If that is correct, the coal-measures must thin out at that locality. The strata of Coddington Cove, Bishop Rock and "The Cliffs" belong to the coal-measures, to which also may be assigned the carbonaceous beds of Taggart's Ferry, the Glen, and of the shore between High Hill and Brown's Points on the East Passage. Here also would seem to belong the Dutch Island and Beaver Head beds which, however, have been subjected to greater metamorphism. The conglomerate of Miantonomah Hill, both Jackson and Ch. Hitchcock regard as above the coal beds, although it strongly resembles that of Easton's Point and differs from that of Coaster's Harbor Island. I could not find the outcrops of conglomerate above the "Cliffs" series to which Professor Ch. Hitchcock alludes on the east side of Almy's Pond, and which he coördinates with that of Miantonomah Hill. What relations exist between the coal-measures of "The Cliffs" and the epidotic and chloritic schists south of Sheep Point is uncertain. A fault has been supposed and the slickensides crossing the strata at Ochre Point and along "the Cliffs" point to a disturbance in a N.–S. or N.N.E.–S.S.W. line, which, if continued south, would border on the outlying masses of epidotic schist opposite 15. The recess between Ochre Point and 14 was formed by erosion of the softer beds. But this does not explain the presence of the coal-measures between the epidotic schists at 14 on the S.E. and the protogine at 44 on the N.W. Here we must resort to the supposition either of Archæan Islands and shallows in the Carboniferous estuaries, or of a double system of faults or of folds followed by erosion of the softer beds.

The mica schists of the Narraganset shore belong to a highly metamorphic belt which includes Dutch Island. A question arises as to the age of these two beds of mica schist. Those of the shore differ chiefly from those of the island by the absence of garnets and graphitic beds and the presence of veins of granite. Farther west occurs the bed of graphite associated either with these schists or with an adjoining gneiss coördinate with that of Narraganset Pier. We have then either a contact of Archæan beds, containing graphite, with highly metamorphic Carboniferous beds, containing graphitic schist, or else, both beds belong either to the Archæan or the Carboniferous. A middle ground has been taken on this question. The protogine of Conanicut and Newport differs from that of Narraganset Pier in containing two kinds or colors of feldspar; besides, the protogine at the pier is not prevalent, the rock being more generally micaceous than chloritic, whereas the opposite case exists at Newport and Conanicut. From the relative dip and position of the mica schists of Bonnet Point, etc., and of the gneiss, granite and protogine south, these mica schists would seem to overlie the latter, but if we consider them as "pre-carboniferous" a question as to their relations to the epidotic, chloritic and hornblendic schists, which in other parts succeed the protogine, arises. They may provisionally be supposed as synchronous with these or as underlying them.

In accordance with these views the accompanying geological map and section have been prepared. They continue westward, the map (Plate I), and the general section (Plate III), of the first paper,* and the following table enumerates and describes all the beds of the south end of Narraganset Bay in

* The layers of "quartz and clay aggregate" in contact with protogine in Mackerel Cove are more inclined than in the section, and the overlying sideritic argillytes are folded, in places, near the surface somewhat like the beds of Dutch Island. The coal-measures in the Western Passage are supposed to dip away from the basin rock, as was also supposed in the case of the chloritic argillytes, in the general section of first paper, at the other side of the basin, but it is a stratigraphical possibility that these beds dip against the sides of the basin as they seem to against the isolated mass of protogine in its center, and as the underlying beds (.5), in the Western Passage seem to against the mica schists (.02).

their chronological order, as far as determined, beginning with the oldest:

·01. *Granite, Gneiss, Protogine.*—Coarse and fine granite and gneiss, of black mica, more or less pinkish feldspar, and quartz, passing in some places into a protogine of chlorite, pink, or a pinkish and a greenish feldspar, and quartz, in others into a granite of light-colored mica, cream-colored feldspar and quartz. The bed of plumbago probably belongs in the gneiss. Veins of coarse, pink granite, sometimes without mica, and of crypto-crystalline, pink feldspar and quartz. One vein or seam of yellow serpentine. (West Island, Narraganset Pier, Newport, and Conanicut.) 1300′+.

·02. *Mica schist*, dark and light colored, both with black mica, the light more quartzose and with quartz pebbles. Veins of coarse granite of cream-colored feldspar, light mica and quartz. 1450′.

1. *Hornblende, chlorite* and *mica schist.*—The hornblende schist of hornblende and triclinic feldspar, sometimes with a little mica, passing into a chlorite schist of chlorite with a little calcite and possibly quartz. This alternating several times with mica schist,* the mica schist passing into a siliceous or an argillaceous schist. Veins of milky quartz with chlorite and also sometimes with crystals of feldspar, also veins of zoisite. ("Paradise" in Middletown.) 950′.

1.5. *Epidotic and chloritic schist.*—In places argillaceous, serpentine or talcose, with nodules and veinlets of crystalline epidote, massive and schistose chlorite, the chlorite schist with a little calcite; sometimes with pebbles of quartz. A few layers of ferruginous chlorite, and of quartzyte with quartz pebbles, in the lower part. Veins of cryptocrystalline pink feldspar and quartz, and of milky quartz. 400′–600′.

2. *Chloritic argillyte.*—Bluish green or dark purple schist and slate, sometimes grayish and micaceous instead of chloritic, generally with minute passages or nodules of amorphous calcite, the latter, when large, traversed by veins of crystallized calcite. Where very chloritic it contains crystals of magnetite, when less so, often cubical iron pyrites. The green slates in places with passages and large masses of white quartz, the purple ones with passages and nodules of dark purple and red jasper, and in Newport harbor with several thick layers of grayish and pinkish dolomite. Veins of milky quartz and chlorite sometimes with crystallized, flesh-colored feldspar. 500′–2000′.

* A similar series seems to occur near Providence (see Jackson, pp. 75, 76), and near New Haven (see J. D. Dana, Manual of Geology, third edition, also this Journal, III. vol. vi. On the Rocks of the Helderberg era in the valley of the Connecticut, etc.)

3. *Siliceous argillyte.*—(Flinty slate of the Hitchcocks, Primordial felsite of Shaler, Conglomerate I of first paper), dark gray, purple or green, more or less schistose, siliceous or argillaceous; in many places an impure serpentine; at Sachuest Neck with a slaty conglomerate containing a few pebbles of red jasper. Seams of precious serpentine and talc, near which calcite, picrolite and chrysotile. Veins of cryptocrystalline granite. 500′–2000′.

4. *Quartz and clay aggregate.*—A highly metamorphic, coarsely stratified, dark gray or black aggregate of very coarse quartz grains and fine argillaceous matter, including a few layers of fine, carbonaceous slate with Carboniferous plants. Annularia longifolia. Veins of milky quartz. 750′.

5. *Sideritic argillyte.*—(Lower argillaceous schist of first paper.) Light and dark gray, argillaceous, in some places hydro-micaceous or talcose, schist, generally with disseminated, minute nodules of crystalline siderite, sometimes with cubical iron pyrites, in several localities striped, light and dark, across the bedding. Veins of milky quartz with chlorite, frequently also with ferruginous, crystalline calcite. One or two veins of argillaceous rock with cubical iron pyrites. 600′–2000′.

6. *Quartzyte Conglomerate.*—(1st and 2d conglomerate of Ch. Hitchcock, Conglomerate II of first paper) consists of large pebbles and bowlders of finely stratified quartzyte with a little mica (or very quartzose mica schist), containing, in certain localities, Lingulæ, and cemented together with an argillaceous and siliceous, in places a micaceous cement containing crystals of magnetite. Veins of milky quartz. ("Paradise," "Purgatory," etc.) 750′.

7, 8, 9. *Coal measures.*—Alternating dark and light gray, argillaceous schists (sometimes ochraceous or with minute ferruginous nodules), grits, sandstones, quartzyte conglomerates (of smaller pebbles than 6), carbonaceous argillytes or slates with large ferruginous nodules, numerous species of coal plants, and beds of plumbaginous anthracite. At Dutch Island the argillaceous schists are replaced by garnetiferous, mica schists including a few layers of garnetiferous, hornblende or chlorite schist.* Veins of milky quartz, rarely with chlorite, at Dutch Island both hyaline and milky, with feldspar. 2000′.

These beds give a total thickness of from 9,200 to 13,800 feet, or, supposing 1 to be synchronous with 1.5, of 8,250′ to 12,850′. Of these only Nos. 4–9, or 3700′–4100′, are certainly of Carboniferous age. Professor Shaler assigns No. 3 to the Primordial, but it is unfossiliferous as are all below 4. Prof. Hunt refers 2 and 3 to the Huronian. Mr. W. O. Crosby,

* At the Portsmouth coal mines, in this basin, crystallized siderite, marcasite and calcite, as well as graphite and asbestos, occur in proximity to the coal beds.

after studying certain hornblendic and chloritic rocks in Rhode Island and Massachusetts, and examining the granite near Tiverton,* is disposed to assign them to the Montalban; and as these rocks present some analogies to .01, 1 and 1.5, his opinion is of weight here, but the metamorphic character of the whole series, including the coal-measures, should make us cautious in the application of chemical methods of classification which might be valid in a region where the Carboniferous beds had preserved their normal constitution.

An analysis of 200 measurements of the dip at the south end of the bay yields these results: There are 12 different directions of the dip: A, W.N.W.–E.S.E.; A″, W.–E.; B, N.N.E.–S.S.W.; B″, N.E.–S.W.; B‴, N.–S.; C, N.N.W.–S.S.E. Of these, A″, B″, B‴, varying but 22° one way or the other from A, B, C, may be attributed to minor causes, leaving three main flexures 45°–90° apart. As none of the twelve dips are confined to the Pre-carboniferous beds the flexures must all have taken place, to some extent at least, as late as the close of the Carboniferous age. The most prevalent ones are A and B, the former giving a strike of N.N.E.–S.S.W. (or N. 33 E.–S. 33 W. true), parallel with the Appalachian range and, therefore, probably dating to the time of the Appalachian revolution, the latter one of W.N.W.–E.S.E. (or N. 57 W.–S. 57 E.) at right angles to that range. This last was in all probability the cause of the W.N.W.–E.S.E. fissures which characterize the whole region, especially the quartzyte conglomerate.† Two main synclinal axes running N.N.E.–S.S.W. are apparent, one between the Narraganset shore and the southern part of Conanicut, another between the chloritic argillytes and the protogine on Newport Neck which may be traced northward through Coaster's Harbor Island. These flexures traverse the entire series with little regard to their lithological character. As the same bed is often flexed in several directions it is not easy to determine whether unconformable deposition took place anywhere. What appears like unconformity is often the result of lateral pressure and faulting, but, as there is some reason to suppose that the protogine and associated schists in the center of the basin were above water in Carboniferous times, it seems probable that on their borders the Carboniferous beds must lie unconformably, but the highly metamorphic character of the protogine and the subsequent flexure of the entire series has obscured the evidences of it. The irregular vertical distribution of the members of the Pre-carboniferous points either to flexures in those more ancient times, or to changes or differences in the character

* Geology of Eastern Massachusetts. Boston Society of Natural History, 1880, pp. 107, 108, 127, 133, 134.

† Professor Ch. H. Hitchcock notes the complex dips at the coal mines, p. 127.

of the sediments within short distances, or erosion of them, or else to different degrees of metamorphism of the same bed. This last has been erroneously supposed to account for the difference between the chloritic and siliceous argillytes. Whatever may have been the cause, the fact is that the Carboniferous strata lie immediately upon as many as six different kinds of beds at different points. That metamorphism took place in part before the deposition of the Carboniferous beds is possible but not to such an extent as to prevent the subsequent flexure of the whole series; that it took place unequally at different places in later Carboniferous times is probable from a comparison of the Dutch Island and Newport beds. The entire series of beds, with the different veins, affords a succession of lithological and mineralogical facts which can hardly fail to be suggestive to the chemical geologist.

Physiographical.—In attempting to reconstruct the physiography of Carboniferous times in this region we may venture the supposition that the ancient shore, on the east, followed the line now indicated by the range of granite hills trending south from Tiverton towards West Island, and, on the west, that indicated by the corresponding range of Barber's Height and Tower Hill, fifteen miles distant in North and South Kingstown, which trends southward toward Point Judith. A little more than midway from the east shore of this basin, we may suppose, was an island of protogine, siliceous and chloritic argillyte (or of the rocks which these now represent), about four miles in diameter, covering what is now part of Conanicut, Newport Neck and harbor. The rest of this end of the basin, with perhaps an exceptional islet at "Paradise," was alternately marsh or estuary, but in its eastern half was at one time either the theatre of powerful or long continued, local, erosive influences operating on some protruding quartzytes, or else afforded a channel for stone-laden ice floes or powerful currents bringing detritus from the north. The plowing out of the east, west and central passages of Narraganset Bay, as well as of Mackerel Cove and the smaller inlets between Easton's Point and "the Cliffs," on one side, and Sachuest Neck, on the other, and the lands back of them, with so little regard to anticlinal or synclinal axes, may be attributed, as suggested by Professor Shaler, in part to pre-glacial, but largely to glacial erosion.

Newport, R. I., December, 1883.

ART. XXXIII.—*On Mesozoic Dicotyledons;* by LESTER F. WARD.

IN the following remarks on Mesozoic Dicotyledons, I confine the term *Dicotyledons* to that sub-class of the vegetable kingdom which is embraced under the term *Angiosperms* in most modern text-books of botany. This is the usage of most vegetable paleontologists[1] and the reasons for adopting it have been frequently stated.[2]

The Dicotyledons occupy somewhat the same position in the history and development of plants that the Mammalia occupy with respect to animals. They constitute the dominant type and in their rapid march have now so completely gained the ascendant as to dwarf all other forms into relative insignificance. They include nearly all the deciduous forest trees, the shrubby undergrowth, the leafy herbage and the weeds of all temperate regions.

But this has not always been the case. In fact the reign of the Dicotyledons, geologically considered, has been very brief. Although there is evidence that the earth has been covered with vegetation since the beginning of the Carboniferous age at least, still there is nothing to warrant us in saying that a single dicotyledonous plant existed prior to the close of the Jurassic. Indeed, we do not know from the actual discovery of specimens that this type appeared earlier than the second recognized group of the Cretaceous—the Urgonian. Until quite recently the presence of these plants in formations lower than the Miocene was so rare that it was with the Tertiary rather than with the Cretaceous that the existing dominant vegetation of the globe was assumed to have originated.

Notwithstanding this, some of the earliest, if not the very earliest, discoveries of these forms were in cretaceous strata. In the stone-quarries of the Harz mountains near Blankenburg, were found, near the beginning of the eighteenth century, prints of large leaves which the workmen believed to be those of the grape vine, and which were mentioned by Scheuchzer, Brückmann, and Walch, but without any attempt at their scientific determination.

A brief historical review of the discovery, identification and publication of dicotyledonous species in Cretaceous strata of Europe and America, including the arctic regions, will show the importance which this subject is assuming among paleontologists.

[1] Göppert, Geinitz, and one or two others conform to the Jussiæan system.
[2] See the American Naturalist, vol. xii (June, 1878), pp. 359–378.

In 1833 Zenker[3] took up in earnest the study of the Blankenburg leaf-prints and described, figured and named five species belonging to two genera. One of these genera he rightly concluded to have no living representatives, and he therefore named it *Credneria*, after his friend Professor Credner, who collected the specimens.

In 1841 Göppert[4] figured a number of dicotyledonous leaves from the Quadersandstein of Silesia, but did not venture to give names to them.

The next year Geinitz[5] identified three species in the lower Quader of Saxony at Niederschöna, the fossil flora of which place was so well worked up by Ettingshausen in 1867.

In 1845 Corda[6] figured some dozen leaves from Trziblitz, Luschitz, Perutz, and Weberschan, in Bohemia, some of which localities he placed in the Gault, but they are probably all in the Lower Quadersandstein, or Cenomanian. He made no attempt to refer these forms to genera and species.

Unger's *Synopsis*[7] appeared the same year, in which sixteen species of Cretaceous Dicotyledons are recognized down to that date. Göppert,[8] however, admitted only thirteen species in his table published in Bronn's *Naturgeschichte*, which also appeared in 1845.

Debey[9] in 1848 enumerates sixteen species as previously published and adds to these twenty-seven others from the neighborhood of Aix-la-Chapelle, most of which, however, he contents himself to call *Phyllites*, and as no figures were made, it is probable that some of these were not Dicotyledons. He also gives four *Carpolithes* which he identifies with dicotyledonous orders.

The same year Göppert[10] published a supplement to his Flora of the Quadersandstein in which a number of Dicotyledons are recognized.

In Ettingshausen's *Proteaceen der Vorwelt*, 1851,[11] four Creta-

[3] Beiträge zur Naturgeschichte der Urwelt, von Jonathan Carl Zenker. Jena, 1833.

[4] Ueber die fossile Flora der Quadersandsteinformation in Schlesien, etc., in Nova Acta Naturæ Curiosorum, vol. xix, Taf. xlvii, li, liii.

[5] Characteristik der Schichten und Petrefacten des sächsisch-böhmischen Kreidegebirges, von Dr. Hans Bruno Geinitz. Heft 3, Dresden and Leipzig, 1842, p. 97.

[6] In: Die Versteinerungen der böhmischen Kreideformation, von Aug. Em. Reuss. Stuttgart, 1845–46, Taf. l, li.

[7] Synopsis plantarum fossilium autore Fr. Unger, M.Dr., Lipsiæ, 1845.

[8] Naturgeschichte der drei Reiche, xv, 2 (Handbuch einer Geschichte der Natur, iii, 2) von Heinrich G. Bronn, Stuttgart, 1849, pp. 44–57 and 66.

[9] Uebersicht der urweltlichen Pflanzen des Kreidegebirges überhaupt und der Aachener Kreideschichten insbesondere, von Dr. M. Debey, in Verhandlungen des naturhistorischen Vereines der preussischen Rheinlande, 5. Jahrgang 1848, p. 113.

[10] Zur Flora des Quadersandsteins, in Nova Acta Nat. Cur. xxii, 1, p. 365.

[11] Sitzungsberichte der mathem.-naturw. Classe der kaiserlichen Academie der Wissenschaften, Wien. Bd. vii, Heft iv, 1851, p. 711.

ceous species are enumerated, and Von Otto[12] in his *Additamente*, 1852—54, also described Proteaceæ from the Quader of Saxony; while Miquel[13] in 1853 described a few Dicotyledons from the upper Cretaceous of Limburg.

In 1856 Dunker[14] described and figured in the *Palæontographica* four species from Blankenburg in addition to those of Zenker, and one cluster of fruit which he believed to belong to *Credneria*, and to indicate strongly that those ancient plants belonged to the Polygonaceæ, Zenker had divined that they might be amarantaceous.

One year later Stiehler[15] reviewed in the *Palæontographica* the whole subject of the Cretaceous flora of the Harz mountains, and added to all previous results the discoveries made by Hampe, a druggist of Blankenburg, in the marls near that place. Out of the numerous forms of *Credneria* he carves a new genus which he calls *Ettingshausenia*, and of which he makes eight species. He admits seven species of *Credneria*, and figures several others which he calls new species, but without assigning specific names to them.

Thus far America had contributed nothing to the flora of the Cretaceous, but in 1858 Heer described in the proceedings of the Academy of Natural Sciences of Philadelphia[16] eight species of Dicotyledons which had been collected by Doctor Hayden in Kansas and Nebraska. These, however, he erroneously believed to be Miocene.

The next year Mr. Lesquereux[17] contributed a paper to this Journal in which a number of fossil plants from Nanaimo, Vancouver's Island, and from Bellingham Bay were described as Miocene. It is now known that Nanaimo is Cretaceous, and his paper enumerates six species of Dicotyledons from that locality.

Nothing further appears to have been done until 1863, when Dr. Newberry[18] reported, in the Boston Journal of Natural History upon certain fossil plants from Orcas Island, British Columbia, collected by the Northwest Boundary Commission. He

[12] Additamente zur Flora dis Quadergebirges in Sachsen, von Ernst von Otto. Heft ii, Leipzig, 1854, p. 44.

[13] De fossile planten van het Krijt in het hertogdom Limburg, Haarlem. 1853. Verhand. Geol. Kaart Nederl. i, pp. 33–56.

[14] Ueber mehre Pflanzenreste aus dem Quadersandsteine von Blankenburg, von Wilhelm Dunker. Palæontographica, iv, 1856, pp. 179–183, tab. xxxii–xxxv.

[15] Beiträge zur Kenntniss der vorweltlichen Flora des Kreidegebirges im Harze, von August Wilhelm Stiehler. Palæontographica, v, pp. 45–80, Taf. ix–xv.

[16] Fossil Plants of the Lower Cretaceous beds of Kansas and Nebraska, by Oswald Heer. Proc. Acad. Nat. Sci. Phil., 1858, pp. 265, 266.

[17] On some fossil plants of recent formations, by L. Lesquereux, Am. Journ. Sci., II, xxvii, 1859, pp. 359–366.

[18] Descriptions of fossil plants collected by Mr. George Gibbs, Geologist to the U. S. Northwest Boundary Commission under Mr. Archibald Campbell, U. S. Commissioner, by J. S. Newberry. Boston Journ. Nat. Hist., vii, 1863, pp. 506–524.

declared the horizon Cretaceous, and among the plants described were four Dicotyledons.

In 1866 appeared the somewhat famous *Phyllites crétacées du Nebraska* of Capellini and Heer,[19] the latter of whom determined the fossil plants which the former had himself helped to collect at Blackbird Hill, Nebraska, in the now well known Dakota Group. The Cretaceous character of these fossils was here rather grudgingly conceded and has never since been seriously doubted.

While America had been thus coming forward Europe had remained in the background for about ten years, or since Stiehler's monograph of the Harz in 1857. It was not till 1867 that Ettingshausen[20] published in the Sitzungsberichte of the Vienna Academy his valuable paper on the fossil flora of Niederschöna in Saxony. The horizon of this place is considerably lower than that of Blankenburg and belongs at the base of the Quadersandstein formation of Germany. Nevertheless, the species nearly all belong to living genera—Quercus, Fagus, Ficus, Laurus, Protea, etc. Twenty-eight species are enumerated.

In the same volume Unger[21] described and figured four Dicotyledons, thus far unknown, from the Gosau (upper Senonian) of Austria, at St. Wolfgang and Neue Welt. Though contenting himself to call them all *Phyllites*, he yet ventured to assign two of them to the Magnoliaceæ and two to the Proteaceæ.

Returning to America, we find in 1868 the two most important contributions yet made in this country to the Cretaceous flora of the west. These were Dr. Newberry's *Notes on the later extinct floras of North America*, published in the Annals of the New York Lyceum of Natural History (April),[22] and Mr. Lesquereux's paper in this Journal[23] for July of the same year. Though prepared quite independently of each other, these two papers followed the same method and reached the same results. Both authors give lists of the American Cretaceous species known up to that date, Dr. Newberry enumerating 20 and Mr. Lesquereux 21 Dicotyledons. The number of species described

[19] Verhandl. d. schweiz. Gesellsch. d. Naturf. Zurich, 1866.

[20] Die Kreideflora von Niederschoena in Sachsen, ein Beitrag zur Kenntniss der ältesten Dicotyledonengewächse, von Const. Freih. v. Ettingshausen. Sitzb. lv, Abth. 1, pp. 235–264, Taf. i–iii.

[21] Kreidepflanzen aus Oesterreich, von Dr. F. Unger, l. c. pp. 642–654, Taf. i, ii.

[22] The figures corresponding in the main to the species here described were published in separate form by the U. S. G. and G. Survey of the Territories, F. V. Hayden, Geologist-in-charge, under the title: "Illustrations of Cretaceous and Tertiary Plants of the Western Territories of the United States," which did not appear until 1878.

[23] On some Cretaceous fossil Plants from Nebraska, by L. Lesquereux. Am. Journ. Sci., II, xlvi, 1868, pp. 91–105.

by Dr. Newberry as new was 45, and the number by Mr. Lesquereux was 47. Nine species from Fort Ellsworth, Kansas, included in Mr. Lesquereux's list, the descriptions of which did not appear until the following year,[24] do not enter into the figures above given. It will thus be seen that about seventy-five species of Dicotyledons had been described from the Dakota Group and other American Cretaceous strata down to the year 1869.

Far less could be said for Europe at this date. Hosius,[25] in 1869, was able to enumerate in his *Geognosie Westfalens* twenty-five characteristic species of the Quadersandstein, which had been described and figured either by Von der Marck[26] or by himself.[27] In this year, too, Heer published his *Fossil Flora of Moletein in Mähren*, which belongs to the lower Quadersandstein, or base of the Cenomanian. Twelve species are described and carefully figured.

In Hayden's annual reports of the geological survey of the Territories for 1870 and 1871[29] Lesquereux continues to enlarge the list of American species, and in 1872, Heer,[30] in his *Fossil Flora of Quedlinburg* makes further additions to that of Europe.

We are thus brought down to the year 1874, which is marked by three very important publications.

Schimper's *Traité de Paléontologie Végétale* was completed in that year, in the fourth volume[31] of which 109 species of Cretaceous Dicotyledons are recognized. Of these 46 are American, which shows that the author was far behind in the literature of the subject. He also expresses serious doubts as to the Cretaceous age of these plants, although this had been long settled here beyond a peradventure.

Next should be mentioned Heer's *Kreideflora der Arctischen Zone*, which appeared in 1874 in volume three of his *Flora Fossilis Artica.* In this work he describes one solitary dicotyledonous species (*Populus primæva*) in the schists of Kome—Urgonian—by far the most ancient form thus far met with, and 33 species in the higher strata of Atane, which are now gener-

[24] On fossil leaves from Fort Ellsworth, Nebraska. Transactions of the American Philosophical Society, Philadelphia, vol. xiii, new series, pp. 430–433, pl. xxiii.

[25] Die in der Westfälischen Kreideformation vorkommenden Pflanzenreste (Beiträge zur Geognosie Westfalens), von A. Hosius. Münster, 1869.

[26] Fossile . . . Pflanzen aus dem Plattenkalk von Sendenhorst. Palæontographica, xi, 1865.

[27] Ueber einige Dicotyledonen der westfälischen Kreideformation, Palæontographica, xvii, 2, pp. 89–104, Taf. xii–xvii.

[28] Beiträge zur Kreideflora. I. Flora von Moletein in Mähren. Zurich, 1869.

[29] On the fossil plants of the Cretaceous and Tertiary formations of Kansas and Nebraska, Ann. Rep. 1870, p. 370. Fossil Flora, Cretaceous Strata, Kansas. Ann. Rep. 1871, p. 301.

[30] Beiträge zur Kreideflora. II. Zur Kreideflora von Quedlinburg.

[31] Pp. 677–679.

ally believed to correspond with the Cenomanian of Europe. These researches of Heer appeared too late to be embodied in Schimper's great work.

Finally, as crowning this fruitful year's labor, appeared Mr. Lesquereux's important quarto volume on the "Cretaceous Flora of the Western Territories,"[32] reviewing the results of all previous researches in this country, and describing and illustrating 107 species of American Cretaceous Dicotyledons. In Hayden's annual report for the same year[33] 26 species are described and some figured, but most of these were also more fully treated in the *Cretaceous Flora.*

During the succeeding six years little activity was manifested in this field, the attention of paleobotanists being principally directed to the floras of later formations, but in 1880 Hosius and Von der Marck published in the *Palæontographica*[34] their *Flora der westfälischen Kreideformation*, an important work reviewing the entire Cretaceous flora of Westphalia. Although fossil plants had been found throughout almost the entire Cretaceous series as there represented, still it was only in the Senonian that any Dicotyledons were detected. At two quite distinct horizons within the Senonian such plants were found, 37 species being credited to the upper and 24 to the lower Senonian, or 61 species.

Quite an important paper by Dr. Debey appeared in 1881[39] describing certain very interesting querciform leaves from the sands of Aix-la-Chapelle. Fifteen species are described and well illustrated, all of which are referred to *Dryophyllum*, a genus founded long ago by Debey on unpublished material and to which Saporta refers four of the forms from the travertines of Sézanne. It had been announced[40] that Debey had collected in the vicinity of Aix-la-Chapelle no less than two hundred species of dicotyledonous plants, and it is to be hoped that this paper may form a beginning, at least, of the much-needed work of acquainting vegetable paleontologists with the nature of this remarkable flora.

The sixth volume of Heer's *Flora Fossilis Artica* appeared in 1882. In this the Cretaceous flora of Kome and Atane are reviewed with fresh materials. While unable to find any com-

[32] Contributions to the Fossil Flora of the Western Territories, Part I. The Cretaceous Flora. By L. Lesquereux, being Report of the U. S. Geological Survey of the Territories, F. V. Hayden, Geologist-in-charge, vol. vi. Washington, 1874.

[33] Pp. 271–365, pl. i–viii.

[34] Vol. xxvi, 1880.

[39] Sur les feuilles querciformes des sables d' Aix-la-Chapelle, par M. Debey. Bruxelles, 1881. (Compte rendu du Congrès de botanique et d' horticulture, 1880.)

[40] Schimper, Traité de Paléontologie Végétale, Paris, 1869–1874. Tome iii, pp. 671, 673.

panions for the solitary *Populus* of Kome, he adds largely to the dicotyledonous flora of Atane. From 33 species in 1874 this flora now rises to 95. In the seventh volume of the same work, which unfortunately must now be the last, a new Cretaceous flora is announced, that of Patoot, also in Greenland, which is regarded as extreme upper Cretaceous. Dicotyledons here abound and no less than 74 species are made known in Heer's work.

Within the past few months an important paper has been contributed to the Royal Society of Canada by Principal Dawson,[35] in which 30 species, mostly new, from two distinct horizons of the Cretaceous of British Columbia are described and figured.

Lastly I am able to add to this enumeration one of the most important works that has ever been produced on vegetable paleontology, but which is still unpublished, though now ready for the press. I refer to Mr. Lesquereux's *Cretaceous and Tertiary Floras*, which is to form the eighth volume of the series of quartos of the U. S. Geological Survey of the Territories in charge of Dr. F. V. Hayden. In this work the author again exhaustively reviews the entire subject of the American Cretaceous flora, and we find the number of Dicotyledons thus far yielded by the Dakota Group to have reached 167. In his table of distribution he attempts to embrace the flora of the entire Cenomanian formation, to which he doubtless rightly believes our Dakota Group to belong. The total number of Dicotyledons thus marshaled is 312. Large as these figures seem, there is much reason to believe that they fall in both cases considerably below the actual state of science at the present time; as will be seen by the tabular statement given below.

If we now turn from this strictly chronological enumeration to a consideration of the stratigraphical position in which these plants have been found, as indicating their relative age, we shall find the results no less interesting than is the history of their discovery.

The various countries of the globe where geology is studied have adopted divisions for their geological formations corresponding to the character of the rocks in each country. These divisions cannot be made to harmonize with exactness when it is sought to compare widely separated regions. The attempt here made to correlate the sub-divisions of the European, Arctic and North American Cretaceous can therefore at best only lay claim to approximate accuracy.

[35] Transactions, pp. 15–34, pl. i–viii.

The Quadersandstein of Germany, in which the greater part of the European fossil plants have been found, is an extensive formation, reaching in Saxony and Bohemia from the lower Cenomanian to the White Chalk, or upper Senonian. Its middle portion is occupied by the Pläner sandstone and Pläner marls, which extend downward into the upper Cenomanian and upward to the base of the Senonian. The somewhat local character and indefinite boundaries of the Quader formations have rendered it customary on the Continent, even with German geologists, to adopt the system of d'Orbigny as now modified and to speak of the Cenomanian, Turonian and Senonian instead of Lower Quader, Pläner and Upper Quader, and it is also now common to apply these terms to formations in other parts of the world which are supposed to occupy the same stratigraphical positions.

The leading European localities from which Cretaceous Dicotyledons have been collected are: Saxony (Niederschöna), Moravia (Moletein), Bohemia (Trziblitz, Perutz), Silesia (Oppeln, Tiefenfurth), the Harz district (Blankenburg, Quedlinburg), Westphalia (Legden, Sendenhorst), and the vicinity of Aix-la-Chapelle. The first four of these localities belong to the lower Quadersandstein, or Cenomanian, that of Niederschöna lying near its base. The Cretaceous of the Harz district is probably lower Senonian. In Westphalia, Hosius and Von der Marck find fossil Dicotyledons at two different horizons, both of which, however, they place in the Senonian. The region about Legden, Ahaus, Haltern, etc., is regarded as lower Senonian, while Sendenhorst, Haldem, etc., are said to be upper Senonian. The iron-sand near Aix-la-Chapelle is probably still higher and occupies the extreme upper Senonian.

The next greatest source, outside of the United States, of the class of fossils under consideration is Greenland. The Kome beds, as already remarked, are distinctly fixed in the Urgonian, which is lower Cretaceous, and lies between the Neocomian and the Gault. The discovery of a dicotyledonous plant at this horizon is one of the most interesting facts of paleontological science. The beds of Atane, where the greater part of the species were found, although called upper Cretaceous by Heer, are admitted by him to exhibit in their fossil remains so close a relationship with the American Dakota Group as to render it probable that they are of the same age. Patoot, on the other hand, is set down as extreme upper Cretaceous, and Heer says that its invertebrate fauna indicate its identity with the Fox Hills of our Western Territories.

The localities in British Columbia from which Cretaceous Dicotyledons have come are all regarded by the Canadian geologists as upper Cretaceous. The inland portions, situated on the Pine and Peace rivers, are said by Dr. Dawson to correspond to the Niobrara of the northwestern United States, which he also correlates with the lower Senonian of Europe. Vancouver's Island and the localities on the Pacific coast are higher and are placed in the upper Senonian, though he does not correlate them with any of the groups of American geologists. Fossil plants were found on the Bow and Belly river which is said to agree with the Pierre Group but the dicotyledonous remains appear to have been indistinct and indeterminable.

With the exception of the Dakota Group, which is commonly regarded as Cenomanian, and in which such a profusion of dicotyledonous vegetation is embedded, no fossil plants have thus far been described from the Cretaceous of the western Territories. Nevertheless, I have myself collected and brought to Washington the past season some dicotyledonous leaves from a locality on the upper Missouri river some seven miles below Coal Banks, whose position is fixed with certainty in the Fort Pierre Group, No. 4 of Meek and Hayden, which Dr. C. A. White regards as merely forming the lower portion of the Fox Hills. The material thus obtained, though meager and fragmentary, is sufficient to render it quite certain that we here have forms nearly allied to *Platanus latiloba* of Newberry (*Sassafras mirabile* Lesqx.) and perhaps connecting this with *Platanus nobilis* Newby., from the Laramie strata that overlie these beds, as well as forms resembling *Quercus salicifolia* Newby., and other Cretaceous genera and species. There is therefore ground for hoping that when this and other similar localities are thoroughly studied a new Cretaceous flora may come to light in the northwest.

I have in this paper intentionally omitted all consideration of the great Laramie group although this is regarded by many as Cretaceous. This is because it seems at least to be more recent than any of the European, Arctic or British American plant-bearing beds, while its abundant flora consists in large part of types represented in the Miocene of Europe.

It thus appears that throughout both hemispheres the conditions required for the preservation of vegetable remains in Cretaceous time have existed in a marked degree during two epochs only, the Cenomanian and the Senonian, separated from each other by a period, perhaps equal to either, during which marine forms of animal life are chiefly found. A few Dicotyledons only occur in the Turonian of Europe, as e.g. *Magnolia telonnensis* from Toulon, while the Colorado Group (Fort Benton, Niobrara) of our Western Territories has thus far proved destitute of plant life.

If now we take up the several subdivisions of the Cretaceous formation in their stratigraphical order, beginning with the lowest, we shall see that in the Neocomian, or lowest member, no plant remains of the sub-class we have been studying have as yet ever been detected.[36]

In the Urgonian, or next higher group, one species, *Populus primæva* Heer, has been collected at Pattorfik in Greenland. In volume vi of his *Flora Fossilis Arctica*, which appeared in 1882, or eight years subsequent to the original description of this plant, Heer continued to adhere to this species as well as to its anomalous stratigraphical position.

The Gault, like the Neocomian, has thus far furnished no Dicotyledons, though not always destitute of plant remains.[37]

It is with the Cenomanian that there seems to have burst in upon the world a great and luxuriant dicotyledonous vegetation. It is found alike in Saxony, Bohemia, Silesia, in Greenland and in the western United States. Upwards of three hundred and fifty species, representing all three of the divisions of the sub-class (*Apetalæ*, *Polypetalæ*, *Gamopatelæ*), and consisting chiefly of living genera have been described.

It was formerly supposed that the beds at Blankenburg occupied a much lower position than that to which I have assigned them, and such as would place them in the Turonian, at least, if not in the Cenomanian, and Mr. Lesquereux, in the large and important work which is about to appear,[38] includes the species of Heer's Quedlinburg Flora in his table of distribution of the Cenomanian. It is now quite certain, however, that the Cretaceous of the Harz district is much higher, and authorities seem to agree in placing it in the lower Senonian. On the other hand the upper boundaries of the Cenomanian in France and elsewhere are somewhat imperfectly established. For this and other reasons I have felt justified in relegating the few species that have been classed as Turonian to the Cenomanian, of which great group they seem to be but straggling outliers.

In the Senonian, both in Europe and in British Columbia, two quite distinct horizons for fossil plants seem to occur, separated from each other by a considerable interval. In view of this I have attempted to divide this group into two horizons and am thus able to show the lower and upper Senonian separately. From the lower Senonian we have about eighty species and from the upper about one hundred and eighty.

36 The supposed Neocomian Dicotyledons of Russia (Eichwald, Lethæa rossica, ii, pp. 58 et seq.) are shown by Heer (Fl. foss. arct. iii, Theil 2, S. 26) to come from the lower Senonian corresponding to the Harz district.

37 Heer assigns the plant-beds of Spitzbergen to the Gault (l. c. S. 24), and Coemans finds nine new spacies of fossil plants in the Cretaceous of Hainaut (Mém. de l'acad. Royale de Belgique, xxxvi, 1867) which Briart and Cornet (l. c. xxxiii, p. 46) placed in the Gault.

38 Cretaceous and Tertiary Floras. Report of the U. S. Geol. Survey of the Territories, vol. viii. Washington, 1883.

The following table exhibits the number of dicotyledonous species thus far recognized in each of the groups of the Cretaceous for the four principal geographical areas within which they have been collected :

Cretaceous Dicotyledons.

Geological Position.	Europe.	Greenland.	British America.	United States.	Total.
Upper Senonian	81	74	24	--	179
Lower Senonian	67	--	14	--	81
Turonian	--	--	--	--	--
Cenomanian }	53	114			351
Dakota Group }	--	--	--	184	
Gault.	--	--	--	--	--
Urgonian	--	1	--	--	1
Neocomian.	--	--	--	--	--
Total	201	189	38	184	612

As all the plants with which we are here concerned are found in the Cretaceous some may be surprised that this paper should have been entitled *Mesozoic* rather than *Cretaceous* Dicotyledons. The reason for the title chosen is simply that it may tend somewhat to enlarge the view of the true history and age of this great type of vegetation. When we see that more than three hundred and fifty species of fully developed Dicotyledons, implying the existence of many more, were flourishing in all their present luxuriance in the middle Cretaceous, and that even in the lower Cretaceous one species is known to have existed belonging to a genus that still survives, we cannot if we would, repress the thought that the ancestors of these forms must have come down through older periods of the Mesozoic.

That we shall ever discover the true progenitors of the known Dicotyledons it is, of course, impossible to say, but that they had progenitors science no more hesitates to assume than any one would hesitate to assume that a foundling child must have had parents. Moreover, such is the slow and secular character of the development of living forms on the globe that no one would suppose it possible for so prominent a group of plants as were the Dicotyledons in the Cenomanian age to have attained that condition in anything short of a vast geologic period.

It is to be hoped that we are at last approaching the beginning, at least, of a solution of this truly great problem of the origin of the Dicotyledons. I have myself seen at least one slight, it may be, but very interesting sign of possible progress in this direction. Certain quite defective, but very instructive, specimens collected in the upper Jurassic of Virginia by Professor Wm. M. Fontaine, and which he kindly brought to

Washington for my inspection, certainly possess all the essential elements of dicotyledonous leaves, although at the same time bearing a certain recognizable stamp of the cryptogamic and gymnospermous vegetation that characterizes that earlier age. What is to be the final verdict of science upon these forms cannot now be told, but it is to be hoped that the Mesozoic strata, not only in Virginia, but in all parts of the world may be diligently searched and the materials carefully studied, with a view to discovering these certainly merely "missing links" of a chain that can but have been once complete.

It is remarkable that both in its flora and its fauna the life of this continent has been thus abruptly truncated. The sudden irruption of a perfectly developed mammalian fauna at the beginning of the Tertiary is not less astonishing than the appearance unannounced of many hundreds of species of highly organized dicotyledonous plants in the middle Cretaceous. The advocates of special creation, and likewise the hunters after a lost Atlantis, were they informed upon the facts which science itself so plainly teaches, could ask no stronger argument for either of their positions. But such persons are usually not so informed, and it seems almost impossible for them to become so and still hold such views, for, fortunately, knowledge is a poison that contains its own antidote, and the very possession of the facts suffices to preclude a perverse use of them.

ART. XXXIV.—*On the Tourmaline and Associated Minerals of Auburn, Maine;* by GEORGE F. KUNZ.

[Read before the American Association for the Advancement of Science, at Minneapolis, August, 1883.]

IN 1868, the Rev. Luther Hills called attention to a specimen of tourmaline found by Mr. G. C. Hatch on the farm of the latter. At this time some work was done, but only one crystal being found, which was cut into a fine 2 kt. light green gem, the locality was abandoned on the ground that the deposit was probably a superficial one. (See The Tourmaline, by Dr. A. C. Hamlin, pp. 72, 73). After this considerable searching was made and some blasting was done, and in 1883, Mr. N. H. Perry, of South Paris, found the tourmaline in place. The locality is Mount Apatite, which is about four miles north of west of the cities of Lewiston and Auburn, Maine. The work to date, [January, 1884,] has all been carried on in a space twenty by eight feet, and to a depth of eight feet. Nearly 1500 crystals have been found, from very small ones 10^{mm} to the largest one 105^{mm} long. They differ in general appearance from the other Maine tourmalines, and are as a rule somewhat lighter in color and of more brilliant polish. They are found colorless, light pink, light blue, light puce colored, bluish pink, and light green, and at times nearly all these colors are found in one crystal. As a rule sections show the characteristic variety of color, such as blue and pink, green and pink, colorless and green or pink, or bluish, when viewed through the length of the crystal. Some of the faintly colored crystals afforded gems that deepened very much in color after cutting.

The crystals are generally hemimorphic, terminated with a modified pink cap at one end, and at the other with a basal termination which is often white, and either loose in the cavities, or else on, and oftentimes penetrating, smoky quartz and feldspar. The majority of the crystals were more or less flawed. Faces commonly observed are: O, R, $-\frac{1}{2}$, I, i-2.

Lepidolite was found in some abundance, in distinct isolated hexagonal crystals implanted in layers on masses of this mineral, or on crystals of quartz and feldspar. Although not sharply enough defined for good measurements, they are the finest crystals of this mineral that I have as yet observed from any locality. In size they vary from 1^{mm} to 8^{mm} in width, and from 1^{mm} to 15^{mm} in length, and large masses of parts of crystals 30^{mm} to 40^{mm} in width have been observed.

The *apatite* is finer in color and form than any as yet observed at any American locality. It occurs light pink, purple, light blue, blue-green and green, and the luster and transparency are so perfect as to resemble at times the tourmaline found with it. Some were sold as gems by the enthusiastic local collectors, although the softness renders it unfit for that purpose. Faces observed commonly, are O, $\frac{1}{2}$, 1, 1-2, 2-2, I, i-2. The crystals occur singly or in small groups, and vary in size from 1^{mm} to 15^{mm} in length, and from 1^{mm} to 20^{mm} in width.

The *quartz* occurs in crystals which are smoky in color and nearly 200^{mm} long. These and nearly all the crystallized quartz here are capped or coated with a white opaque coating, and the large quartz crystals are at times penetrated by the colored tourmalines.

The *albite*, which resembles the cleavelandite, of Chesterfield, Mass., occurs here in abundance, in plates piled together and forming irregular and triangular spaces. In these spaces and on the sides of the crystals are found implanted nearly all the minerals described.

The other associated minerals are orthoclase, beryl, garnet, cassiterite, gummite, autunite, muscovite, leucopyrite, cookeite, biotite, amblygonite, zircon and a mixture of orthoclase and quartz forming a graphic granite.

To Mr. N. H. Perry much credit is due for his care and zeal in developing this locality, and I am indebted to him for his kindness in furnishing all the information at his command, and for loaning specimens without obligation to purchase.

August, 1883.

ART. XXXV.—*On Andalusite from Gorham, Maine*; by George F. Kunz.

[Read before the American Association for the Advancement of Science, August, 1883.]

At Gorham, Maine, on the shores of Sebago Lake, some excavating was done for a road about one year ago, and in a mass of rock thrown out in blasting, Mr. Hayden, of Raymond, Maine, found the specimens of andalusite now exhibited. These crystals, for perfection, color and size, are equal to those found at any known locality where this mineral does not occur in gem form. The color is mostly a brownish flesh tint and at times the pink hue fades to a faint grayish pink. The crystals are opaque but translucent in pieces of from 3^{mm} to 5^{mm} in thickness. A broken crystal measured 90^{mm} (a), 53^{mm} (b), 48^{mm} (c). Several measured over 80^{mm} in length, and one fragment of a large crystal measured 55^{mm} on one face, and may have measured originally over 70^{mm} on the prism. Some crystals are very small, being 1^{mm} in diameter. The specific gravity was as follows: of No. 1, 3·2, of No. 2, 3·4. The hardness on the side of the prism is from 6 to 6·5, on the O plane about 7·5.

The crystals consist of a simple orthorhombic prism with the O plane largely developed; the other faces have not been fully determined as yet, but are possibly $1\text{-}\breve{\imath}$ and $1\text{-}\bar{\imath}$. They occur in a quartzyte vein in a mica schist of a brown color, scattered through which are beautiful small crystals of pyrrhotite. These which I exhibit and a few fragments are all that have been found as yet in the locality. A hasty visit to the place failed to bring to light any more specimens, the rock having been thrown into the excavation and all traces of the mineral thus obliterated. More attention paid to this locality would probably repay the mineralogist with a good reward.

ART. XXXVI.—*On the White Garnet form Wakefield, Canada;* by GEORGE F. KUNZ.

[Read before the American Association for the Advancement of Science, at the Minneapolis Meeting, August, 1883.]

AT McBride's, Lot 7, Range 1, Township of Wakefield, 21 miles north of Hull on the right bank of the Gatineau River, Canada, there have been found some remarkable white garnets. This occurrence has been known to a number of collectors for some years, but as yet little information regarding it has been published. On visiting the locality I found that the garnets occur in a vein from several inches to over one foot in width in the crystalline magnesian limestone, and I traced the vein east and west a distance of over 75 feet. This vein has been followed to the depth of more than six feet. The crystals vary in size from 1^{mm} to 80^{mm} in diameter and in color from colorless to yellow and brown; some of them are transparent enough to yield small gems. The brown color is very often the result of the oxidation of the associated pyrrhotite. The form is that of a dodecahedron, either alone or modified by the trapezohedron 2-2.

Associated with the garnet are crystals of pyrrhotite and fine crystals of a white pyroxene, the adhering crystals being held together sufficiently by the pyroxene to form fine groups of this mineral when the limestone has been removed by acid. Perfect isolated crystals are very uncommon. Determinations of the specific gravity of the mineral gave 3·6002 and 3·5948; of the Orford garnet 3·52 and 3·53. An analysis of the garnet by C. Bullman, Ph.B., yielded the following results:

Silica	38·80
Alumina	22·66
Sesquioxide of iron	1·75
Oxide of manganese	·3
Lime	35·
Magnesia	·68
	99·19

The spectroscope gave no potassium lines, soda was not determined.

An analysis of white garnet from Orford, Canada, by T. Sterry Hunt (see Geological Survey of Canada, p. 496), gave

SiO_2	Al_2O_3	CaO	MgO	FeO, MnO	Na_2O, K_2O	ign
38·60	22·71	34·83	0·49	1·60	0·47	1·10=99·80

ART. XXXVII.—*Horizontal Motions of small Floating Bodies in relation to the Validity of the Postulates of the Theory of Capillarity;* by JOHN LECONTE.

THAT my attempt to refer the phenomena of the horizontal motions of small floating bodies under the action of capillary forces, "exclusively to the elastic reactions of the tense surface film, whose form is modified by the proximity of the partly immersed solid bodies,"* should not have commanded the assent of many physicists, was to have been expected. The imperfections and shortcomings of my explanation of this class of phenomena in relation to the accepted theory of capillarity, as pointed out in the articles of Mr. J. T. Riley and Mr. A. M. Worthington,† served to fix my attention on the difficulties and ambiguities which invest one of the most obscure and unsatisfactory points in molecular mechanics. The still more recent discussions of Laplace's "Theory of Capillarity" by Lord Rayleigh and by Mr. Worthington,‡ afford glaring illustrations of the perplexities which environ the mathematical theory of this class of phenomena.

A more careful and somewhat prolonged consideration of these difficulties has led me to question the *validity* of one or more of the *fundamental postulates* of the generally accepted physical theory of capillarity, and to seek for a solution of some of these perplexities in the erroneous assumptions.

These *postulates*, as enunciated by the late Prof. J. Clerk-Maxwell (*Encyc. Britannica*, ninth edition, Article "Capillary Action"), may be stated as follows:

1. "For any given liquid surface, as the surface which separates water from air, or oil from water, the surface-tension is the same at every point of the surface and in every direction. It is also practically independent of the curvature of the surface, although it appears from the mathematical theory that there is a slight increase of tension where the mean curvature of the surface is concave, and a slight diminution where it is convex. The amount of this increase and diminution is too small to be directly measured." Moreover, tense liquid films "act like a sheet of india-rubber when extended, both in length and breadth, that is, it must exert surface-tension. The tension of the sheet of india-rubber, however, depends on the extent to which it is stretched, and may be different in different directions; whereas, the tension of the surface of a liquid remains the

* This Journal, III, vol. xxiv, pp. 416–425, December, 1882. Also Phil. Mag., V, vol. xv, pp. 47–56, January, 1883.

† Phil. Mag., for March, 1883, p. 191 et p. 198.

‡ Phil. Mag., for October and November, 1883, p. 309 et p. 339.

same however much the film is extended, and the tension at any point is the same in all directions."

2. It is generally assumed that Young's law of the constancy of the angle of contact between the surface of any given liquid and a given solid, obtains under the same conditions of cleanness and of temperature; and notably in all cases in which the surface of the solid has been well wetted with the liquid.

These constitute the *essential postulates*, so far as the mathematical theory relates to the *surface-tension* of liquid films as the physical cause of capillary phenomena. And to this aspect of the subject our attention will be restricted.

The admirable mathematical researches of Laplace in relation to this intricate problem in molecular mechanics, confirmed as they were, in all essential features, by the more refined analytical investigations by Gauss, of Poisson, and of Hagen, seemed to have long satisfied physicists that the mathematical theory of capillarity fully accounted for all the observed phenomena. The discrepancies between theory and experiment brought prominently to notice by the careful experiments of M. Simon (of Metz),* confirmed as they have been by the experimental researches of Bède,—do not seem to have disturbed confidence in the essential validity of the fundamental principles of the physical theory. And the still more glaring inconsistencies of the theory, revealed in the remarkable posthumous memoir of M. G. Wertheim,† do not seem to have attracted the attention which they deserve. The results obtained by the last mentioned experimenter, Prof. J. P. Nichol‡ regards as invalidating the basis of the mathematical theory, and he maintains that the whole subject needs to be re-investigated under a fuller and wider view of the conditions of the physical problem.

Indeed, it is very evident, that notwithstanding the classical researches of Laplace, Gauss and Poisson, and the more recent investigations of Dupré and Maxwell, the mathematical theory of capillarity presents difficulties which have not yet been fully surmounted. In common with many other problems in molecular physics, we here encounter difficulties and uncertainties originating in the different physical interpretations of the mathematical processes and their results. They involve the consideration of the true signification of mathematical results which are known to have been reached by processes which are *not rigorously exact.* Many of the differential equations are utterly unmanageable and incapable of integration unless certain *assumptions* are made. Hence questions arise in relation

* Ann. de Chim. et de Phys., III, vol. xxxii, pp. 5–41, 1851.
† Ann. de Chim. et de Phys., III, vol. lxiii, pp. 129–201, 1861.
‡ Cyc. of the Physical Sciences, Article "Capillarity," Third Edition, 1868.

to the warrantableness of such assumptions in particular cases. In short, we plunge into the quicksands of partial differential equations, of discontinuous functions and of integrals containing arbitrary functions, the arbitrariness of which has a signification in the applications of the functions to physical questions.

In the mathematical theory of capillarity, the integration of the fundamental differential equations is only capable of being effected in certain particular cases, so that experimental verification has been confined within very narrow limits. Beyond these restricted boundaries we are virtually deprived of the assistance of those wonder-working mathematical symbols whose brief logic speaks so convincingly to the human intellect. For, it must be borne in mind, that in problems of this character, no deduction from analysis is worthy of confidence which does not admit of a rational physical interpretation, capable of being tested by observation or experiment.

Restricting myself to the consideration of the physical cause of the horizontal motions of small floating bodies when brought near to one another, it is evident that if the surface tension is precisely the same in all parts of the liquid surface and is not at all modified by the formation of the adjacent meniscuses,—and further, if the angle of contact of the liquid with the solid remains constant—the horizontal as well as the vertical component of the elastic reaction of the intervening tense film must be independent of its radius of curvature. Now, the question is, are these two conditions or postulates realized in the class of phenomena under consideration? Some physicists have thought it possible that the angle of contact might vary with the curvature of the film adjacent to the wall of the solid; but the invariability of this angle, at least in the case of liquids which wet the surfaces of the solids,—seems to be generally admitted, as verified by numerous experiments, provided the temperature remains the same.

But the postulate that, at a given temperature, the surface-tension of a given liquid film is independent of the radius of curvature, is by no means certain. On the contrary, there are a number of capillary phenomena, which seem to point to a much more complete analogy between the reaction of a tense elastic film of liquid and that of an extended sheet of india-rubber, than is indicated by Prof. Maxwell in the postulate. Indeed, they seem to render it almost certain that, like the extended sheet of india rubber, the tension of the surface film of the liquid depends upon the extent to which it is stretched; and consequently, that when the film becomes, from any cause, sharply *curved*, the tension is really augmented.

In fact, the assumption of the constancy of the tension of liquid films at given temperatures, under all conditions of extension and curvature, is evidently a mathematical deduction from Jurin's experimental law in relation to the elevation or depression of liquids in tubes and between parallel plates. Now, it is well known, that this law is very far from being experimentally verified for tubes of moderately large diameters and for parallel plates at considerable distances apart. In other terms, the constancy of the tension of liquid films is approximately verified by such experiments, only when the radius of curvature is very small.

Now, in the class of phenomena under consideration, the radii of curvature of the meniscuses are not very small. The movements of the floating bodies are observed to take place when they are more than two centimeters distant. The question of fact to be decided is, do the tensions of the external and internal meniscuses change with the alteration of the curvature of the united intervening meniscus due to the proximity of the partly immersed floating solids? If experiment answers this question in the affirmative, then the horizontal components of the tensile reaction of the exterior and interior meniscuses become unequal, notwithstanding the constancy of the angle of contact of the liquid film with the two sides of each of the floating solids: hence the bodies are urged in the direction of the greater horizontal component due to the change of tension.

Before submitting the experimental evidence in relation to this question, it is proper to indicate more definitely *how* the surface-tension of a liquid film is *measured*. This important capillary *constant*, usually designated by T, is defined by Maxwell,* "either as the surface energy per unit of area, or as the surface-tension per unit of contour, for the numerical values of these two quantities are equal." Hence in the case of a liquid surface in contact with the surface of a solid, the whole surface-tension at the line of contact of the liquid film is equal to T× length of contour in unit lengths.

Assuming the constancy of the angle of contact and the constancy of the surface-tension (T), it is easy to deduce Jurin's law for the elevation or depression of liquids in tubes and between parallel plates; and conversely, to find the numerical value of T, the assumed constant of surface-tension. Thus let

d = diameter of vertical tube,
  and d' = distance between vertical parallel plates.

T = tension per unit-length of contour, for tubes,
  and T′ = tension per unit-length of contour, for parallel plates.

a = angle of contact (constant), for tubes,
  and a = angle of contact (constant), for parallel plates.

* "Encyc. Britannica," Ninth Ed., Article, "Capillary Action."

$w =$ weight of unit-volume of liquid, for tubes,
and $w =$ weight of unit-volume of liquid, for parallel plates.

$h =$ mean height of meniscus above level, for tubes,
and $h' =$ mean height of meniscus above level, for parallel plates.

Then for cylindrical tubes, the whole force exerted at the margin of the surface of the liquid in the interior $= \pi d \times T$; and its vertical component $= \pi d \times T \times \cos a$. This latter must be in equilibrium with the *weight* of the column of liquid elevated or depressed above or below the hydrostatic level. This weight $= \frac{\pi}{4} d^2 \times w \times h$. Hence, equating this force with the vertical component of the tension, we have $\frac{\pi}{4} d^2 \times w \times h = \pi d \times T \times \cos a$ ∴ $h = \frac{4T \times \cos a}{d' \times w}$; which gives Jurin's law of inverse diameters. Similarly, for Parallel Plates, we have, $h' = \frac{2T' \times \cos a}{d' \times w}$. And, as according to the postulate, for any given liquid and solid, we must have $T = T'$, it follows from the above, that when $d = d'$, $h' = \frac{h}{2}$.

From the foregoing equations, expressions for the values of T and T′ can be readily deduced: Thus, we have,

$$T = \frac{h \times d \times w}{4 \cos a}, \text{ and } T' = \frac{h' \times d' \times w}{2 \cos a}.$$

In the case of water in a clean glass tube which has been well wetted with that liquid, the angle a is very generally assumed to be *zero*, that is to say, the interior wall of the tube is tangential to the marginal surface of the meniscus,—so that $\cos a = 1$. This assumption is in the highest degree *improbable;* for, in the case of all liquids which wet the surface of glass tubes, experiment shows, that the value of a depends upon *temperature*. It appears from the experiments of Brünner and of Wolf on the elevation of ether, bisulphide of carbon, oil of naphtha, and alcohol contained in strong capillary glass tubes; that when subjected to high temperatures, each of these liquids was observed to descend with the increase of temperature,—the meniscus becoming less and less concave, and at length the surface of the liquid in the tube becomes *horizontal*, or $a = 90°$. In such cases, doubtless, the value of T likewise undergoes a progressive diminution with augmentation of temperature. In view of the above-indicated experimental results, it is curious to witness the persistency with which the assumption is reiterated by even the best physicists, that the value of a for water in a clean glass tube is *zero*.*

Moreover, even under ordinary conditions of temperature and pressure, the careful experiments of Quincke† prove, that at the temperature of 20° (C.), the actual angle of contact (a) of water with clean glass in the presence of air =25° 32′. However, this factor being constant for any given temperature, its absolute value does not alter the result so far as the experimental test is concerned. For any given liquid at a given temperature, if the postulate, that T or T′ is *invariable*, is true, we should have $\frac{h\times d\times w}{4\times \cos a}=\frac{h'\times d'\times w}{2\times \cos a}=$ Constant. Now, if h and h', and d and d' are measured in centimeters, in the case of water $w=1$ gram weight; so that the formulæ give the values of T and T′ in grams weight per centimeter of contour. Consequently, for water in contact with clean glass, we have

$$\text{T per centimeter of contour} = \frac{h\times d\times 1}{4\cos a}\text{ grams weight.}$$

$$\text{T}'\text{ per centimeter of contour} = \frac{h'\times d'\times 1}{2\cos a}\text{ grams weight.}$$

Now, according to this fundamental postulate of the capillary

* These changes in the values of T and a, due to the influence of *temperature*, are not inconsistent with the remarkable deductions announced by the great geometer Clairaut as early as 1743 (Théorie de la Figure de la Terre. Paris, 1808. pp. 105–128). To show this, let P=molecular attraction of the liquid for itself; p=molecular attraction of the solid for the liquid. Then, Clairaut indicated the following laws: (1) When $p=\frac{P}{2}$, the meniscus is horizontal; (2) When $p>\frac{P}{2}$, the meniscus is concave; (3) When $p<\frac{P}{2}$, the meniscus is convex. Now, in the case of water, alcohol, ether, etc., in contact with clean glass, at ordinary temperatures, $p>\frac{P}{2}$: and assuming that when the temperature augments, the attraction of the solid for the liquid (p) diminishes *faster* than the attraction of the liquid for itself (P); it is evident, that at a certain definite temperature, p must $=\frac{P}{2}$, and consequently, the meniscus becomes horizontal; and at a still *higher* temperature $p<\frac{P}{2}$, and the meniscus becomes convex. The experiments of Brünner and of Wolf have verified these deductions in the case of several liquids which wet glass. On the contrary, in the case of mercury in contact with glass, $p<\frac{P}{2}$; so that, when the temperature augments p becomes still *smaller*, the meniscus increases in convexity and the depression is *augmented*. This last result has been confirmed by the experiments of Frankenheim, who found the depression of mercury in glass tubes to be augmented by increase of temperature.

† Phil. Mag., IV, vol. xli, p. 265, (Table X). 1871. In a later memoir Quincke, (Phil. Mag., V, vol. v, p. 325, 1878,) found this angle (a)=28° 48′ for water in glass capillary tubes. His experiments show that the value of a depends on the *cleanness* of the glass; but it never became *zero*, except under extraordinary circumstances.

theory, these values should be the *same* for the same liquid at the same temperature; and moreover, these values ought to be the same for all variations of h and d, and h' and d' respectively. Finally, as this postulate depends upon the verification of Jurin's law, it follows that the products, $h \times d$ and $h' \times d'$ respectively ought to be *constant* for each pair of the factors; and also, that when $d=d'$, $h' \times d' = \frac{h \times d}{2}$.

These deductions of theory can, unfortunately, *only* be experimentally tested in the case of water in contact with clean glass. In order to make the comparison of the results of theory and experiment, I have computed the following table in which the values of d, h, d' and h' are furnished by the admirable experiments of M. Simon (of Metz).* The value of a is taken, in accordance with Quincke experiments, as $=25° 32'$; but inasmuch as this divisor is assumed to be *constant*, its *absolute* value is of no consequence in the comparison.

Water in Tubes.				Water between Parallel Plates.			
d in millimeters.	h in millimeters.	$h \times d$.	$T=\frac{h \times d}{4 \cos a}$ in grams. percentim. of contour.	d' in millimeters.	h' in millimeters.	$h' \times d'$.	$T'=\frac{h' \times d'}{2 \cos a}$ in grams. percentim. of contour.
25·300	0·019	0·481	0·0013	23·000	0.021	0·49	0·0027
18·000	0·200	3·600	0·0100	18·000	0·062	1·12	0·0062
14·000	0·440	6·160	0·0171	14·000	0·140	1·96	0·0109
8·600	1·510	12·986	0·0360	10·000	0·340	3·40	0·0188
5·400	3·650	19·710	0·0546	5·000	1·250	6·25	0·0346
2·200	12·800	28·160	0·0780	2·090	4·230	8·84	0·0490
1·250	24·000	30·000	0·0831	1·260	7·420	9·35	0·0518
0·570	55·600	31·692	0·0878	0·518	19·300	9·91	0·0549
0·360	89·000	32·040	0·0888	0·404	25·000	10·10	0·0560
0·140	233·000	32·620	0·0904	0·140	73·780	10·33	0·0572
0·050	663·000	33·150	0·0918				
0·025	1333·000	33·325	0·0923				
0·012	2884·000	34·608	0·0959				
0·0061	6828·000	41·651	0·1154				

A glance at the numbers contained in the foregoing table clearly indicates the following conclusions:

1. The numbers in the columns headed $d \times h$ and $d' \times h'$ show that Jurin's law fails to be even approximately verified, when d and d' respectively exceed 0·2 of a centimeter.

2. That when $d=d'$, $d' \times h'$ in all cases falls short of being equal to $\frac{d \times h}{2}$; the ratio of the products, under these condi-

* Ann. de Chim. et de Phys., III, vol. xxxii, pp. 12 et 19, (1851.)

tions, instead of being as 1 to 2, as the theory demands, is more nearly as 1 to π, as pointed out by Simon.

3. The numbers in the columns of T and T′ show that if the angle of contact remains the same, the computed values of the surface-tensions in the cases of tubes and parallel plates, are not constant under variations of d and d' respectively; in fact, they do not even approach constancy until d and d' become respectively less than 0·2 of a centimeter. On the contrary, the values of T and T′ respectively augment with the diminution of d and d'. Thus, a change in the value of d from 1·8 to 1·4 centimeters increases T in the ratio of 100 to 171; and a similar change in d' augments the value of T′ in the ratio of 62 to 109. Again, a change in the value of d' from 1·0 to 0·5 centimeters, increases T′ from 0·0188 to 0·0346 grams per centimeter of contour.*

4. The same columns show, that instead of T being equal to T′ (as required by theory), the former, under the same values of d and d', always exceeds the latter in nearly the ratio of 1·6 to 1, or $\frac{\pi}{2}$ to 1.

In the light of these experimental results, it would almost seem that the somewhat ambiguous expression "superior tension" of the intervening meniscus used by me in my article on the "Apparent Attractions and Repulsions of small Floating Bodies"† (to which exceptions have been justly taken), is, after all, the declaration of a physical reality.

In applying these results of experiment to the explanation of the horizontal motions of small floating bodies, it must be borne in mind that the phenomena under consideration begin to manifest themselves when the bodies are at such distances from one another, that these alterations of surface-tension become comparatively large as their proximity increases. In other terms, we have seen that the value of the surface-tension instead of being constant under all conditions, as the theory of capillarity assumes, is, in reality, an inverse function of the radius of curvature of the meniscus; so that the elastic reaction of the tense liquid film acts unequally on the opposite sides of the floating bodies, and thus becomes the true physical cause of their motions.

Thus far I have considered the phenomena in question as due exclusively to the change in the surface-tension incident to the proximity of the floating solids; but it is evident that a

* The value of the assumed "capillary constant," T, for water given by Quincke 0·08253 grams per centimeter of contour, evidently corresponds to its value in a glass tube whose internal diameter is about 0·15 of a centimeter. In the C. G. S. system this is equivalent to $0·08253 \times g = 80·962$ dynes.

† This Journal, III, vol. xxiv, p. 421, December, 1882.

change in the magnitude of the angle of contact, would likewise produce similar results. It is, *à priori*, by no means improbable that, at the same temperature, there may be some change in this angle with a change in the radius of curvature of the meniscus; but inasmuch as such alterations in this angle could hardly have escaped observation, it seems more probable that the phenomena are due to the changes of surface-tension in portions of the film investing the floating masses.

It is highly desirable that similar comparisons of the results of theory and experiment should be extended to other liquids than water; in other words, Simon's experiments should be repeated with other liquids.

It is not my purpose to supplement my previous article by any further discussion of the difficulties and inconsistencies of the hydrostatic explanation of this class of phenomena:—like Prof. J. D. Everett, I find it difficult to "conceive of negative pressure existing in the interior of a liquid." In this paper I have endeavored to establish the reality of the inequality of the tensile reaction of the liquid film on the opposite sides of the floating bodies when they are brought near to one another. This principle obviously explains the motions in each of the three cases considered in my previous paper; while at the same time, it serves to connect these phenomena with the perplexing capillary movements due to the difference of the surface-tensions of different liquids or of the same liquid in different states, which have engaged the attention of Tomlinson, Van der Mensbrugghe and others. In both classes of phenomena, the motions are obviously due to modifications of the tensile reaction of the surface films in parts that are adjacent to one another.

Berkeley, California, January 15, 1884.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the reduction of Gases to Normal Volume.*—In the ordinary methods of measuring gases, long and tedious calculations are required to reduce the results to normal volume. Kreusler has proposed an apparatus by which these reductions may be much facilitated. It consists of a U-tube, one of whose legs terminates in a funnel and the other in a pipette-like enlargement, this latter ending above in a capillary tube. The gas-vessel thus formed has a capacity of about 50 c.c. actual; but its capacity is called 100 units of volume, and a mark is made on the tube below the bulb, corresponding to this capacity. A graduation based on these units is continued downward as far as is necessary; to 120 in the author's

apparatus. Since the graduation permits a unit to be divided into tenths, each division corresponds to 0·001 of the normal volume of the instrument. The adjustment is made by filling the tube with mercury nearly to the 100 mark, and, as the measurement is generally made on moist gas, adding a layer of water of equal depth on each surface. A calculation is then made to determine the space which 100 units of volume of dry air at the normal temperature and pressure would occupy when moist and under the temperature and pressure shown by the thermometer and barometer at the time of the calculation; and the water meniscus is brought carefully to this exact reading on the scale of the instrument. The capillary tube above is then closed with wax; or after repeated experiments have proved the adjustment correct, it is closed by fusion of the glass. To use the apparatus, the mercury is brought to stand at the same height in both legs of the tube, and the level of the water meniscus is read off; call it v. Then for any volume V of a gas at the same temperature, the volume V_0 dry and at normal pressure is given by the proportion $v : 100 :: V : V_0$; whence $V_0 = V\frac{100}{v}$. By surrounding the bulb with water it may readily be brought to any required temperature. A second form of the apparatus, less exact but smaller and more portable, is described in the paper.—*Ber. Berl. Chem. Ges.*, xvii, 28, Jan., 1884. G. F. B.

2. *On the Influence exerted by the surrounding Gaseous Medium on the Production of Electricity by Induction-machines.*—HEMPEL has studied the effect which varying the gaseous atmosphere surrounding a Töpler machine exerts upon its production of electricity. For this purpose the axis of the machine was made vertical, passing air-tight through an iron table upon which a glass bell to contain the machine, was secured. The useless space in this bell was filled with paraffin. The quantity of electricity was measured by the number of discharges which took place in the air between the poles of the machine from a Leyden jar in circuit, for a given number of turns of the machine. When the machine was enclosed in hydrogen 850 rotations per minute gave 9 discharges from the jar, while in air this number of rotations gave 45 discharges. In carbon dioxide, 850 rotations gave 47 discharges, a portion of the gas being decomposed into carbon monoxide and ozone. With 400 rotations per minute, in air at the ordinary pressure, the machine gave 15 discharges of the jar; while when the pressure was increased to two atmospheres 32 discharges were obtained per minute. On lowering the pressure to half an atmosphere, the jar could not be charged. An attempt to surround the machine with petroleum—a substance of high insulating power—gave no result. The researches are still in progress.—*Ber. Berl. Chem. Ges.*, xvii, 145, Feb., 1884. G. F. B.

3. *On the method employed for cleaning the Liebig Statue.*—On the 6th of November, the marble statue of Liebig, in Maximilian Place, Munich, which had been erected only the previous

August, was found to be covered with black spots and streaks, some miscreant having attempted to disfigure it. At first the dark material was supposed to be only mud, and an attempt was made to wash it off. But finding this of no avail, a commission, consisting of Drs. MAX VON PETTENKOFER, ADOLF BAEYER, and CLEMENS ZIMMERMANN, was entrusted with the matter and empowered to examine the question chemically and devise a method for restoring the statue. On examination about 300 of these black spots, nearly all round and of the size of a hazel-nut, were counted upon the statue itself, fourteen being on the face. The granite base of the monument was similarly stained. On testing one of these spots, formed under one of the feet, the presence of manganese was proved. A streak on the bronze wreath attached to the granite base disappeared when treated with nitric acid, and the solution gave a precipitate with hydrogen chloride which was soluble in ammonia and darkened in the light; thus proving the presence of silver. It therefore appeared that the stains were produced by solutions of silver nitrate and potassium permanganate. Laboratory experiments were then made to devise a method of removing these stains, which penetrated some millimeters into the marble. The process finally determined on was to treat these stains first with yellow ammonium sulphide, in order to convert the silver and the manganese into sulphides, and then with potassium cyanide, in which these sulphides are soluble. Experiments in the laboratory proving satisfactory, the process was tried on the 20th of November, on two stains upon the hand of the statue. A paste was made of fine porcelain clay mixed with ammonium sulphide and applied to these spots, being renewed after 24 hours. The day after, this paste was removed, the stains washed with water and a second paste applied, made with clay and a concentrated solution of potassium cyanide. After four hours the stains appeared fainter; and on renewing the application, not the slightest trace of the stain was observable on the following day. The work was then carried forward uninterruptedly, and on the 13th of December the statue was completely restored to its original purity and beauty; a result confirmed by the authorities on the 22nd in a special announcement.—*Ber. Berl. Chem. Ges.*, xvii, 230, Feb. 1884.
G. F. B.

4. *On the Combustion of the Diamond.*—Having obtained some exceptionally pure and white specimens of diamond, very free from ash, FRIEDEL has submitted them to combustion in a current of oxygen with a view of determining the atomic weight of carbon. The oxygen, prepared from a mixture of copper oxide and potassium chlorate, was passed over heated copper oxide, then through a Liebig potash bulb and a series of U-tubes containing pumice soaked in potash, caustic potash in sticks, pumice moistened with sulphuric acid and phosphoric oxide, the junctions being made without rubber. Bohemian tubes proving too soft at the temperature required, tubes of porcelain were used in the combustion, being heated by a Wiesnegg combustion furnace. The products of com-

bustion passed through two U-tubes containing pumice moistened with sulphuric acid and phosphoric oxide, then through a Liebig potash bulb and a tube with pumice moistened with potassium hydrate, then through a tube with solid potash, and finally through one containing phosphoric oxide. A precisely similar series of tubes was used as a tare. The diamonds were weighed in a platinum boat after heating to low redness. Two blank experiments having established the integrity of the apparatus, two combustions were undertaken. In the first 0·4705 gram of clear white Cape diamonds, in small crystals, were used, and gave 1·7208 grams carbon dioxide. Since the ash weighed 0·0007 gram, the carbon consumed weighed 0·4698 gram. Considering that of oxygen as 16, this gives 12·017 as the atomic weight of carbon. Since this weight of carbon should have given 1·7229 of carbon dioxide, there was a loss of 0·0021 gram. In the second combustion 0·8621 gram of diamond was used and 3·1577 grams of carbon dioxide was obtained. Subtracting the ash 0·0005, there remains for the weight of carbon, 0·8616 gram. This gives 12·007 for the atomic weight. Taking 12 for the atomic weight, the carbon burned should have yielded 3·1592 of CO_2; a loss of 0·0015 gram. The ash consisted of minute white flocks, yellowish in places and showing small black specks, some of which were attracted by the magnet. Others were transparent and acted on polarized light. Certain Brazil diamonds showed nebulous spots of a dark green color, which became brown at the temperature of boiling cadmium; proving that these diamonds were formed at a temperature lower than this.—*Bull. Soc. Ch.*, II, xli, 100, Feb., 1884. G. F. B.

5. *On the behavior of Carbon monoxide toward air and moist Phosphorus.*—The experiments of REMSEN and KAISER, tending to prove that carbon monoxide mixed with air is not oxidized when passed over moist phosphorus, having been questioned by Leeds and Baumann, the former chemists have repeated their experiments, using larger volumes of air and taking all the precautions which further experience suggested. A blank experiment, in which air alone, carefully purified, was passed over moist phosphorus, having shown the production of carbon dioxide, the apparatus was reconstructed with the greatest care so as to exclude organic matter of every kind, the joints being all of ground glass. The air, contained in a gasometer of 30 liters capacity, was passed slowly, two or three bubbles per second, first through a red-hot tube of hard glass containing copper oxide, then through three wash bottles, the first two of which contained caustic soda and the last baryta water, and finally into a bell jar over mercury, within which floated a glass pan containing the phosphorus. From the bell jar the ozonized air passed through two wash bottles, the first containing distilled water and the second baryta water. This latter was protected from the air by a potash tube. The result was precisely the same. Ten liters of air caused a distinct turbidity, and twenty to thirty gave a precipitate. Hence the conclusion of the authors that the carbon dioxide obtained must have

come from carbon contained in the phosphorus used. Though this conclusion was directly established, the quantitative experiments were not satisfactory, owing to the difficulty of regulating the oxidation. Repeating the above experiment with carbon monoxide, no increased production of the dioxide could be detected.—*Ber. Berl. Chem. Ges.*, xvii, 83, Jan., 1884. G. F. B.

6. *On the Temperature obtained by Oxygen in a state of Ebullition, and on the Solidification of Nitrogen;* by M. S. Wroblewski. —Of all the gases formerly regarded as permanent, hydrogen alone showed no sign of liquefaction at the temperature of $-136°$ C. Even when this gas is submitted, at the above temperature, to a pressure of 150 atmospheres, and the pressure is then suddenly removed, no mist is formed in the tube containing the gas. Evidently, in order to liquefy hydrogen, we must employ a lower temperature than the minimum obtainable by means of liquid ethylene allowed to boil in a vacuum. Of the gases which are more difficult to liquefy than ethylene, and which might be used for the production of a much more intense cold, oxygen appeared to me to be the most serviceable.

The conditions under which the liquefaction of oxygen takes place being already ascertained by my previous researches, it follows that this gas can, at the present time, be liquefied in considerable quantities with great ease. Numberless processes and apparatus are conceivable which would allow of this liquefaction being effected in such a manner that the commercial production of liquid oxygen, if I may so express myself, is only a question of material means at the service of the experimenter. Thus since the beginning of October I have used liquid oxygen as a refrigerating agent.

When liquefied in large quantity and allowed to evaporate briskly by the sudden removal of the pressure, oxygen does not solidify like carbonic acid, but it leaves a crystalline residue on the bottom of the vessel in which it was contained in the liquid state and upon the object to be cooled, plunged in the oxygen. I cannot say whether this residue is composed only of crystals of oxygen or whether it arises from possible impurities, since the oxygen which I use in these experiments is prepared from a mixture of potassium chlorate with manganese peroxide. This residue disappears as the temperature commences to rise. If the object to be cooled is contained in a glass tube, the thin layer of this opaque residue is often very troublesome to the observer.

Another circumstance, which renders it very difficult to employ liquid oxygen as a cold-producer, is the necessity of using closed apparatus capable of great resistance. Hitherto I have not been able to obtain oxygen in a stable liquid condition under the pressure of one atmosphere. I have had, in consequence, to place the objects to be cooled in the apparatus, which I fill with liquid oxygen, and I can only avail myself of the cold which the boiling oxygen produces at the moment when the pressure is removed. As these apparatus are in part constructed of glass, great inconvenience results owing to the constant danger of serious explosions.

After several accidents had occurred during these experiments, my assistants and myself, in order to obviate the danger, never worked without masks. But the greatest difficulty to contend with is the short duration of the ebullition of the oxygen, and consequently the too short duration of the cold.

I have attempted to measure the temperature which the boiling oxygen produces. For this purpose I have adopted a method of thermo-electric measurement which, in addition to being highly sensitive, allows us to record all the sudden changes of temperature of the medium. The indications of the apparatus employed have been compared with those of a hydrogen-thermometer between +100° C. and −130° C. The nature of the function connecting these indications admits of an extrapolation being made. Reserving the description of my method for a future communication, I give here *one hundred and eighty-six degrees below zero* (−186° C.) as the first approximation to the temperature which is produced on the liberation from pressure of liquefied oxygen.

I have submitted nitrogen successfully to the action of this cold. This gas compressed, cooled in boiling oxygen, and then slightly released from pressure, solidifies and falls like snow in crystals of remarkable size.—*Comptes Rendus*, Dec. 31, 1883.—*Phil. Mag.*, Feb., 1884.

7. *Diary of a Magnetic Survey of a portion of the Dominion of Canada chiefly in the Northwestern Territories ;* executed in the years 1842–44, by LIEUT. LEFROY, R.A., now GENERAL SIR J. H. LEFROY, C.B., etc., with maps, 192 pp. 8vo. London, 1883. (Longmans, Green & Co.).—The magnetic observations made by Lieutenant Lefroy in the years 1842–44 have been, since their publication in Sabine's Contributions to Terrestrial Magnetism (Phil. Trans. 1846), the principal authority for the accepted positions of the isogonic, isoclinic and isodynamic lines over most of British America as well as for the position of the north magnetic pole. Their author has now performed an important service to this branch of physical science in presenting these observations in convenient form, and with all the fulness of personal explanation which future observers in the same region could ask for. The body of the volume consists of a diary of the series of observations made in the Northwest at 314 stations, extending west to the Peace River and north to Fort Good Hope on the Mackenzie. In addition, the preliminary observations made in Canada and the United States are also given. The discussion of the instruments employed, of the variation in the magnetic elements observed and of other points, adds interest and value to the volume. Four large maps give the positions of the magnetic lines for the same epoch over the region covered by Lieutenant Lefroy, in preparing which observations by Captain R. W. Haig, Captain T. E. L. Moore and some others have been included.

8. *Notes on Electricity and Magnetism*, designed as a companion to Silvanus P. Thompson's Elementary Lessons by J. B. MURDOCK. 139 pp. 16mo. New York, 1884. (Macmillan & Co.).—

Lieutenant Murdock gives in this little volume a series of class-room notes, supplementary to the excellent text book of Professor Thompson; they will be of material assistance to the many teachers who use and appreciate the value of the latter work.

9. *The Relative Proportions of the Steam Engine*, being a rational and practical discussion of the dimensions of every detail of the steam engine; by WILLIAM DENNIS MARKS. Second edition, revised and enlarged. 215 pp. Philadelphia, 1884 (J. B. Lippincott & Co.).—This volume by Professor Marks is an admirable one, useful alike to the student and to the practical engineer. In this new edition three additional lectures are given upon the following subjects: the limitation of the steam engine; the cheapest point of cut-off; the errors of the Zeuner valve-diagram.

10. *Ueber den Polabstand, den Inductions und Temperatur-coefficient eines Magnetes und über die Bestimmung von Trägheitsmomenten durch Bifilarsuspension.* — Messrs. W. HALLOCK and F. KOHLRAUSCH have recently contributed to the Society at Göttingen a brief account of some experiments undertaken to determine the polar distances of a magnet, the coefficient of induction and temperature, and the moment of inertia as given by the method of bifilar suspension. The complete memoir will be published later.

II. GEOLOGY AND NATURAL HISTORY.

1. *Paleontological similarity of the East-American Acadian and Potsdam groups.*—Mr. R. P. WHITFIELD, in a paper on new Primordial fossils, contained in the American Museum, of New York, published in Bulletin No. 5 of the Museum, expresses the opinion that the Potsdam sandstone is not yet proved to be of a different geological horizon from that of the other Atlantic Primordial areas, or of those of the Mississippi valley. The New Brunswick and Massachusetts localities afford the *Paradoxides* type of trilobite; but, he remarks, this is not necessarily a consequence of difference in time. Looking to the other fossils, the facies of the New Brunswick fauna is no older than that of the lower beds in Wisconsin, for the same type of *Conocephalites* occurs in each; and the Brachiopods, *Orthis Billingsi* and *Discina Acadica* (if a Brachiopod), are of newer type than any in the Wisconsin fauna. As to the *Discina*, he states that, according to a specimen received by him from Mr. Matthews, it is certainly not a *Discina*, and probably the fossil is the imprint of a univalve shell, either of the genus *Palæacmea* or *Stenotheca*; and Palæacmea is known from Wisconsin, and both of these genera from New York. Moreover, his *Orthisina orientalis*, described in the paper, from Georgia, Vermont, he says closely resembles and may be identical with the Wisconsin and Lake Pepin *Orthisina Pepina* of Hall.

2. *Soil-cap movements.*—In a paper read before the Royal Dublin Society in November, 1882, Professor V. Ball draws attention to the effects of land-slips or soil-cap movements in throwing

dams across valleys and making lakes, and refers to a case at Naina Tal in the Himalayas where a land-slip appears to have produced this result. He points out, also, that they make bowlder deposits resembling those of glacier origin, and sometimes cause a shallowing of channels and sea-borders which might be taken as evidence of an elevation of the land. He cites from a paper by Dr. Coppinger in the Quarterly Journal of the Geological Society of London (xxxvii, 245, 1881), about soil-cap slides over sloping surfaces of rock in western Patagonia, which carried along, besides trees and other plants of the surface, "a *moraine profonde*" of rocks, stones and trunks of trees, filling valleys and lakes, that, after a removal by water of the finer part, became a deposit of bowlders piled on one another, in true glacier-made style.

3. *Handbuch der Botanik*, von Professor Dr. N. J. C. Müller, Münden. 2 Bände (648, 482 pp.), 8vo. Heidelberg, 1880.

Pflanzenphysiologie. Ein Handbuch des Stoffwechsels und Kraftwechsels in der Pflanze, von Dr. W. Pfeffer, Professor an der Universität Tubingen. 2 Bände (383 u. 474 pp.), 8vo. Leipzig, Engelmann, 1881.

Vorlesungen über Pflanzenphysiologie, von Julius Sachs. (Professor an der Universität Würzburg), (991 pp.), 8vo. Leipzig, Engelmann, 1882.

Traité de Botanique, par Ph. Van Tieghem, Professeur au Muséum d'Histoire Naturelle (1656 pp.) 8vo. Paris, Librairie F. Savy. 1884.

Handbuch der Botanik, herausgegeben von Professor Dr. A. Schenk, unter mitwirkung, von Cohn, Detmer, Drude, Frank, Kienitz-Gerloff, Kraus, Müller (zu Lippstadt), Sadebeck, u. a. 8vo. Breslau, Trewendt. [Now publishing in parts which appear somewhat irregularly, as the first portion of an Encyclopedia of Natural History.]

These are the principal comprehensive works upon their respective subjects which have appeared within the last few years. A treatise upon Pharmaceutical and Medical Botany by Luerssen rivals these in size and in carefulness of management throughout, but cannot be described in detail in the present notice. Neither is it convenient to examine at present the newer text-books of smaller size, by Reinke, Wiesner and Baillon. They are merely mentioned in passing, to indicate that there is considerable activity on the continent, in the preparation of manuals for students of botany. Müller's Handbook is a remarkably difficult work both for the general and special reader. It has altogether too much mathematical physics in it for the former, and too little for the latter; that is, it stops just short of being what it could have been made under a different treatment. By a slight rearrangement of the copious material and with a few necessary additions, it would be a useful work of reference; by a complete removal of the unnecessary mathematics and some of the puzzling diagrams which are nowhere explained, it would be a stimulating handbook for a certain class of botanical students. But, as it stands, it is the least useful text-book upon its subject: Grassmann's Pflanzenleben rivals it in obscurity, but does not approach it in the wealth of disarranged material.

Pfeffer's Vegetable Physiology is a masterly treatise. It presents in systematic form, and with references throughout, a synoptical exposé of nearly all that is known in regard to the functions of the organs of vegetation. The arrangement is convenient both for study and reference. The general statements are cast in the mould of a physicist and chemist rather than in that of a morphologist, and bear, for the most part, evidence of critical examination of the phenomena. For instance, when dealing with the subject of osmosis, the author views the whole matter in the light of his personal experiments, and yet does not throw any part of the theme out of proportion. Likewise in the management of assimilation and of movements, he is guided by his own observations, and therefore is all the more free to criticise the writings of others. It should be said, however, that his criticisms are fair and are generally expressed in a kindly manner. The first volume deals with the reception of inorganic matter by plants and their conversion of this into organic substance. The great topics of absorption and assimilation are treated with much detail, while the minor ones of transmission and transpiration of water receive almost as much attention. The formation of nitrogenous compounds within the plant, a subject to which Pfeffer has devoted much time, is treated pretty fully but is not left in a wholly satisfactory state, nor is the subject of respiration, especially that which is known as "intra-molecular," so extensively presented as it appears to deserve. In the second volume, the release of energy is discussed under growth, movement, and the production of light, heat and electricity. Nearly every page exhibits personal familiarity with the phenomena described and not merely with the literature. The propositions are everywhere well presented, but the arguments in support of them are not always as clearly put. Part of the fault comes no doubt from the unwillingness to place headings at the proper places in the statement and thus due proportions are not always preserved. As a trustworthy work of reference in the laboratory, as a guide which will seldom lead astray and never far from the right, the treatise is a thoroughly satisfactory contribution to vegetable physiology.

Professor Sachs has been repeatedly asked by his publishers to prepare a fifth edition of his text-book, but he felt so much unwillingness to undertake the revision, that a compromise was at last effected with which both he and the publishers may well be satisfied. The systematic portion is turned over to a most promising young professor who has recently established himself at Rostock, and the work has already appeared under Goebel's name and with Sachs's sanction. The rest of the text-book has been wholly recast, and is now published as a series of forty-six lectures. It may be said at the outset, that the lectures are interesting in the extreme. They are characterized by felicity of expression and by the exclusion of unnecessary matters, so that from first to last the reader's interest is not permitted to flag. Their thoroughly attractive character ensures the early translation into other languages.

The first series comprises eleven lectures upon the histological and morphological characters of plants in general. All plant organs are placed in two categories, root and shoot. The former comprises that part of the plant which on or in a substratum serves as a hold fast, and in the latter case acts as an organ for conducting into the plant nutritive matters held in the substratum. The shoot (or the shoot-system) is that part which unfolding outside of the substratum produces plant-substance and serves for propagation, bearing organs of reproduction which are never seen on roots. That both fulfill their characteristic functions depends on their diverse reactions with the natural forces. To be sure, there are roots which *may* produce shoots, and shoots *do* give rise to roots; but this only shows that in the progressive development of the vegetable world, with progressive adaptation of the different organs to special conditions of life, individual characters disappear and new ones arise. According to this view no distinction is made between the rhizoids of a thallophyte and the root of a vascular plant. These new morphological categories cannot prove as satisfactory to students as those given in his text-book, root, stem, leaf, plant-hair. In the first eleven lectures the whole field of general histology and morphology is well covered. A second series, of two lectures only, treats of the most general conditions of plant life, such as temperature, light, habitat, etc., and the most general phenomena presented by a living plant, to wit: osmotic power, turgescence, tension of tissues, together with some explanation of the mechanics of a plant.

In the third series, Nutrition in the widest sense is dealt with in twelve lectures which range from absorption of liquids and gases, through assimilation and elaboration, to the final release of the products of respiration. In this series insectivorous plants are spoken of. The fourth series is the freshest in material and treatment. It takes up very fully the whole subject of the growth of the cell, formation of new cells non-sexually, and the increase in size of the whole plant. The newest researches are referred to and illustrated by good diagrams from many sources, some of the very best drawings now appearing for the first time. In the fifth series the movements of various kinds are treated of, in much the same manner as in the last edition of the text-book. The concluding series of six lectures takes up the principal kinds of sexual reproduction in a very general manner. Much of the matter in these lectures is speculative of course, and is not likely to be received without question. But all statements are clearly made, and the interdependence of the topics always kept in mind. The notes of reference at the end of each lecture must be meant as hints to Professor Sachs's own students, since they refer very largely to work done either by him or in the Würzburg laboratory. The notes do not pretend to cover the literature of the subject.

To many American students of Botany, Professor Van Tieghem is known as a successful investigator of some difficult problems in histology and physiology, and for his work in the department of cryptogamic botany. But he is more widely known in this country as the editor of a French translation of Sachs's Text-book. It will be remembered that many of the very long paragraphs of the original were broken up in the translation into shorter ones with appropriate headings, often embodying in a few words the gist of what followed. In the volume now before us the author has adopted the same plan. If it were not for this convenient method of reference the work would be far from attractive; but with it, its encyclopedic character is more or less masked. Moreover, a substantial gain has been made for the general reader by suppressing, as far as possible, references in the text to the sources of the author's information. Hence the story is, so to speak, continuous. At the beginning of the great divisions, copious references to the literature are given, and occasionally they are noted in the text. The work is divided into a general and a special part. The first book of the former is devoted to a study of the external form of the adult plant and of the phenomena which are exhibited in this state. Division of labor; and kindred subjects are treated in a general manner, and then follows a particular examination of root, stem, leaf and flower, the chapter given to each of these organs being divided into two parts, Morphology and Physiology. It is obvious that this arrangement leads sometimes to repetition which may be tedious; or, when there is too marked an effort to avoid repetition, some facts may be overlooked. The second book treats of internal morphology and the physiology of the cell and of special tissues; the third traces the development of the plant from its youngest state to its adult form. In the latter, a very general view is taken of the whole vegetable world, and cryptogams receive their proportional share of attention. This book closes with a study of close fertilization, cross-fertilization and hybridization, and with some discussion of the origin of species. Of the latter, the author says: "It (the theory of descent) explains in a simple and satisfying manner why living plants are so well armed for their conflict, why identical members are adapted to the most diverse uses, why there are rudimentary organs, how plants have succeeded each other on the surface of the globe at different geological epochs, etc., etc., all of which problems would remain unsolved without it." "But if we wish to preserve to this theory its scientific value we must deduce our conclusions with prudence and control them by direct observation and by the experimental method."

The second part of the work is devoted to a special study of the orders of lower and of higher plants. The arrangement is novel in some particulars, although not now calling for remark. The work closes with a consideration of the paleontological and geographical relations of plants. Thus it will be seen that the treatise is a general work of wide range. It is characterized from beginning to end by qualities which give it a high value for teachers of botany and for advanced students, namely great clearness of statement, and an emphasis of important points. It is to be regretted that more prominence has not been given by the author to some of the recent German works in a few of the subjects treated, especially as the works are themselves cited by him. But it must be said that these cases of omission are comparatively few and do not seriously impair the value of the excellent treatise.

The encyclopedic handbook now in course of publication under the editorship of Professor Schenk, promises to be a valuable collection of morphological, histological and physiological monographs. Of course, in a work prepared by many hands, the repetitions are numerous and there is much waste of energy. On the other hand, we are given several views of the same subject and this may lead to a clearer conception of matters in doubt. The most noteworthy papers thus far at hand are the following: Mutual relations of flowers and insects (with regard to crossing) by H. Müller, Vascular cryptogams by Sadebeck, Diseases of Plants by Frank, Morphology of Phanerogams by Drude, Physiology by Detmer, Algæ by Falkenberg, Physiological adaptations of tissues by Haberlandt, and Comparative development of the Organs of Plants by Goebel. There does not appear to be any "editing" in the true sense of the word, if indeed any such thing were possible with so diverse contributions. The accumulation of material ready for coördination is however very great and the work will be an abundant source to which teachers will go for illustration. Special monographs may be noticed in a future number. G. L. G.

4. *Tendency in Variation.* — In the review in this Journal of Darwin's Origin of Species, which appeared very shortly after the publication of that "epoch-making" work, the writer intimated that there was reason to believe "that variation has been led along certain beneficial lines, like a stream 'along definite and useful lines of irrigation.'" Mr. Darwin devoted the closing page of his next work to this suggestion, and argued that, under his view of the case, plan should be superfluous. It may be doubted if he ever convinced himself that it was so, although he has convinced a host of his followers, who, as often happens, were more facile believers than their master. A good many years have passed; and now, wherever we turn from the speculators to the investigators who have been working upon the problem of descent with variation, we meet with this idea of definite tendency. The suggestion, and the need of it, are well brought out by that veteran investigator of the Foraminifera, Dr. Carpenter, in his recent paper in the

Philosophical Transactions (part ii, 1883), *On an Abyssal Type of the Genus Orbitolites; a Study in the Theory of Descent*,—the closing portion of which is here reproduced.

"I propose, in the last place, briefly to examine the bearing of the remarkable case of 'descent with modification,' which I have thus detailed, upon the general 'Theory of Descent' and of the 'Origin of Species.'

"Those who find in 'natural selection' or the 'survival of the fittest' an all-sufficient explanation of the 'origin of species,' seem to have entirely forgotten that before 'natural selection' can operate, there must be a range of varietal forms to select from; and that the fundamental question is (as Mr. Darwin himself clearly saw, at any rate in his later years), *what gives rise to variations?* No exercise of 'natural selection' could *produce* the successive changes presented in the evolutionary history of the typical *Orbitolites*, from *Cornospira* to *Spiroloculina*, from *Spiroloculina* to *Peneroplis*, from *Peneroplis* to *Orbiculina*, from *Orbiculina* to the 'simple' forms of *Orbitolites*, and from the 'simple' to the 'complex' forms of the last-named type. And as all these earlier forms still flourish under conditions which (so far as can be ascertained) are precisely the same, there is no ground to believe that any one of them is better fitted to survive than another. They all imbibe their nourishment in the same mode; and no one type has more power of going in search of it than another. That they are all dependent on essentially the same conditions of temperature and depth of water, is shown by their occurrence in the same marine areas. That they all equally serve as food to larger marine animals, can scarcely be doubted; and it is hardly conceivable that any of their devourers would discriminate (for example) between the disks of a large *O. marginalis*, a middle-sized *O. duplex* and a small *O. complanata*, which even the trained eye of the naturalist cannot distinguish without the assistance of a magnifying-glass.

"To me, therefore, it appears that the doctrine of 'natural selection' can give no account of either the origin or the perpetuation of those several types of Foraminiferal structure which form the ascending series that culminates in *Orbitolites complanata*. On the other hand, there seems traceable throughout that series a *plan* so definite and obvious, as to exclude the notion of 'casual' or 'aimless' variation. Between the simple spirally-coiled sarcodic cord of a young *Cornuspira*, and the discoidal body of an *Orbitolite*, with its thousands of sub-segments disposed with the most perfect symmetry, and connected together in most regular and uniform modes, who (in the absence of the intervening links) would have suspected any genetic relation—who would have ventured to construct a pedigree? And yet we find the gradations from the one to the other to be not only most complete, but often significant of further progress; many of the changes being such as seem to have no meaning except as anticipations of greater changes to come. Thus, the slight constrictions that show themselves in the first spiral coil of *O. tenuissima* are what constitute the essential difference between the spire of *Cornuspira* and that of *Spiroloculina*; marking an imperfect septal division of the spire into chambers, which cannot be conceived to affect in any way the physiological condition of the contained animal, but which foreshadows the complete septal division that marks the assumption of the Peneropline stage. Again, the incipient widening-out of the body, previously to the formation of the first complete septum, prepares the way for that great lateral extension which characterizes the next or Orbiculine stage; this extension being obviously related, on the one hand, to the division of the chamber-segments of the body into chamberletted sub-segments, and, on the other, to the extension of the zonal chambers round the 'nucleus,' so as to complete them into annuli, from which all subsequent increase shall take place on the cyclical plan.

"In *O. marginalis*, the first spiral stage is abbreviated by the drawing-together (as it were) of the 'spiroloculine' coil into a single Milioline turn of greater thickness; but the Orbiculine or second spiral stage is fully retained. In *O. duplex*, the abbreviated Milioline center is still retained, but the succeeding Orbiculine spiral is almost entirely dropped out, quickly giving place to the cyclical plan. And in the typical *O. complanata* the Milioline center is immediately surrounded by a complete annulus, so that nothing remains of the original spire save the one turn of the circumambient segment. So, in the passage from the 'simple' to the 'complex' type, we have a remarkable anticipatory step in *O. duplex*, which can scarcely be supposed itself to derive any advantage from the substitution of a double for a single row of communications between the annuli, since *O. marginalis* flourishes equally well with its single row; but which forms, so to speak, a stepping-stone to a higher grade.

"Everything in this history, then, shows *a well-marked progressive tendency along a definite line towards a highly specialized type of structure in the Calcareous fabric;* and this without any corresponding departure from the original homogeneity of the animal body which forms that fabric. And as being, so far as I know, altogether unique in these peculiarities, I venture to offer this study of a humble protoplasmic organism, brought up from an ocean-depth of nearly two miles, to the consideration of those who believe, with Sir James Paget, that the highest laws of our [biological] science are expressed in the simplest terms in the lives of the lowest orders of Creation."

APPENDIX.

ART. XXXVIII.—*Principal Characters of American Jurassic Dinosaurs*; by Professor O. C. MARSH. Part VIII. *The Order Theropoda*. (With Plates VIII–XIV.)

THE carnivorous *Dinosauria* form a well marked order, which the writer has called the *Theropoda*, in his classification of this group.* Although much has been written about these reptiles since Buckland described *Megalosaurus* in 1824, but little has really been made out in regard to the structure of the skull, and many portions of the skeleton still remain to be determined.

The fortunate discovery of two nearly perfect skeletons of this order, as well as a number of others with various important parts of the skeleton in good preservation, has afforded the writer an opportunity to investigate the group, and some of the results are here presented. A more detailed description of these fossils, and others allied to them, will be given in another communication.

Of the carnivorous Dinosaurs from the American Jurassic, there are four genera, which each represents, apparently, a distinct family. These genera are *Allosaurus*, *Cœlurus*, *Labrosaurus*, and the new genus *Ceratosaurus*, here described. In the present article, *Allosaurus* and *Ceratosaurus* will be mainly used to illustrate the more important characters of the order, and the relations of the other genera to them will be indicated in the classification presented in conclusion.

* This Journal, vol. xxiii, p. 81, January, 1882. See also vol. xxi, p. 423, May, 1881; p. 339, April, 1881; and vol. xvii, p. 89, January, 1879.

The specimen of *Ceratosaurus* here first described presents several characters not hitherto seen in the *Dinosauria*. One of these is a large horn on the skull; another is a new type of vertebra, as strange as it is unexpected; and a third is seen in the pelvis, which has the bones all coössified, as in existing Birds. *Archæopteryx* alone among adult birds has the pelvic bones separate, and this specimen of *Ceratosaurus* is the first Dinosaur found with all the pelvic bones anchylosed. Another feature of this skeleton, not before seen in the *Theropoda*, is the presence of osseous dermal plates. These extend from the base of the skull along the neck, over the vertebræ. The plates appear to be ossified cartilage.

This interesting fossil is quite distinct from any hitherto described, and, as it represents a new genus and species, may be called *Ceratosaurus nasicornis*. It also belongs to a new family, which may be named the *Ceratosauridæ*.

The skeleton, which is almost perfect, is over seventeen feet in length by actual measurement. The animal when alive was about half the bulk of the species named by the writer *Allosaurus fragilis*, which is from the same geological horizon. A second skeleton, some parts of which, also, are here described, is referred to the latter species.

The Skull.

The skull of *Ceratosaurus nasicornis* is very large, in proportion to the rest of the skeleton. The posterior region is elevated, and moderately expanded transversely. The facial portion is elongate, and tapers gradually to the muzzle. Seen from above, the skull resembles in general outline that of a crocodile. The nasal openings are separate, and lateral, and are placed near the end of the snout, as shown in Plate VIII.

Seen from the side, this skull appears Lacertilian in type, the general structure being light and open. From this point of view, one special feature of the skull is the large, elevated, trenchant horn-core, situated on the nasals (Plate VIII, fig. 1, *b*). Another feature is the large openings on the side of the skull, four in number. The first of these is the anterior nasal orifice (*a*); the second, the very large triangular antorbital foramen (*c*); the third, the large oval orbit (*d*); and the fourth, the still larger lower temporal opening (*e*). A fifth aperture, shown in the top view of the skull (Plate VIII, figure 3, *h*), is the supra-temporal fossa. These openings are all characteristic of the *Theropoda*, and are found also in the *Sauropoda*, but the antorbital foramen is not known in any of the other *Dinosauria*.

The plane of the occiput, as bounded laterally by the quadrates, is inclined forward. The quadrates are strongly inclined backward, thus forming a marked contrast to the corresponding bones in *Diplodocus*, and the other *Sauropoda*. The occipital condyle is hemispherical in general form, and is somewhat inclined backward, making a slight angle with the long axis of the skull. The basi-occipital processes are short, and stout. The par-occipital processes are elongate and flattened, and but little expanded at their extremities. They extend outward and downward, to join the head of the quadrate.

The hyoid bones appear to be four in number. They are elongate, rod-like bones, somewhat curved, and in the present specimen were found near their original position.

The parietal bones are of moderate size, and there is no parietal foramen. The median suture between the parietals is obliterated, but that between these bones and the frontals is distinct.

The frontal bones are of moderate length, and are closely united on the median line, the suture being obliterated. Their union with the nasals is apparent on close inspection.

The nasal bones are more elongate than the frontals, and the suture uniting the two moieties is obsolete. These bones support entirely the large compressed, elevated horn-core, on the median line. The lateral surface of this elevation is very rugose, and furrowed with vascular grooves. It evidently supported a high, trenchant horn, which must have formed a most powerful weapon for offense and defense. No similar weapon is known in any of the *Dinosauria*, but it is not yet certain whether this feature pertained to all the members of this family, or was only a generic character.*

The premaxillaries are separate, and each contained only three functional teeth. In the genera *Compsognathus* and *Megalosaurus*, of this order, each premaxillary contained four teeth, the same number found in the *Sauropoda*. In the genus *Creosaurus*, from the American Jurassic, the premaxillaries each contain five teeth, as shown in Plate IX, figure 3.

The maxillary bones in the present specimen are large and massive, as shown in Plate VIII, figure 1. They unite, in front, with the premaxillaries by an open suture; with the nasals, laterally, by a close union; and, with the jugal behind, by squamosal suture. The maxillaries are provided each with fifteen functional teeth, which are large, powerful, and

* The "horn" of *Iguanodon* described by Mantell, and since regarded as a carpal spine, proves to be the distal phalange of the thumb.

trenchant, indicating clearly the ferocious character of the animal when alive. These teeth have the same general form as those of *Megalosaurus*, and the dental succession appears to be quite the same.

Above the antorbital foramen on either side, is a high elevation composed of the prefrontal bones. These protuberances would be of service in protecting the orbit, which they partially overhang.

The orbit is of moderate size, oval in outline, with the apex below. It is bounded in front by the lachrymal, above this by the pre-frontal, and at the summit the frontal forms for a short distance the orbital border. The post-frontal bounds the orbit behind, but below, the jugal completes the outline.

The jugal bone is ⊥-shaped, the upper branch joining the post-frontal, the anterior branch uniting with the lachrymal, above, and the maxillary below. The posterior branch passes beneath the quadrato-jugal, and with that bone completes the lower temporal arch, which is present in all known Dinosaurs.

The quadrato-jugal is an L-shaped bone, and its anterior branch is united with the jugal by a close suture. The vertical branch is closely joined to the outer face of the quadrate.

The quadrate is very long, and compressed antero-posteriorly. The head is of moderate size, and is enclosed in the squamosal. The lower extremity of the quadrate has a double articular face, as in some birds. One peculiar feature of the quadrate is a strong hook, on the upper half of the outer surface. Into this hook of the quadrate, a peculiar process of the quadrato-jugal is inserted, as shown in Plate VIII, figure 1.

The pterygoid bones are very large, and extend well forward. The posterior extremity is applied closely to the inner side of the quadrate. The middle part forms a pocket, into which the lower extremity of the basi-pterygoid process is inserted. To the lower margin of the pterygoid is united the strong, curved, transverse bone, which projects downward below the border of the upper jaws, as shown in Plate VIII, figure 1, *t*.

There is a very short, thin columella, which below is closely united to the pterygoid by suture, and above fits into a small depression of the post-frontal.

The palatine bones are well developed and, after joining the pterygoids, extend forward to the union with the vomers. The latter are apparently of moderate size.

The pre-sphenoid is well developed, and has a long pointed anterior extremity.

The whole palate is remarkably open, and the principal bones composing it stand nearly vertical, as in the *Sauropoda*.

The Brain.

The brain in *Ceratosaurus* was of medium size, but comparatively much larger than in the herbivorous Dinosaurs. It was quite elongate, and situated somewhat obliquely in the cranium, the posterior end being inclined downward. The position of the brain in the skull, and its relative size, is shown in Plate IX, figure 1. A side view of the brain-cast is shown in the same plate, figure 2.

The foramen magnum is small. The cerebellum was of moderate size. The optic lobes were well developed, and proportionally larger than the hemispheres. The olfactory lobes were large, and expanded. The pituitary body appears to have been very large.

The Lower Jaws.

The lower jaws of *Ceratosaurus* are large and powerful, especially in the posterior part. In front, the rami are much compressed, and they were joined together by cartilage only, as in all Dinosaurs. There is a large foramen in the jaw, similar to that in the crocodile, as shown in Plate VIII, figure 1, *f*. The dentary bone extends back to the middle of this foramen. The splenial is large, extending from the foramen forward to the symphysial surface, and forming in this region a border to the upper margin of the dentary. There were fifteen teeth in each ramus, similar in form to those of the upper jaws.

A peculiar dentary bone, recently found, and here referred to *Labrosaurus*, is shown on Plate IX, figure 4. It is edentulous in front, and the posterior portion is much decurved. The teeth are more triangular than in the other genera of this order. The species it represents may be called *Labrosaurus ferox*.

The Vertebræ.

The cervical vertebræ of *Ceratosaurus* differ in type from those in any other known Reptiles. With the exception of the atlas, which is figured in Plate X, all are strongly opisthocœlian, the cup on the posterior end of each centrum being unusually deep. In place of an equally developed ball on the anterior end, there is a perfectly flat surface. The size of the latter is such that it can only be inserted a short distance in the adjoining cup, and this distance is accurately marked on the centrum by a narrow articular border, just back of the flat anterior face. This peculiar articulation leaves more than three-fourths of the cup unoccupied by the succeeding vertebra, forming, apparently, a weak joint. This feature is shown in Plate X, figures 2, 3, and 4.

The discovery of this new form of vertebra shows that the terms opisthocœlian and procœlian, in general use to describe the centra of vertebræ, are inadequate, since they relate to one end only, the other being supposed to correspond in form. The terms convexo-concave, concavo-convex, plano-concave, etc., would be more accurate, and equally euphonious.

In *Ceratosaurus*, as in all the *Theropoda*, except *Cœlurus*, the cervical ribs are articulated to the centra, not coössified with them, as in the *Sauropoda*. The latter order stands almost alone among Dinosaurs in this respect, as both the *Stegosauria* and the *Ornithopoda* have free ribs in the cervical region.

The dorsal and lumbar vertebræ are bi-concave, with only moderate concavities. The sides and lower surface of the centra are deeply excavated, except at the ends, as shown in Plate X, figure 5. These vertebræ show the diplosphenal articulation seen in *Megalosaurus*, and also in *Creosaurus*, as shown in Plate XIV, figure 3.

All the pre-sacral vertebræ are very hollow, and this is also true of the anterior caudals.

There are five well coössified vertebræ in the sacrum in the present specimen of *Ceratosaurus nasicornis*. The transverse processes are very short, each supported by two vertebræ, and they do not meet at their distal ends.

In the type specimen of *Creosaurus*, there are only two sacral vertebræ coössified. In *Megalosaurus*, there are five, and the number appears to vary in different genera of the *Theropoda*, as it does in the *Sauropoda*.

The caudal vertebræ are bi-concave. All the anterior caudals, except the first, supported very long chevrons, indicating a high, thin tail, well adapted to swimming. The tail was quite long, and the distal caudals were very short.

The Fore Limbs.

The fore limbs in *Allosaurus*, and in fact in all known *Theropoda*, were very small. The scapula and coracoid resembled those of *Megalosaurus*. The humerus was short, and somewhat sigmoid in form. The shaft was hollow, as in all the limb bones of this genus. The manus was peculiar in having some of its digits armed with powerful compressed claws, which formed most effective weapons. These claws, in some allied forms, have been referred to the hind feet, but the latter, in all the known *Theropoda*, have their claws round, and not compressed. The fore limb of *Allosaurus fragilis* is shown on Plate XII.

The Pelvic Arch.

The pelvic bones in the *Theropoda* have been more generally misunderstood than any other portion of the skeleton in Dinosaurs. The ilia, long considered coracoids, have been since usually reversed in position; the ischia have been regarded as pubes; while the pubes themselves have not been considered as part of the pelvic arch.

Fortunately, in the present specimen of *Ceratosaurus*, the ilium, ischium, and pubes are firmly coössified, so that their identification and relative positions cannot be called in question. The ilia, moreover, were attached to the sacrum, which was in its natural place in the skeleton, and the latter was found nearly in the position in which the animal died. The pelves of *Ceratosaurus* and of *Allosaurus* are shown in Plate XI.

The ilium in *Ceratosaurus* has the same general form as in *Megalosaurus*. In most of the other *Theropoda*, also, this bone has essentially the same shape, and this type may be regarded as characteristic of the order. In *Creosaurus*, the anterior wing is more elevated, and the emargination below it wider, as shown in Plate XIV, figure 1, but this may in part be due to the imperfection of the border.

The ischia in *Ceratosaurus* are comparatively slender. They project well backward, and for the last half of their length the two are in close apposition. The distal ends are coössified, and expanded, as shown in Plate XI.

The pubes in *Ceratosaurus* have their distal ends coössified, as in all the known *Theropoda*. They project downward and forward, and their position in the pelvis is shown in Plate XI. Seen from the front, they form a Y-shaped figure, which varies in form in different genera. The upper end joins the ilium by a large surface, and the ischium by a smaller attachment. The united distal ends are expanded into an elongate, massive foot, as shown in Plate XI, which is one of the most peculiar and characteristic parts of the skeleton.

The pubes of *Megalosaurus* have not yet been identified, but there can be little doubt that they are of the same general type as in *Ceratosaurus* and *Allosaurus*, shown in Plate XI. The pubes of *Cœlurus* are represented on the same plate. They pertain to a new species, which may be called *Cœlurus agilis*. This animal was at least three times the bulk of the type, the vertebræ of which are represented on Plate XIII. Owen has figured the pubes of another species of this genus, under the name *Poikilopleuron pusillus*, but he regarded the specimen as an "abdominal hæmapophysis and hæmal spine." (Palæontographical Society, vol. xxx, Plate I, 1876.)

The extremely narrow pelvis is one of the most marked features in this entire group, being in striking contrast to the width in this region in the herbivorous forms found with them. If the *Theropoda* were viviparous, which some known facts seem to indicate, one difficulty, naturally suggested in the case of a reptile, is removed.

Another interesting point is, the use of the large foot at the lower end of the pubes, which is the most massive part of the skeleton. The only probable use is, that it served to support the body in sitting down. That some Triassic Dinosaurs sat down on their ischia is proved conclusively by the impressions in the Connecticut River sandstone. In such cases the leg was bent so as to bring the heel to the ground. The same action in the present group would bring the foot of the pubes to the ground, nearly or quite under the center of gravity of the animal. The legs and ischia would then naturally aid in keeping the body balanced. Possibly this position was assumed habitually by these ferocious biped reptiles, in lying in wait for prey.

The Hind Limbs.

Several restorations of the posterior limb of *Megalosaurus* have been attempted, but the imperfect material at hand was not sufficient to ensure entire success. In the restoration of *Allosaurus*, given in Plate XII, figure 2, only the bones found together have been placed in position. The relative proportions of the femur and tibia are shown in this figure, and the general structure of the foot. The astragalus and calcaneum are distinct from the tibia and fibula, as in all the known *Theropoda*, although their coalescence has been regarded as certain in some of the genera.*

In the foot of *Allosaurus fragilis*, represented in Plate XII, no tarsal bones of the second row were found, although the adjoining bones were nearly in their natural position. Whether the former were imperfectly ossified, or lost, in this instance cannot be determined with certainty, but there is evidence of the presence of these bones in several other members of the group. In the present foot, there were three functional digits. The metatarsals are very long, and fitted closely to each other, especially at their upper ends. The phalanges and claws were mostly found near the positions here assigned to them.

* *Compsognathus* is cited as an instance of this union, but in a careful study of the original specimen in Munich. the writer found evidence that the astragalus is distinct, although closely attached to the tibia. Baur has since proved this conclusively (Morpholog. Jahrbuch, VIII). In the *Stegosauridæ* alone, among known Dinosaurs, is the astragalus coössified with the tibia. This, however, is not a character of much importance.

The specimens of *Theropoda* here first described, including the type specimen of *Ceratosaurus nasicornis*, are from the Atlantosaurus beds of the Upper Jurassic, in Colorado, where they were found by Mr. M. P. Felch. The associated fossils are various *Sauropoda*, *Stegosauria*, and *Ornithopoda*, together with Jurassic Mammals.*

Classification.

The main characters of the order *Theropoda*, and of the families now known to belong to it, are as follows:

Order THEROPODA.

Premaxillary bones with teeth. Anterior nares at end of skull. Large antorbital opening. Vertebræ more or less hollow. Fore limbs very small; limb bones hollow. Feet digitigrade; digits with prehensile claws. Pubes projecting downward, with distal ends coössified.

(1.) Family *Megalosauridæ*. Anterior vertebræ convexo-concave; remaining vertebræ bi-concave. Pubes slender. Astragalus with ascending process.

Genera, *Megalosaurus* (*Poikilopleuron*), *Allosaurus*, *Cœlosaurus*, *Creosaurus*, *Dryptosaurus* (*Lælaps*).

(2.) Family *Ceratosauridæ*. Horn on skull. Cervical vertebræ plano-concave, remaining vertebræ bi-concave. Pubes slender. Pelvic bones coössified. Osseous dermal plates. Astragalus with ascending process.

Genus, *Ceratosaurus*.

(3.) Family *Labrosauridæ*. Lower jaws edentulous in front. Cervical and dorsal vertebræ convexo-concave. Pubes slender, with anterior margins united. Astragalus with ascending process.

Genus, *Labrosaurus*.

(4.) Family *Zanclodontidæ*. Vertebræ bi-concave. Pubes broad elongate plates, with anterior margins united. Astragalus without ascending process. Five digits in manus and pes.

Genera, *Zanclodon*, ? *Teratosaurus*.

* The presence of various genera of Dinosaurs closely allied to these American forms in essentially one horizon in the Isle of Wight, suggests that the beds in which they occur are not Wealden, as generally supposed, but Jurassic.

(5.) Family *Amphisauridæ.* Vertebræ bi-concave. Pubes rod-like. Five digits in manus, and three in pes.

Genera, *Amphisaurus* (*Megadactylus*), ? *Bathygnathus*, ? *Clepsysaurus*, *Palæosaurus*, *Thecodontosaurus*.

Sub-order CŒLURIA.

(6.) Family *Cœluridæ.* Vertebræ and bones of skeleton pneumatic. Anterior cervicals convexo-concave; remaining vertebræ bi-concave. Cervical ribs coössified with vertebræ. Metatarsals very long, and slender.

Genus, *Cœlurus.*

Sub-order COMPSOGNATHA.

(7.) Family *Compsognathidæ.* Cervical vertebræ convexo-concave; remaining vertebræ bi-concave. Three functional digits in manus and pes. Ischia with long symphysis on median line.

Genus, *Compsognathus.*

Of these seven well marked families, the *Amphisauridæ* and *Zanclodontidæ* are Triassic, the *Megalosauridæ* are Jurassic and Cretaceous, while the others are all Jurassic alone.

There are still some very diminutive carnivorous Dinosaurs that cannot at present be referred to any of the above families; but this may in part be due to the fragmentary condition in which their remains have been found.

The peculiar orders *Hallopoda* and *Aëtosauria* include carnivorous reptiles which are allied to the *Dinosauria*, but they differ from that group in some of its most characteristic features. In both *Aëtosaurus* and *Hallopus*, the calcaneum is much produced backwards. In the former genus, the entire limbs are crocodilian, and this is also true of the dermal covering. In *Hallopus*, the calcaneum is greatly lengthened, and the whole posterior limb is especially adapted to leaping. In both of these genera, there are but two sacral vertebræ, but this may be the case in true Dinosaurs, especially from the Trias. Future discoveries will probably bring to light intermediate forms between these orders and the typical Dinosaurs.

Yale College, New Haven, March 17, 1884.

EXPLANATION OF PLATES.

PLATE VIII.

FIGURE 1.—Skull of *Ceratosaurus nasicornis*, Marsh; side view.

FIGURE 2.—The same skull; front view.

FIGURE 3.—The same skull; top view.

a, nasal opening; *b*, horn-core; *c*, antorbital opening; *d*, orbit; *e*, lower temporal fossa; *f*, foramen in lower jaw; *t*, transverse bone.

All the figures are one-sixth natural size.

PLATE IX.

FIGURE 1.—Skull and brain-cast of *Ceratosaurus nasicornis*, Marsh; seen from above, one-sixth natural size.

a, nasal opening; *b*, horn-core; *c*, antorbital opening; *c'*, cerebral hemispheres; *d*, orbit; *e*, lower temporal fossa; *f*, frontal bone; *h*, supra-temporal fossa; *j*, jugal bone; *m*, maxillary bone; *m'*, medulla; *n*, nasal bone; *oc*, occipital condyle; *ol*, olfactory lobes; *pf*, pre-frontal bone; *pm*, pre-maxillary bone; *q*, quadrate bone; *qj*, quadrato-jugal bone.

FIGURE 2.—Brain-cast of same skull; side view. One-fourth natural size.

c, cerebral hemispheres; *cb*, cerebellum; *m*, medulla; *ol*, olfactory lobes; *on*, optic nerve; *op*, optic lobe; *p*, pituitary body.

FIGURE 3.—Right pre-maxillary bone of *Creosaurus atrox*, Marsh; front view; one-sixth natural size.

2*a*, lateral view, showing outer side; 2*b*, lateral view, showing inner surface.

FIGURE 4.—Left dentary bone of *Labrosaurus ferox*, Marsh; superior view; one-sixth natural size.

FIGURE 5.—The same bone; lateral view, outer side.

FIGURE 6.—The same bone; lateral view, inner side.

PLATE X.

FIGURE 1.—Atlas of *Ceratosaurus nasicornis*, Marsh.

FIGURE 2.—Axis of *Ceratosaurus nasicornis*.

FIGURE 3.—Third vertebra of *Ceratosaurus nasicornis*.

a, side view; *b*, front view; *c*, posterior view; *d*, top view; *e*, inferior view.

FIGURE 4.—Sixth vertebra of *Ceratosaurus nasicornis*; side view.

FIGURE 5.—Dorsal vertebra of *Ceratosaurus nasicornis*; side view.

FIGURE 6.—Fifth caudal vertebra of same species, with chevron in natural position; side view.

All the figures are one-sixth natural size.

PLATE XI.

FIGURE 1.—Pelvis of *Ceratosaurus nasicornis*, Marsh; side view, seen from the left.

FIGURE 2.—Pelvis of *Allosaurus fragilis*, Marsh; the same view.

a, acetabulum; *il*, ilium; *is*, ischium; *p*, pubis.

Both figures are one-twelfth natural size.

FIGURE 3.—Pubes of *Cœlurus agilis*, Marsh.

a, side view; *b*, front view; *c*, foot, or distal end; one-fourth natural size.

PLATE XII.

FIGURE 1.—Bones of left fore leg of *Allosaurus fragilis*, Marsh.

FIGURE 2.—Bones of left hind leg of *Allosaurus fragilis*.

Both figures are one-twelfth natural size.

PLATE XIII.

FIGURE 1.—Cervical vertebra of *Cœlurus fragilis*, Marsh; front view.

1*a*, side view; 1*b*, transverse section of same vertebra.

FIGURE 2.—Dorsal vertebra of *Cœlurus fragilis*; front view.

2*a*, side view; 2*b*, transverse section of same.

FIGURE 3.—Caudal vertebra of *Cœlurus fragilis*; front view.

2*a*, side view; 2*b*, transverse section of same; *a*, anterior; *p*, posterior; *c*, cavity; *f*, lateral foramen; *nc*, neural canal; *r*, coössified rib; *s*, neural spine; *z*, anterior zygapophysis; *z′*, posterior zygapophysis.

All the figures are natural size.

PLATE XIV.

FIGURE 1.—Left ilium of *Creosaurus atrox*, Marsh; seen from the left.

FIGURE 2.—The same, seen from below; both one-tenth natural size.

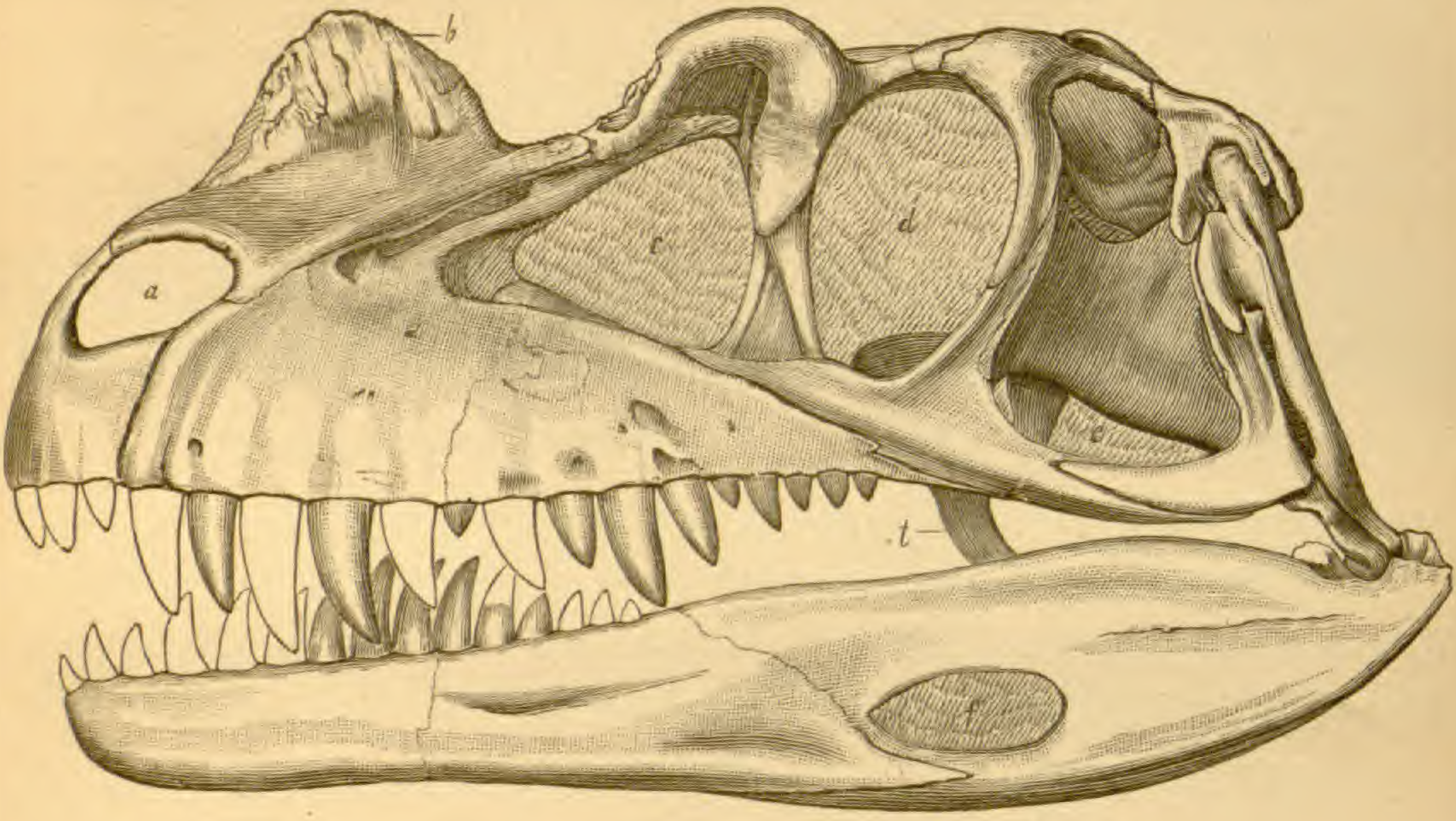
a, anterior, or pubic, articulation; *b*, posterior, or ischiadic, articulation.

FIGURE 3.—Lumbar vertebra of *Creosaurus atrox*; front view.

FIGURE 4.—The same; side view, from the left; both one-sixth natural size.

a, anterior articular face; *p*, posterior articular face; *s*, neural spine; *d*, diapophysis; *z*, anterior zygapophysis; *z′*, posterior zygapophysis.

1



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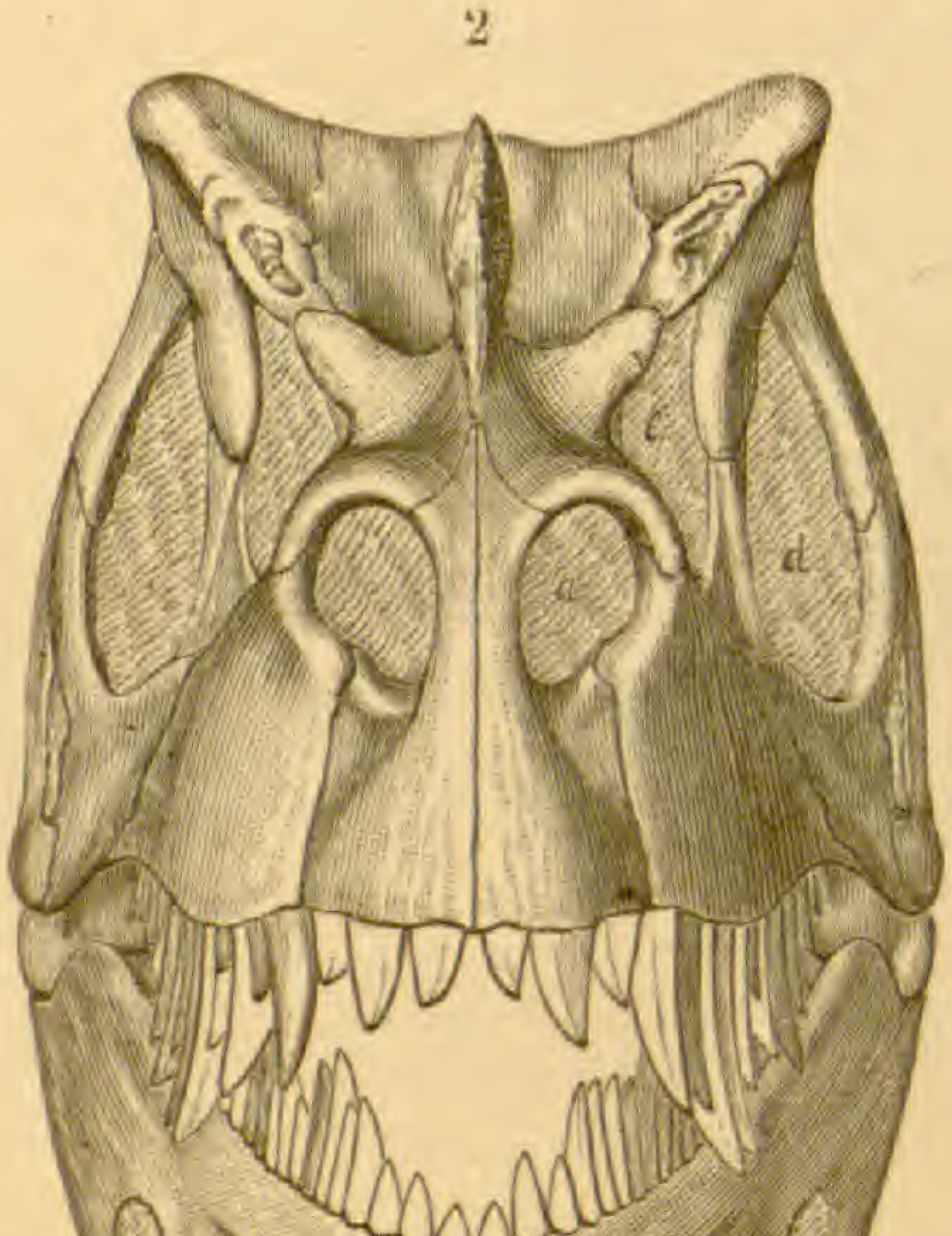
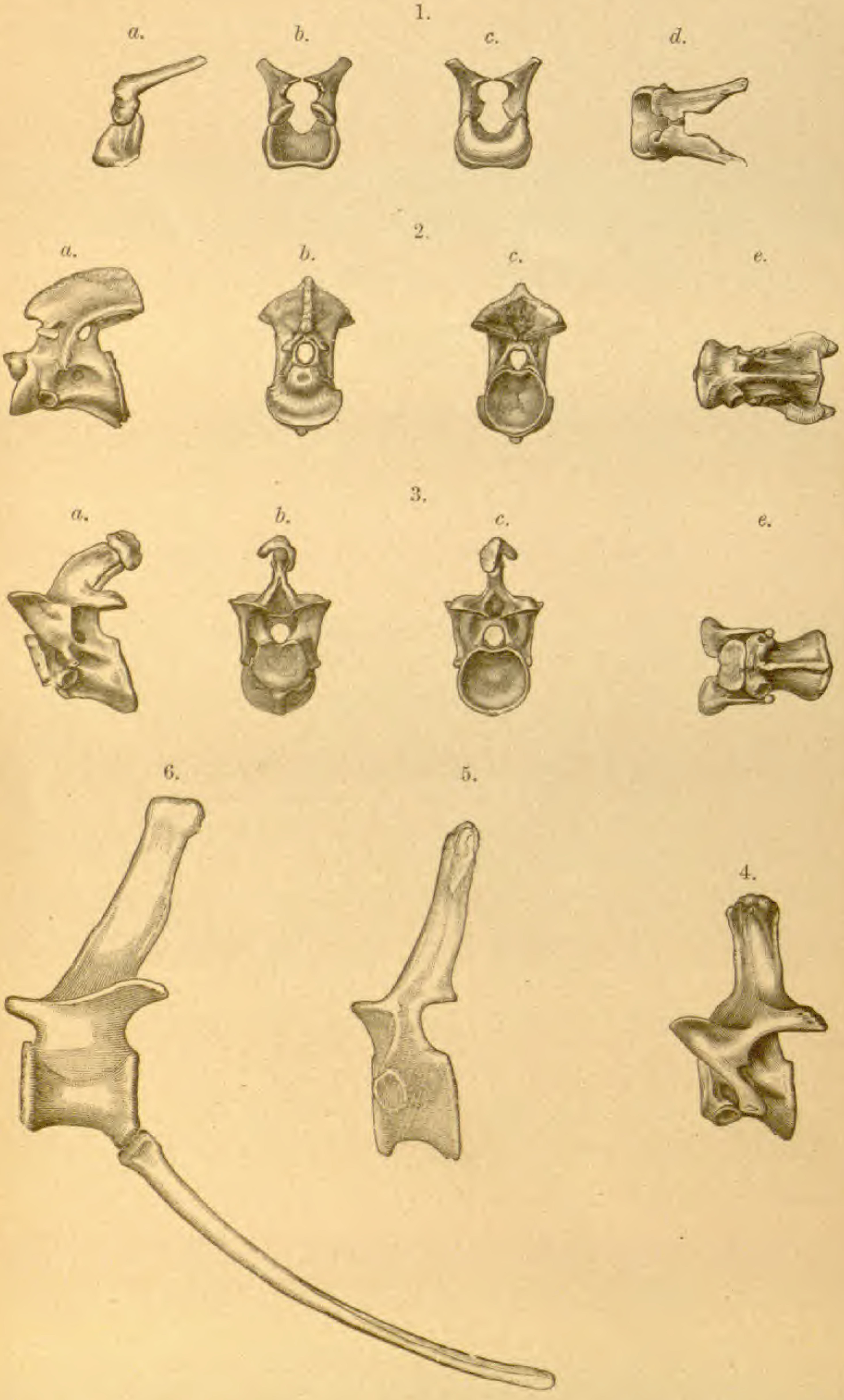


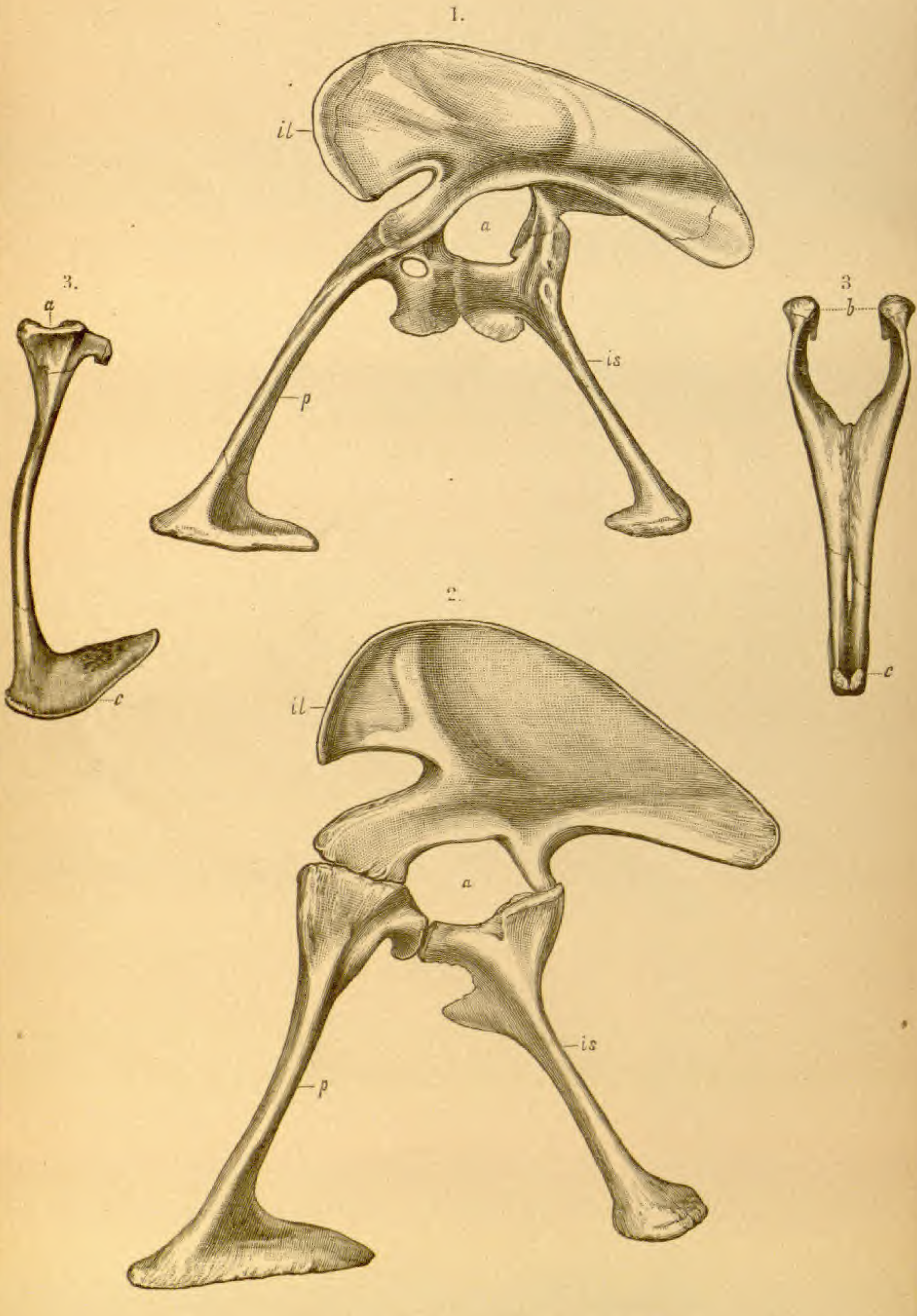
3

SKULL OF CERATOSAURUS NASICORNIS, Marsh. One-sixth natural size.

1, 2, Ceratosaurus; 3, Creosaurus; 4–6, Labrosaurus.

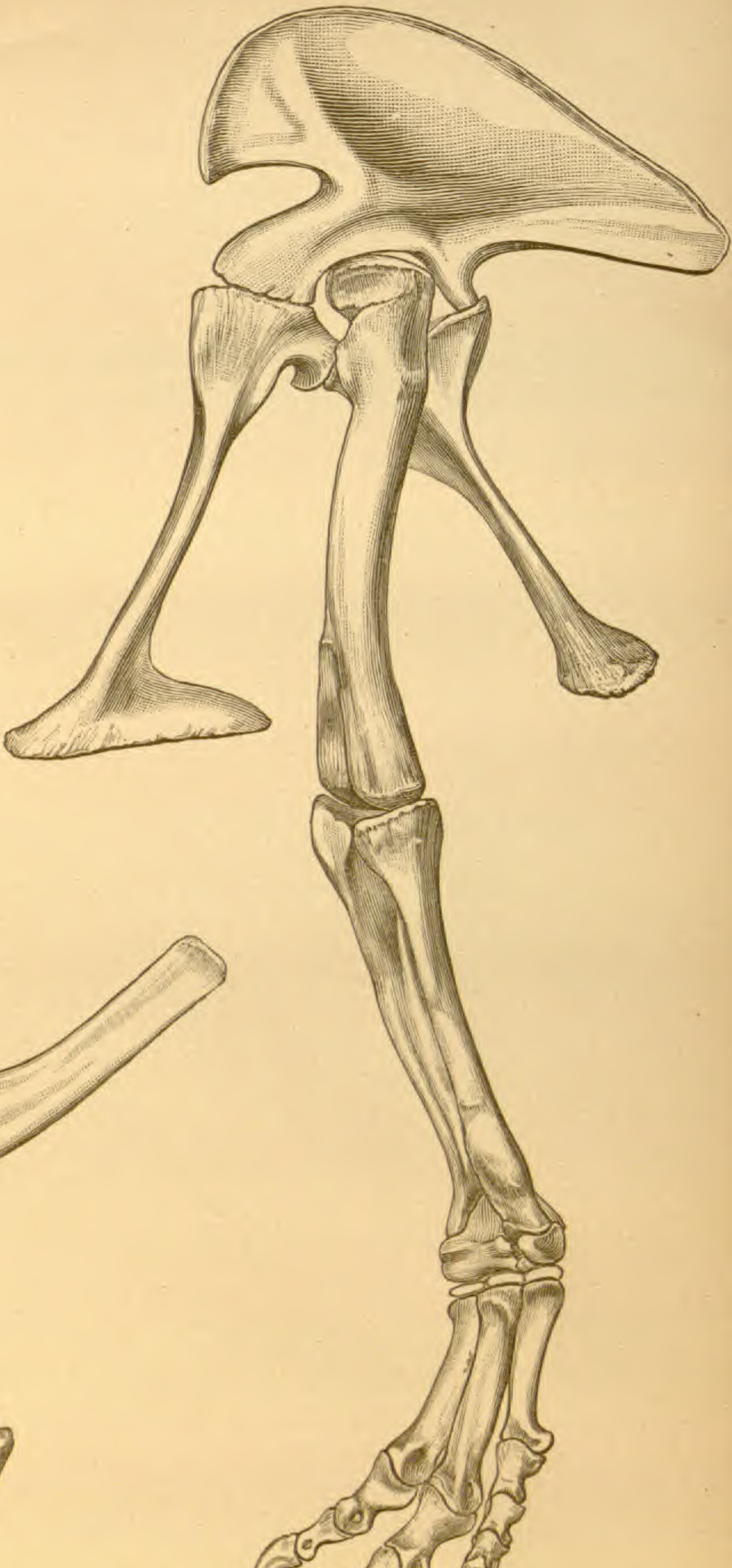


VERTEBRÆ OF CERATOSAURUS NASICORNIS, Marsh. One-sixth natural size.



1, Ceratosaurus; 2, Allosaurus: 3, Cœlurus.

2.



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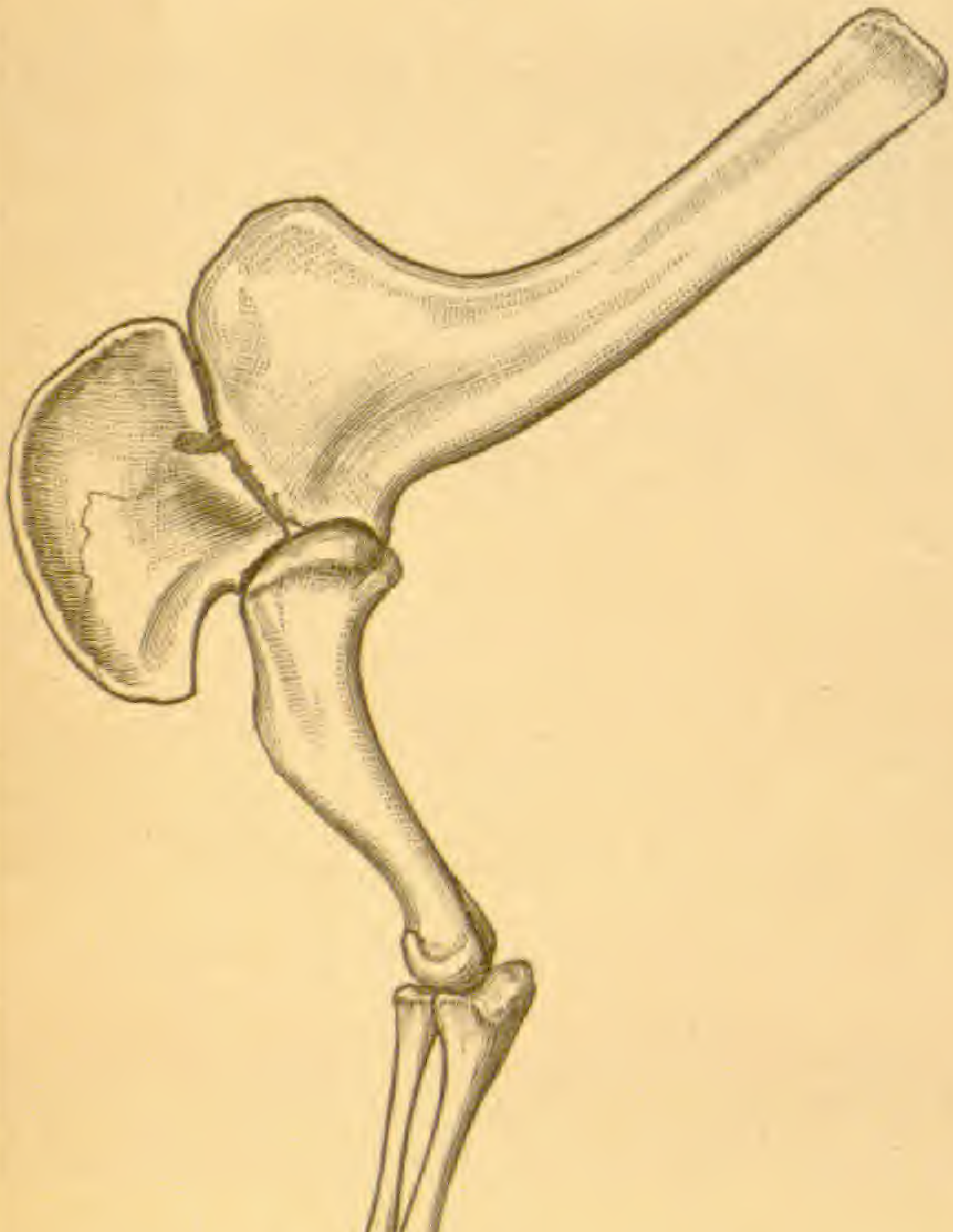
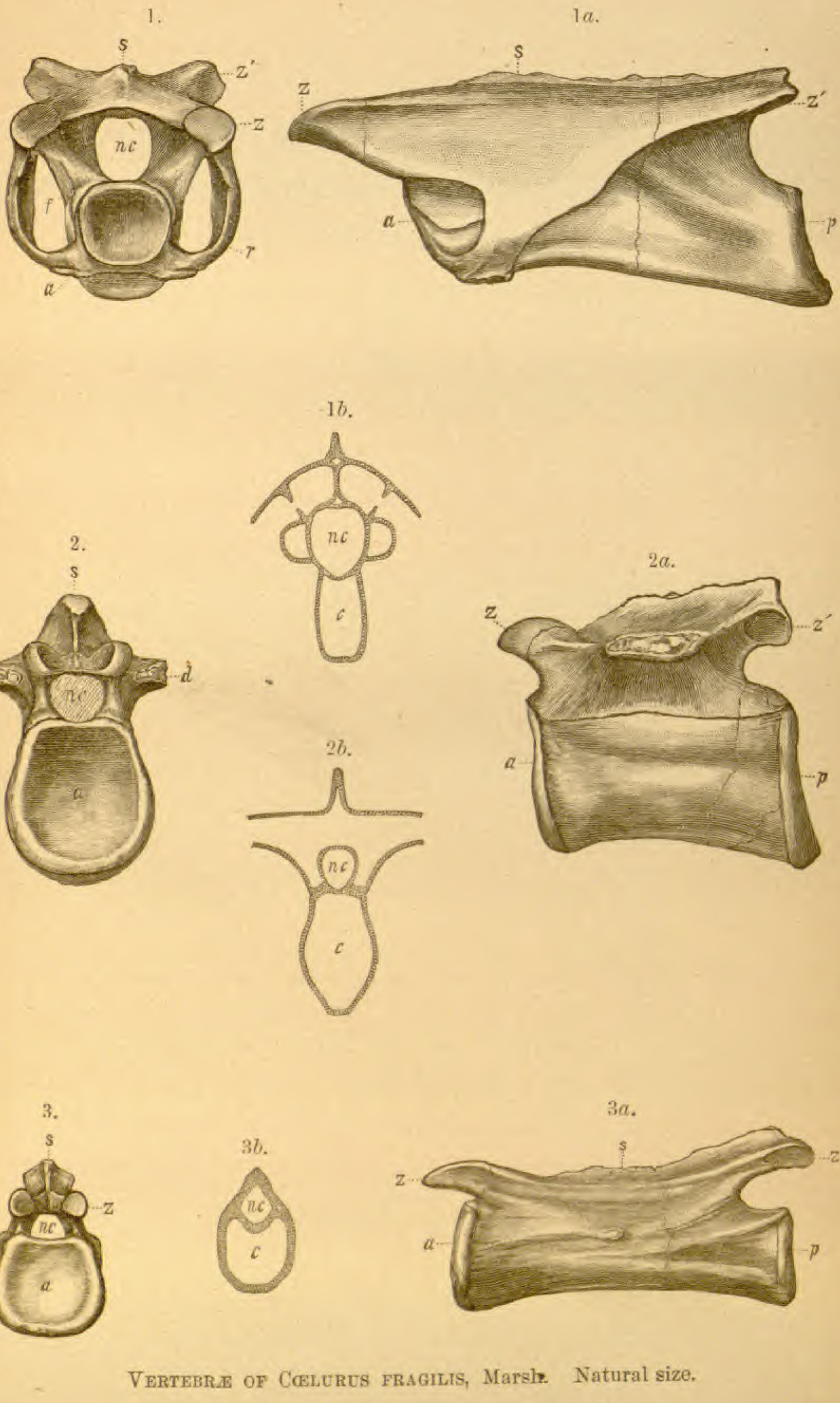
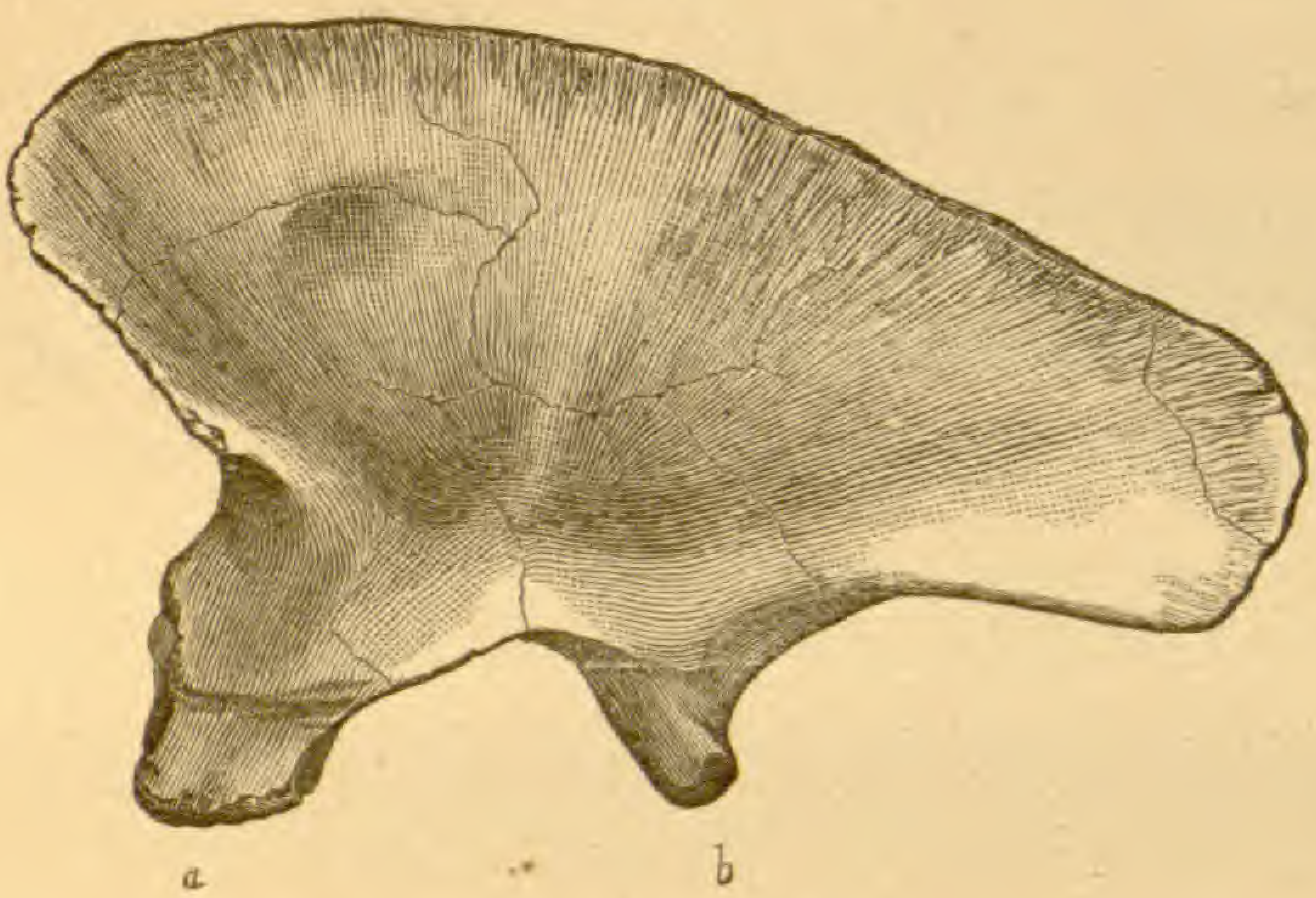


ALLOSAURUS FRAGILIS, Marsh. One-twelfth natural size.



VERTEBRÆ OF CŒLURUS FRAGILIS, Marsh. Natural size.

1.



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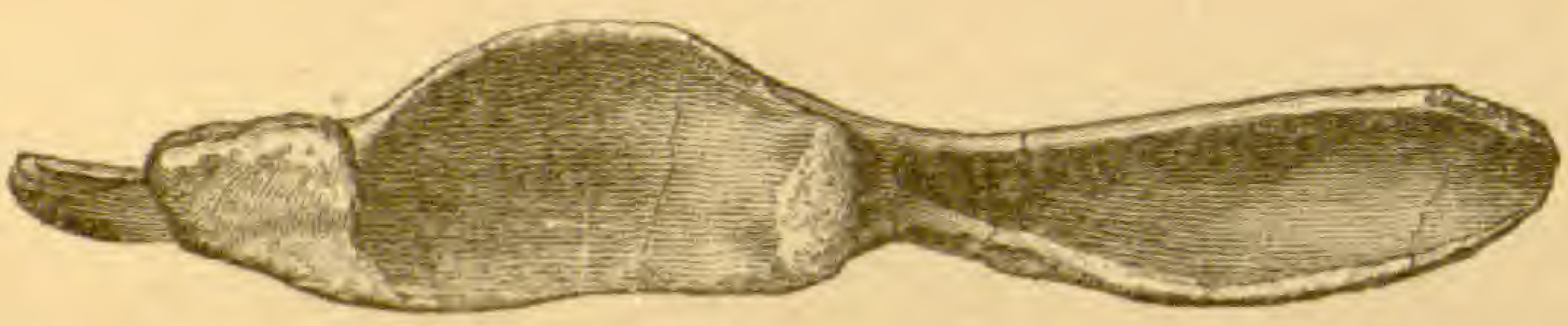

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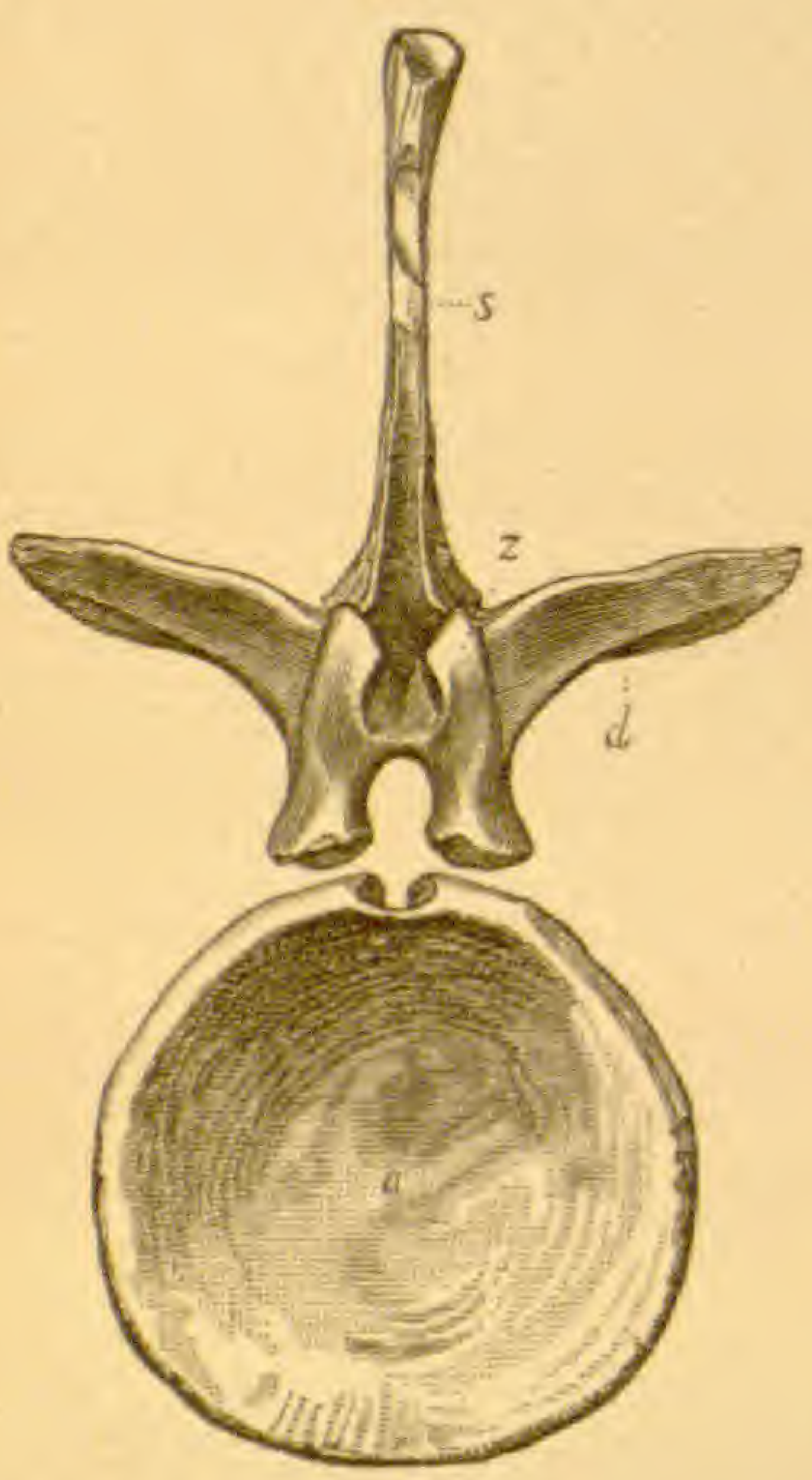

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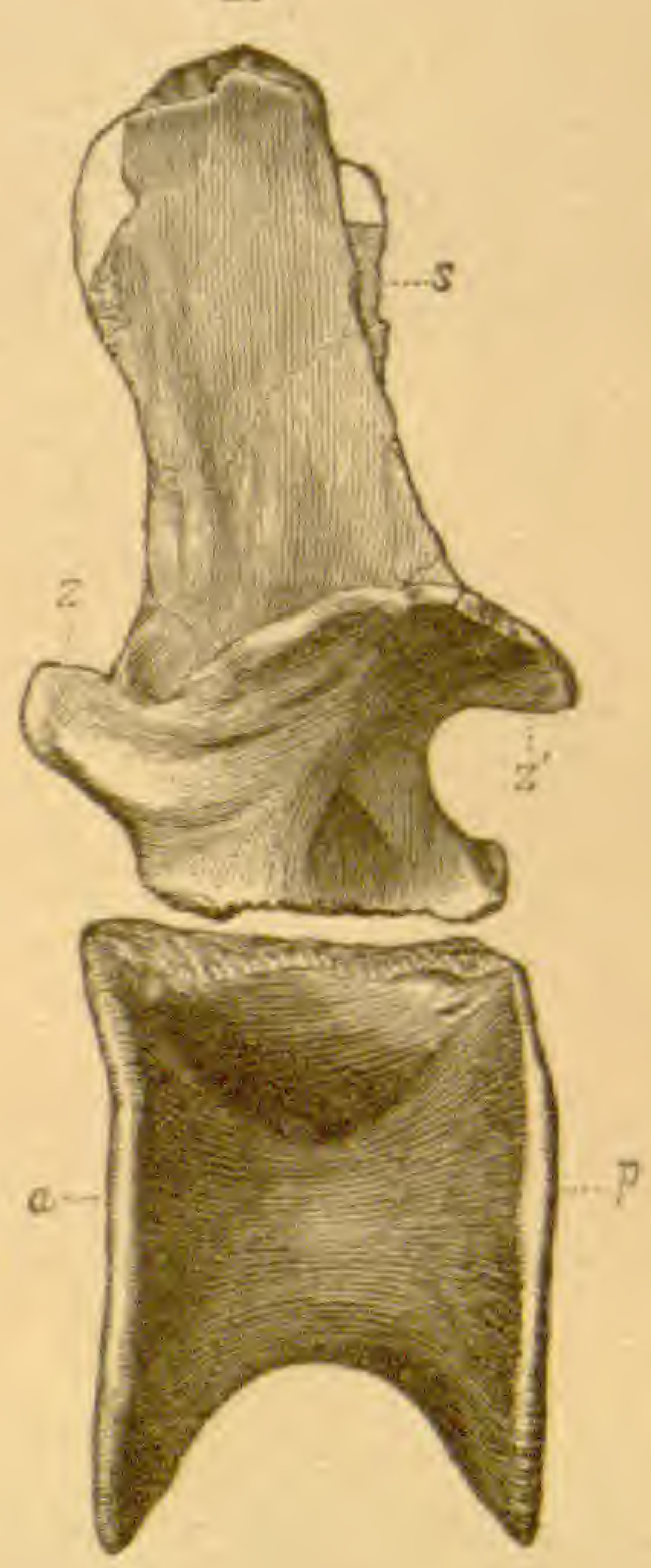
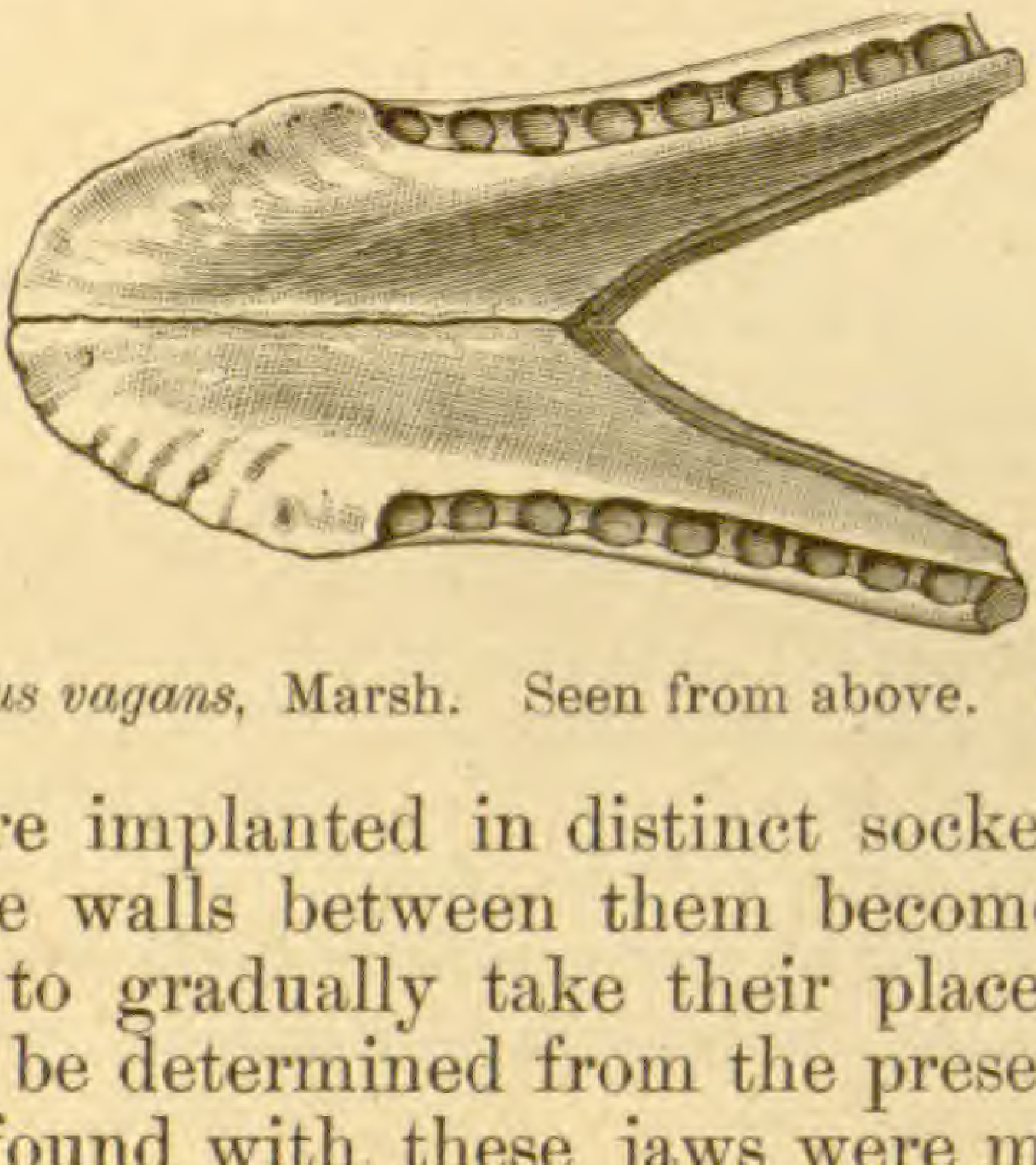


CREOSAURUS ATROX, Marsh.

ART. XXXIX.—*A new order of extinct Jurassic Reptiles* (MACELOGNATHA); by O. C. MARSH.

A NEW type of reptilian life is represented in the Yale Museum by various remains, the most characteristic of which are the two dentary bones of the lower jaws. These bones resemble in many respects the corresponding parts of a Turtle, but are broader, and more nearly horizontal. The jaws were evidently covered with a horny beak in front, but further back they contained teeth. The edentulous portion is flat and thin, and nearly horizontal. The two rami meet in nearly the same plane, and are united at the symphysis by a close suture. The form and general characters of these specimens are represented in the cut below.



Jaws of *Macelognathus vagans*, Marsh. Seen from above. One-half natural size.

The teeth were implanted in distinct sockets, in front, but further back, the walls between them become thinner, and a groove appears to gradually take their place. The form of the teeth cannot be determined from the present specimen.

The remains found with these jaws were mostly Chelonian, but none were associated with them in such position as to warrant the conclusion that they pertained to the same animal.

These fossils indicate a new order of reptiles, which may be called the *Macelognatha*, and the family, *Macelognathidæ*. The genus and species may be termed *Macelognathus vagans*.

These jaws are too solid and massive for Birds or Pterodactyles. With Serpents and Lizards they have evidently only remote affinities. The close union of the rami by suture separates them from the Dinosaurs, and the endentulous beak, from Crocodiles. So far as now known, they appear to be nearest allied to the Chelonia, although Turtles without teeth occur in the same strata with them.

The geological horizon of these peculiar remains is in the Atlantosaurus beds of the Upper Jurassic. The locality is in Wyoming Territory.

Yale College, March 21st, 1884.

THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. XL.—*Remarks on Professor Newcomb's "Rejoinder;"* by JAMES CROLL, LL.D., F.R.S.*

IN this Journal for last January, Professor Newcomb has done me the honor to reply to my remarks in the October number on his Review of 'Climate and Time,' which appeared in this Journal, May, 1876. With regard to this Rejoinder of his, I regret that I must repeat what I said about his Review, viz: that nearly all his objections are based on strange, and to me unaccountable, misapprehensions of my reasoning and of the views which I actually hold. I have no desire to continue this controversy, but may be allowed briefly to refer to those points on which I have been so thoroughly misunderstood.

Of course I fully concur in Professor Newcomb's opening remarks as to the desirability of "a purely mathematical investigation of the subject." Such an investigation, however, is, I think, impossible at present. In a question so complex and difficult as that of the cause of the Glacial epoch, depending as it does on the consideration of so many different elements, some of which are but little understood, logical analysis rather than mathematics will require to be our instrument in the mean time. The question must first assume a clear, definite and logical form before mathematics can possibly be applied to it.

Prof. Newcomb objects that my language is wanting in quantitative precision—that I use such terms as "great," "very

* Communicated by the Author.

great," "small," "comparatively small," and so forth, without any statement of the units of comparison relatively to which these expressions are employed. No one reasoning on the combined influence of a multitude of physical causes could well avoid the almost continual use of such terms. Besides, my critic forgets that in almost every case in which I use these terms numerical exactness is not attainable; and even if it were, it would, as a rule, be of little service, seeing that the conclusion generally depends on the simple fact that one quantity is less or greater than another, not on *how much* less or *how much* greater the one may be than the other. Although my arguments are logical, few writers, I venture to say, have done more than myself to introduce definite quantitative exactness into the questions I have discussed.

Prof. Newcomb gives his readers to understand that I assume Newton's law of cooling to be correct; and that I apparently nowhere adduce the more correct law of Dulong and Petit—viz: that if we take a series of temperatures in arithmetical progression, the corresponding rates of radiation of heat will not be in arithmetical progression, but in a series of which the differences continually increase. If he will refer to the 'Reader,' Dec. 9, 1865, Phil. Mag., Feb. 1870, 'Nature,' April 1, 1880, and 'Climate and Time' (the book he reviewed), p. 37, he will there see the question discussed at considerable length. He will also find reference made to a remarkable circumstance connected with radiation which perhaps may be new to him. It is this: the law of Dulong and Petit (that as the temperature of a body rises the radiation of the body increases in a much higher ratio) holds true only of the body considered as a mass. The probability is, as has been shown by Prof. Balfour Stewart, that the individual particles composing the body obey Newton's law in their radiation; in other words, the radiation of a material particle is directly proportionate to its absolute temperature.

Further, in estimating the extent to which temperature is affected by a change in the sun's distance, Newton's law makes the extent too great; while the formula of Dulong and Petit, which is an empirical one, makes it, on the other hand, too small. This formula has been found to agree pretty closely with observation within ordinary limits, but it completely breaks down when applied to determine high temperatures. For example, it is found to give a temperature for the sun of only 2130° F., or not much above that of an ordinary furnace. It is probable also that it will equally break down when applied to very low temperatures, such as that of space.

I am very much pleased to find that Prof. Newcomb draws a conclusion from Dulong and Petit's law favorable to my theory of the cause of the Glacial epoch, which certainly did escape my notice. And it is a curious circumstance that Mr. Hill* has likewise deduced a conclusion even more favorable to glaciation than that of Prof. Newcomb.

Prof. Newcomb says:—" Mr. Croll suggests that I may have forgotten the researches of Pouillet and Herschel into the temperature of space. I reply that I regard the conclusion that the temperature of space is −239° as having no sound basis." This may be perfectly true; but it is hardly a warrant for affirming that practically there is but one source (the sun) from which the surface of the earth receives heat, without even referring to the researches of these eminent physicists, who have arrived at a totally different conclusion. Any one who has read 'Climate and Time' will know that I adopted −239° as the temperature of space, not because I believed that estimate to be correct, but because at the time I wrote there was no other to adopt. In fact, in adopting so high a temperature for space I was doing my theory a positive injury. This is obvious; for the lower the temperature of space the greater must be the decrease of temperature resulting from an increase in the sun's distance due to eccentricity. My opinion all along has been that the temperature of space is little above absolute zero.

As an argument against the conclusion that space can have the high temperature assigned to it by Pouillet and Herschel, he says:—"Photometry shows that the combined light from all the stars visible in the most powerful telescope is not a millionth of that received from the sun, and there is no reason for believing that the ratio of light to heat is incomparably different in the two cases." This very argument from the extreme smallness in the amount of light derived from the stars in comparison to that from the sun, intended by him to convince me of the absurdity of supposing that space possesses a temperature as high as −239°, is just the very argument advanced by myself upwards of eighteen years ago, in the 'Reader' for December 9, 1865, and afterwards reproduced in 'Climate and Time,' at page 39, from which I quote the following:—

"We know that absolute zero is at least 493° below the melting-point of ice. This is 222° below that of space. Consequently, if the heat derived from the stars is able to maintain a temperature of −239°, or 222° of absolute temperature, then nearly as much heat is derived from the stars as from the sun. But if so, why do the stars give so much heat and so very little light? If the radiation from the stars could maintain a thermometer 222° above absolute zero, then space must be far more transparent to heat-rays than to light-rays, or else the stars give out a great amount of heat, but very little light, neither of which

* "Evaporation and Eccentricity as Co-factors in Glacial Periods," Geological Magazine for November, 1881.

suppositions is probably true. The probability is, I venture to presume, *that the temperature of space is not very much above absolute zero.*"

In regard to Professor Newcomb's objections to the reasons which I have adduced to show that the ocean ought to be warmer than the land, I am at a loss to understand how he can have so completely misunderstood me on that point. I thought I had expressed my views with sufficient clearness, but now fear I cannot have done so. I need not, however, again go over my argument in detail, but shall simply state what the views are which I have all along maintained. This will suffice to show that these views are diametrically the opposite of those which my critic has attributed to me.

The temperature of a body can remain stationary only when the rate at which it is losing equals that at which it is receiving heat. If heat be lost more rapidly than it is received the temperature will fall. The fall of temperature will diminish the rate of loss till the rate of loss equals the rate of gain. After this the temperature becomes stationary. If we have two bodies, A and B, the same in every respect, each receiving (say from the sun) the same amount of heat in a given time; and if the only difference between them be that A has a greater difficulty than B in getting quit of the heat which it is receiving; then, for the reason just assigned, A will necessarily stand at a higher temperature than B. Let us now suppose the southern, or water hemisphere, to be A, and the northern, or land hemisphere, to be B. I have endeavored to show ('Climate and Time,' and elsewhere) that A, the water hemisphere, ought to have a higher mean temperature than B, the land hemisphere, because the former has a greater difficulty in getting quit of the heat which it is receiving from the sun than the latter. The question then arises, how is it that the water hemisphere has a greater difficulty than the land hemisphere in getting rid of its heat. It is mainly due to that cause which Professor Newcomb says is quite new to him, viz: the fact that *the aqueous vapor of the air is far less diathermanous to radiation from water than from land.* It is a curious fact that Professor Newcomb, in his "Rejoinder," entirely overlooks this cause assigned by me, although I have stated it fully in my fourth reason. The *period* of the heat-vibrations of the aqueous vapor of the air is the same as that of the ocean, and consequently the aqueous vapor will absorb radiation from the ocean more readily than from the land. A considerable portion of the heat absorbed by the aqueous vapor of the air is thrown back upon the ocean, and in this way the aqueous vapor acts as a screen, or like the glass of a greenhouse, in preventing the ocean from getting quit of its heat so rapidly as the land. The result is that the temperature of equilibrium of the ocean must be higher than that of the land. In other words, before the ocean can manage to throw off its heat into space as rapidly as it is receiving it, its temperature must be higher than that of the land.

The foregoing conclusion follows so obviously from the known properties of aqueous vapor and the principles of thermodynamics that I can hardly believe Professor Newcomb will call it in question. But he will ask how can the transparency of the ocean for heat-rays, the mobility of its particles, and the greater store of heat which it possesses, be a reason why its mean temperature should be higher than that of the land? I thought I had made all this clear. The reason becomes apparent when we consider why it is that the surface of the ocean during night and also during winter is warmer than the surface of the land. The ocean in temperate regions seldom sinks to the freezing-point, while the land is frequently frozen for months. The cause is obvious enough: at night, when the surface of the ocean becomes cool, the cold particles sink and their places are supplied by warm particles from below, and so long as the heat stored up remains, the surface can never become cold. Were it not for the transparency of water for heat-rays, it would be impossible that the ocean could obtain a supply of heat sufficient to maintain its surface-temperature during the entire winter; and, on the other hand, were the particles not mobile, this store could be of little service.

It is true that the land is hotter during the day and also during the summer than the ocean, but it is found that the more equable temperature of the ocean gives a higher mean. This is further shown from another consideration. The land is more indebted for heat to the ocean than the ocean is for heat to the land. For example, a very considerable portion of the warmth enjoyed by Northwestern Europe is derived from the Atlantic. In like manner, Western America is indebted to the Pacific for a large amount of its heat. In addition an immense quantity of the heat received from the sun by the ocean is consumed in producing evaporation, and a large portion of this heat, latent in the vapor, is bestowed on the land during condensation. Yet, notwithstanding this transference of heat from the ocean to the land, the mean temperature of the former is greater than that of the latter. Were it not for its store of summer heat the ocean could not afford to part with so much of its heat to the land during winter and still maintain a higher mean temperature.

I come now to the consideration of the most singular of all Professor Newcomb's misapprehensions—that one, namely, which has reference to my third reason. In that reason I stated, what every physicist knows to be perfectly correct, that the aqueous vapor of the air radiates back a portion of its heat; and the ocean, for reasons which have been already stated, absorbs this radiation more freely than the land. Radiation from the air therefore tends more readily to heat the ocean than it does the land. Professor Newcomb says that this involves the *reductio ad absurdum* of two bodies heating each other by their mutual radiation. This is not the state of the case at all, for both bodies receive their heat from the sun; their mutual radiation simply retains them at a higher temperature than they could otherwise have. Here Professor Newcomb appears to get into confusion owing to the meaning which he attributes to the word "heating." The views which I have advocated in reference to this mutual radiation are as follows: According to the dynamical theory of heat, all bodies above absolute zero radiate heat. If we have two bodies, A at 200° and B at 400°, then, according to Prevost's theory of exchanges, A as truly radiates heat to B as B does to A. The radiation of A, of course, can never raise the temperature of B above 400°; but nevertheless the *tendency* of the radiation of A, in so far as it goes, is to raise the temperature of B. This is demonstrated by the fact that the temperature of B, in consequence of the radiation of A, is prevented from sinking so low as it would otherwise do. All this is so well known to every student of thermodynamics, that I can hardly think Professor Newcomb, on reflection, will dispute its accuracy. And if he admits this, then he must also admit the soundness of my third reason, for this is the principle on which it is based. The aqueous vapor of the air absorbs a considerable amount of the heat which is being constantly radiated by the ocean; a portion of this heat thus absorbed is thrown back upon the ocean, the tendency of which is to keep the surface of the ocean at a much higher temperature than it would otherwise have. Prof. Langley has concluded, from observations made at Mount Whitney, that were it not for the heat thrown back by the atmosphere, or "trapped" as it is popularly called, mercury would remain solid under a vertical sun.

In his Review of 'Climate and Time,' Professor Newcomb advocated, as a fatal objection to my theory, that the quantity of heat received from the sun during summer would be sufficient to melt in a few days the entire amount of snow and ice accumulated during winter.* This objection, I pointed out in my reply (this Journal, Oct., 1883, p. 264), is based on the erroneous assumption that the quantity of snow and ice melted

* Were this objection correct it would prove that there could have been no Glacial Epoch; for it is obvious that had not the sun's heat failed to melt the winter's snow, not during the course of a few days merely but during the entire summer, there could not possibly have been permanent ice.

must be proportionate to the amount of heat received from the sun. In proof of the erroneous nature of this assumption, I refer to the fact that on the lofty summits of the Himalayas and Andes, for example, the quantity of heat received from the sun would be sufficient to melt at least fifty feet of ice per annum, and that is no doubt more than ten times the quantity actually required to be melted; yet notwithstanding the snow remains permanent. The cause of this non-melting I showed is due to the fact that at these elevations, owing to the dryness of the air (want of aqueous vapor), the loss of heat from radiation into stellar space is so excessive that the rays of the sun, intense as they undoubtedly are, are unable to raise the temperature of the snow to the melting-point; consequently, no matter what may be the amount of heat received, the snow can never melt. It may evaporate, but it cannot melt. I further pointed out that, were the aqueous vapor possessed by the atmosphere sufficiently diminished, the snow-line would descend to the sea-level even at the equator, and perpetual snow would cover our globe down to the sea-shore.

I was much pleased to find that Professor Newcomb has not only adopted these views regarding the effects of an absence of aqueous vapor, but suggested that they may yet afford an explanation of the cause of the Glacial epoch. Every one familiar with the subject, however, knows that that epoch was not due to a dryness of the air, but the reverse.

ART. XLI.—*Communications from the U. S. Geological Survey, Rocky Mountain Division.* VI. *On an interesting variety of Löllingite and other Minerals;* by W. F. HILLEBRAND.

[Read before the Colorado Scientific Society, April and Dec., 1883.]

AROUND the base of Teocalli Mountain, on Brush Creek, Gunnison County, Colorado, there occurs, in several mines, a cobaltiferous and nickeliferous variety of löllingite of such peculiar appearance as to arrest my attention at a glance. Close scrutiny so strongly confirmed the interest at first excited, that a series of observations was undertaken, of which the results are embodied in the following.

The precise locality of occurrence of the specimens examined was unknown to Mr. William McCree, who presented them to the Colorado Scientific Society, but Mr. J. G. Ridgley has observed the mineral at various places on Brush Creek, and has investigated its occurrence, particularly at the Luona mine on the northwest slope of Teocalli Mountain. It is here found, according to Mr. Ridgley, associated with native silver, proustite, argentite, pyrargyrite, chalcopyrite, galena, siderite, barite and calcite, the last three composing the gangue. Much of it is decomposed, forming secondary oxidized products, most conspicuous among which is erythrite.

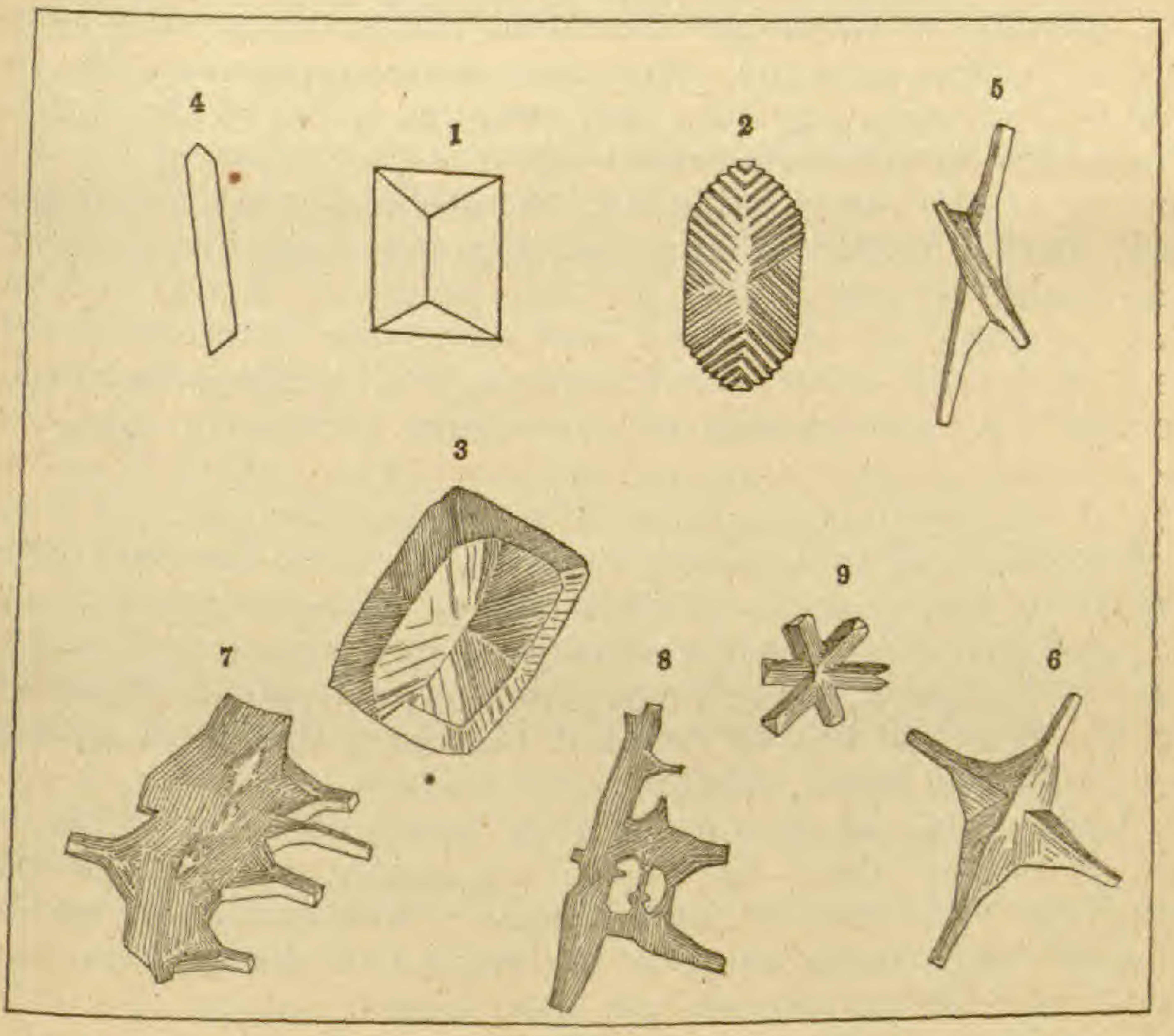
The mineral seems to occur in some quantity, and one of the specimens examined was of several pounds weight. The striking appearance already alluded to becomes visible only on fractured surfaces. There are seen, embedded in the siderite and barite gangue, steely-white forms, one-eighth of an inch, more or less, in diameter, of pronounced radiate structure, the longer radii protruding from the mass, and giving the whole a beautiful stellate appearance. The star forms occur sometimes singly, but more frequently joined together in greater or less number, without losing in any marked degree the peculiar character of the individual. In some specimens the appearance approaches that of a dense homogeneous mass several inches in diameter, but even in the densest portions the radiate structure is generally distinctly discernible.

In order to discover, if possible, a clew to the crystallographic structure, and also to obtain material for analysis, specimens were treated with hydrochloric acid without previous crushing, whereby the siderite and the arseniates of iron, cobalt and nickel were entirely dissolved. The löllingite remained quite black on all parts where the gangue had been eaten away, but surfaces of previous fracture retained their white color. The star-like forms were then seen to be composed of a considerable number of long flattened ellipsoids, interpenetrating at a common center in every direction. When one of these clusters was broken through the star form appeared on the surface of fracture. The aggregates were joined together loosely, now that the cementing material had been removed, though frequently in large clusters of many hundreds of all sizes, from those visible only with the aid of a microscope, to others an eighth of an inch or more in diameter.

A microscopic study of the finer part of the material liberated from its imprisonment in the gangue, and broken off from the larger pieces during the treatment with acid and subsequent washing, furnished the solution to the question as to what was the crystallographic form of the flattened ellipsoids composing the aggregates and the law of the twinning. The fundamental form is that of löllingite, showing only the prism and macrodome, as in fig. 1.* Frequently these two forms are equally developed, producing a resemblance to a low pyramid of the tetragonal system. Very few even of the most minute crystals are

* All the accompanying figures, with the exception of fig. 1, were drawn by the aid of a camera lucida, and therefore make no pretensions to crystallographic accuracy. Fig. 4 is magnified about 15 diameters, the others from 40 to 150 diameters.

perfect in form, and possessed of sufficiently smooth surfaces to allow of even approximate measurement under the microscope. Repeated attempts were made to get these in proper position under the instrument, but in only one case with comparative success, owing to their microscopic size. The angle of the prism was then found to be very nearly 122°, that given for löllingite being 122° 26′.



Parallel to the combination edge of the prism and macrodome there is almost always on the prism a striation (more coarsely marked the larger the crystal), caused by the alternate reproduction of the prismatic and domatic faces. Approaching the combination edge the reproduced dome face becomes relatively larger than that of the prism, the consequence of which is a gradual rounding of the corners and a contraction and eventual disappearance of a distinct terminal dome, the result being as represented in fig. 2, an ellipsoidal form with a slight ridge through the center representing a prism edge. Frequently the corners of a crystal, occupying the position of fig. 1, appear as if modified by a brachydome, but no such form has been observed, the replacement being a straight serrated edge, caused by the same alternation of faces as in the case of rounded corners. Even where the macrodome is well developed it generally shows a continuation in some degree of the prismatic striation parallel to the same combination edge.

The first step toward the complex twin structure is the formation of a simple twin, or rather trilling, by interpenetration of three single crystals having the basal section in common, and a face of the prism as the composition face (fig. 3). A basal section shows a six-rayed star, with angles of very nearly 60°, by microscopic measurement, between the axes of the rays. In the microscopic twins one individual frequently predominates greatly in size over the other two, these appearing often as thin leaves, projecting but a short way out of the larger crystal. These trillings are finally found again interpenetrating, not according to any recognizable law, but seemingly in every direction, and in indefinite numbers, forming thus the complex aggregates first spoken of. All these stages of change in form may be observed with great ease under the microscope, the very smallest crystals alone showing crystallographic faces well defined. As the crystals, single or twin, increase in size, the faces gradually grow more and more indistinct, and finally disappear entirely in consequence of increasing striation.

Notwithstanding repeated attempts, the basal cleavage mentioned in text-books as characteristic of löllingite could rarely be produced, and never a cleavage in any other direction, except in the case of the trillings. Here an individual frequently broke off at the line of union of the three, that is, in a plane parallel to the brachypinacoid.

Aside from the forms distinctly recognizable as löllingite are, however, others belonging, apparently, to two different minerals. The first of these became visible on dissolving the gangue, when there came to the surface of the acid and the water used for washing out the latter a great number of minute but brilliant metallic particles which resolved themselves under the loupe, and still better under the microscope, into thin leaves or blades, of which fig. 4 represents one of the more perfect examples. Its forms appear to consist of two pinacoids of the rhombic system, one very broad, the other very narrow, and a terminal dome having an angle of almost exactly 90° by microscopic measurement. The faces are most brilliantly reflecting. Distinct cleavage was not observable. The second mineral, which is almost always microscopic in size, is represented in figs. 5, 6, 7 and 8. The prominent form is that of a lengthened prism with an angle of very nearly, if not quite, 90°. Repeated measurements gave values fluctuating between 88° and 92° as the extremes. It is terminated at right angles by a basal plane, the four corners of which are frequently replaced by faces which may be those of a pyramid or two domes, according as the habit is pinacoidal or prismatic. The cleavage is parallel to the base. Single crystals are rare, two or more being generally seen interpenetrating as in figs. 5 and 6, generally at an angle of 90°, or united as in figs. 7 and 8. In the latter figure only the outlines, not the faces of the different horizontal individuals, are shown, nor do the numerous vertical attachments present appear either in this figure or in fig. 7. Occasional instances of three prisms, crossing at right angles like the axes of a rectangular system, were observed, and also a single instance of the form represented in fig. 9 where each of the arms showed a domatic face. The most striking feature of all but the last of these different forms is the invariable widening at the point of union or intersection, as shown in the figures.

Even an approximate separation of these two minerals from each other and from the smallest löllingite crystals was impossible, hence no conclusion could be reached as to their quantitative composition. Qualitative tests proved them both to be arseniates of cobalt, the square prismatic forms containing also iron and nickel. An incomplete quantitative test upon a mixture of these three minerals showed a much higher percentage of cobalt and nickel than the analysis of the pure löllingite.

Before the blowpipe the löllingite furnished the reactions mentioned in the text-books, the residue, after treatment on charcoal, being infusible, strongly magnetic, and furthermore, giving the characteristic reaction for cobalt with fluxes. Soluble in nitric acid, giving a pink solution.

Of the analyses given below, I was made upon clusters of löllingite trillings, free, so far as could be determined by the loupe, from attached or penetrating blades or prisms of the other two minerals described. As a check, a small quantity of the single crystals and trillings was picked out with the utmost care under the microscope and subjected to partial analysis (II), no trace of foreign adherent matter being visible. The specific gravity of the material used for the first analysis was 7·335 at 14½° C. Correcting for one-half per cent of siliceous gangue of assumed specific gravity, 2·65, the true specific gravity of the mineral becomes 7·400.

	I.	II.
As	71·18	----
S	0·56	----
Bi	0·08	----
Cu	0·39	----
Fe	22·96	22·69
Co	4·37	4·20
Ni	0·21	0·19
	99·75	

The first of these analyses leads closely to the formula Fe(CoNi)As(S)$_2$, while II shows beyond a doubt that both cobalt and nickel are constituents of the löllingite and not derived from attached crystals of either of the other minerals. The presence of cobalt recalls the glaucopyrite of Sandberger, though the antimony found in that mineral is here wanting. The peculiar comb-like excrescences described by him, indicating rhombic twinning by interpenetration, may be analogous in some degree to the twinned structure of the present mineral.

Some varieties of rhombic $CoAs_2$, all of which, according to Leroy W. McCay,* should be united under the name safflorite, present features remarkably like some of those herein described, notably as regards the tendency to form twins of interpenetration; and from the presence of cobalt it might be suspected that this mineral was rather to be considered as safflorite than löllingite. Its exceedingly high percentage of iron and high specific gravity, as well as the occurrence of a macrodome instead of the brachydome mentioned by Sandberger as peculiar to the rhombic $CoAs_2$ render necessary, however, its classification with löllingite.

Cosalite.

In the collection of the Colorado Scientific Society, are a few specimens of a mineral from the Comstock mine, near Parrott City, La Plata County, Colorado, presented by Mr. R. C. Hills, according to whom it occurs in a quartz vein associated with pyrite, sphalerite, a telluride of unknown composition, though probably sylvanite, and native gold. In the specimens examined it appears in irregular masses of small size, rarely an inch in length, never equally thick, and generally much smaller, without cleavage or recognizable crystalline structure, except for an occasional faint indication of fibrous texture on fractured surface. The fracture is irregular, color grayish-white, but pale yellow on exposed surfaces; hardness about 3·5; specific gravity undetermined.

The outer zone of the small bodies spoken of is found on close examination to be a mixture of two or more minerals, among which minute grains of pyrite were alone recognizable. Sufficient material was however obtained for analysis, free from all impurity, except a little pyrite and 1·29 per cent of insoluble gangue. This afforded the following reactions: in closed tube, sublimate of sulphur; in open tube, formation of sulphur dioxide; on charcoal fusible, giving reactions for lead, bismuth, silver and copper; soluble in chlorhydric and nitric acids, in the former with precipitation of silver chloride. The analysis, after deduction of the gangue, gave these results:

* Inaugural Dissertation, Freiberg, 1883.

Bi	42·97
Ag	8·43
Cu	7·50
Pb	22·49
Fe	0·70
Zn	trace
S	17·11
	99·20

Allowing for the iron and a proportionate amount of sulphur as pyrite, the atomic ratio deduced from the above is:

R	:	Bi_2	:	S
2·02	:	1·00	:	4·98

showing the general formula for the mineral to be $2RS+Bi_2S_3$, wherein R represents Pb and the double atoms Ag_2 and Cu_2. The ratio of Ag_2+Cu_2 : Pb is 1 : 1·11.

Although copper was absent and but 2·65 per cent of silver present in the mineral originally described by Genth as cosalite, it does not appear advisable in the absence of any data as to the crystallographic form to consider this a distinct species, but to class it, as has been done with bjelkite, under cosalite.

A PROBABLY NEW MINERAL.

A portion of the ore from the Missouri mine, Hall's Valley, Park County, Colorado, is composed largely of a sulpho-bismuthite of copper and silver. It occurs in a quartz gangue associated with chalcopyrite and wolframite, and although the latter is only visible on close examination, it comprises from one to two per cent of the whole, as found by special tests.

A considerable quantity was extracted by chemical and mechanical means, free from all foreign matter, except a little attached quartz, and was proven to be wolframite by qualitative chemical tests and by a determination of the specific gravity.

The mass of the sulpho-bismuthite appears throughout the quartz as a dark bluish gray substance without distinct forms of crystallization. In numerous cavities appear small slender crystals, generally bronzed by oxidation and so deeply striated as sometimes to present the appearance under the loupe of bunches of needles. Occasionally they seem to be joined together laterally, forming thin corrugated plates. Owing to this deep striation no crystal faces can be detected either on the sides or the free terminations. The habit is strikingly like that of bismuthinite, for which the crystals were, indeed, at first taken.

After several days' labor, enough material was removed from the cavities for the determination of the metals. It could not, however, be freed altogether from quartz and chalcopyrite. The specific gravity at 17° C. was 5·75. Making correction for 4·43 per cent of quartz and 6·98 per cent of chalcopyrite of assumed specific gravities 2·65 and 4·2, this becomes 6·31. The analysis appears under I below.

The more compact material, excluding as far as possible, the needles, gave, after deducting 59·75 per cent of gangue, the results under II.

III is the analysis of a mineral presented by Mr. William McCree as coming probably from the Missouri mine. In appearance it differs in no respect from the compact material already described, except that no chalcopyrite is distinctly visible in the small specimens at my disposal and the quartz grains are less firmly cemented together. It contains, however, some lead which is entirely wanting in the other specimens analyzed, although the general formula is the same, hence I am led to believe that it came from some other portion of the workings or from an adjacent mine where ore like that from the Missouri mine is reported to occur. The specific gravity was 3·869 at 15° C., which becomes 6·680 on making correction for 47·57 per cent of gangue of ascertained specific gravity, 2·643.

The most marked blowpipe reactions for I, II and III were entirely similar, a sublimate of sulphur appearing in the closed tube, sulphur dioxide escaping in the open tube and the fused fragment or powder on charcoal affording the bismuth reactions with great intensity. All were soluble in nitric and chlorhydric acids, in the latter with precipitation of silver chloride.

	I.	I.	III.
Bi	60·80	63·42	62·51
Ag	0·89	4·09	9·89
Cu	15·96	12·65	6·68
Pb			2·74
Fe	2·13	0·59	0·10
Zn	0·10	0·07	0·07
S	19·94*	18·83*	17·90
	99·82	99·65	99·89

After subtracting from I, 6·97 per cent; from II, 1·91 per cent, and from III, 0·33 per cent of chalcopyrite with the proportions of sphalerite represented by the zinc, the atomic ratios become:

	R	:	Bi_2	:	S
I	3·00	:	3·91	:	14·75
II	3·00	:	3·99	:	14·98
III	3·00	:	4·06	:	15·15

* Calculated.

where R repesents Pb and the double atoms Ag_2 and Cu_2. In each case the ratio is nearly 3 : 4 : 15, which leads to the general formula $3RS+4Bi_2S_3$.

It seems probable that the needle-like crystals are a pure sulpho-bismuthite of copper and that, in the more compact portions, silver replaces a portion of the copper and in some cases a further replacement of copper by lead takes place.

This ore from the Missouri mine is auriferous. The material used for analysis II, gangue and sulphide together, assayed 1·85 ozs. gold to the ton. Mr. Richard Pearce, of the Boston and Colorado Smelting Works assures me that it is frequently much richer, running as high as 40 ozs. to the ton.

Before conferring a name upon this mineral or even definitely claiming it is a new species, I purpose investigating more fully the similar ores which are said to occur in other mines in the neighborhood of the Missouri mine. As this further investigation will, of necessity, be postponed for some time, the results already arrived at are now put on record.

Hübnerite.

In the collection of the Colorado Scientific Society are specimens of hübnerite from the Royal Albert vein, Uncompahgre District, Ouray County, Colorado, presented by Mr. R. C. Hills,

The mineral occurs in long flattened crystals vertically striated, imbedded in quartz, but none sufficiently well formed for measurement could be extracted, in fact, definite faces are rarely visible, though two prisms and the orthopinacoid have been observed. The luster is subvitreous to resinous and the color brownish-black to pale yellow in very thin crystals. In transmitted light the color is ruby-red to yellow slightly tinged with green when the thickness is not too great. Extinction takes place parallel to the vertical axis in a plate parallel to the orthopinacoid and at an angle of 19° to 20° to the same axis in a cleavage section parallel to the clinopinacoid, as observed by DesCloizeaux for wolframite. In the plates parallel to the orthopinacoid a tendency to cleave at right angles to the clinopinacoid and also at angles approximating 61° and 68° to the same face was observed. The specific gravity at 24° C. is 7·177 and the composition as follows:

SiO_2	0·62
Nb_2O_5 ?	0·05
WO_3	75·58
MnO	23·40
FeO	0·24
CaO	0·13
	100·02

which agrees very closely with that required by theory for the formula $MnWO_4$.

This mineral is also found in a mine near Phillipsburg, Montana Territory, according to Mr. Richard Pearce. The specimens in the collection of the Colorado Scientific Society show large flattened crystals of imperfect form in quartz. Mr. A. H. Low, Chemist at the Boston and Colorado Smelting Works, has analyzed the mineral approximately and found—

WO_3	74·82
MnO	25·00
FeO	0·06
	99·88

ART. XLII. — *Notes on American Earthquakes:* No. 13; by Professor C. G. ROCKWOOD, Jr., Ph.D., Princeton, N. J.

THIS article, the thirteenth in the series, embodies such notices as have come to the knowledge of the writer in regard to the earthquakes which occurred in North and South America and the adjacent islands, during the year 1883. The information has been derived from the current newspapers; from the Monthly Review of the U. S. Signal Service; and from Professor F. E. Nipher, Director of the Missouri Weather Service; Charles Carpmael, Superintendent of the Canadian Meteorological Service; and J. M. Batchelder of Cambridge, Mass.

Items which are regarded as doubtful are, as heretofore, printed in smaller type; and in many cases the source of the information is indicated. Also, to avoid the danger of confounding *a. m.* and *p. m.* dates, the system of numbering the hours of the civil day from one to twenty-four has been adopted.

1883.

Jan. 1.—At 2^h 58^m and 8^h 28^m two earthquake shocks at Addison, Me.—*U. S. Weath. Rev.*

A shock in other parts of Maine and Nova Scotia about 22^h on the previous day was noticed in the last report (this Journal, xxv, p. 360).

Jan. 6.—Between 2^h and 3^h a shock was reported to have been felt in northern Ohio.—*N. Y. Times.*

Jan. 9.—At 3^h a shock from east to west at Huntingdon, Ont.—*Canadian Meteorol. Serv.*

Jan. 11.—Between 1^h and 2^h a decided shock was felt along the Mississippi River, from St. Louis, Mo., to Memphis, Tenn.

It was reported from numerous places as far east of the river as Shelbyville in central Illinois, Shawneetown on the Ohio River, and Clarksville and Nashville, Tenn., and from places in southeastern Missouri; but does not seem to have been felt west of a line joining St. Louis and Memphis, unless a doubtful report from Protem, Taney county, in southwestern Missouri, of a slight shock at about 12^h of the 10th is to be referred to the same, which does not seem probable. The most careful statement of time was from St. Louis, where the report was: "Four distinct shocks, beginning at $1^h\ 11^m\ 30^s$, each shock followed by tremors lasting five to ten seconds, direction S.E. to N.W., no sound, entire time 50 to 60 seconds." At other places the time was given all the way from 1^h to 2^h, with a preference for 1:15 or 1:20. In most of the reports no mention is made of more than one shock; but at Memphis three were noted, and at Cape Girardeau, Mo., two; while at Anna, Ill., a slight shock had been noticed at $14^h\ 25^m$ of the 10th. The severity of the movement was greater than in either of the two earthquakes which in the September and October previous had affected this region. Buildings were rocked, chandeliers caused to swing, engine bells rung, etc. The greatest motion was reported from Cairo, Ill., and vicinity, which also is about the middle of the area shaken.

Jan. 11.—At $19^h\ 34^m$ a strong earthquake shock was felt at Iquique, Pisagua, Dolores, Posa Almonte, La Noria and Huanillos, all in southern Peru. The motion lasted about 30 seconds, and a lighter shock followed a few minutes afterward.

Jan. 23.—At 5^h a slight earthquake at Los Angeles, Cal., vibration from north to south. Two distinct shocks were felt, separated by an interval of about two seconds.—*U. S. Weath. Rev.*

Jan. 23.—At $23^h\ 40^m$ a sharp shock at San Francisco, Cal. and vicinity.—*U. S. Weath. Rev.*

Feb. 4.—At 5^h a distinct shock was felt at Bloomington, Ill. and at various places in northern Indiana and southern Michigan. At the former place a prolonged rumbling was heard, followed by the shock. At St. Louis, Mo., this shock was noticed by several observers, as "two sharp *sounds* about four seconds apart," which were not at first attributed to subterranean causes, until it was found that they had been heard by many persons.

Feb. 4.—At $15^h\ 5^m$ a slight shock was felt at Wolfborough, N. H., followed ten minutes later by a second shock which was also reported at Cornish, Me., at $15^h\ 16^m$.

Feb. 5.—At $10^h\ 37^m$ a sharp shock was felt at Panama and in adjacent parts of the Isthmus. The Central and South American Company's submarine cable was somewhat injured.

Feb. 6.—At $16^h\ 30^m$ a slight earthquake at San Diego, Cal., direction of movement from north to south.—*U. S. Weath. Rev.*

Feb. 27.—At about $22^h\ 20^m$ what appeared to be a double shock of earthquake, accompanied by loud noises, was felt in southeastern Connecticut, southern Rhode Island and adjacent parts of Massachusetts, and was so reported by many newspapers. It appears, however, that a brilliant meteor passed over the country, at a low elevation, at the same time, and an investigation of the occurrence by Prof. H. A. Newton of Yale College, renders it probable that all the phenomena of vibration and noise were due to the explosion of this meteor and not to an earthquake.

Feb. 28.—"A strong earthquake shock was felt at Monte Christo, province of Manobi, Ecuador. The earth trembled for several seconds, but no damage was done."—*Newark (N. J.) Daily Advertiser.*

Mar. 5.—A shock at Tarbo, State of Cauca (U. S. of Colombia), extending to Carthagena on the Atlantic.

Mar. 7.—At 23^h 23^m a slight shock at Andes, Chili.

Mar. 8.—At 15^h 10^m a slight shock at Copiapo, Chili.

Mar. 8.—At 18^h an earthquake was felt on the Isthmus of Panama and widely through adjacent portions of the States of Colombia. At Carthagena and Turbu at the mouth of the Atrato it was sharp but not dangerous. In the State of Antioquia it was more severe; and in the towns of Antioquia, Santa Rosa, Yarumal and others, the cathedrals and other buildings were injured.

This and the three preceding notices are from Panama letters in the N. Y. Times.

Mar. 11.—At 10^h 57^m and 11^h 7^m two distinct shocks felt at Waterloo, St. Johns, and Cowansville, Quebec.

Mar. 11.—At 18^h 57^m a slight shock with rumbling, was felt in parts of Harford and Baltimore Counties, Maryland; sufficiently strong to rattle dishes and alarm many people. A second shock was reported to have occurred between midnight and 1^h of the 12th.

Mar. 23.—At 21^h 25^m a slight shock at Huntingdon, Quebec.—*Canadian Meteorol. Serv.*

Mar. 27.—At 20^h 35^m a slight shock at Iquique, Peru, preceded by rumbling noise.—*N. Y. Times.*

Mar. 30.—At 7^h 48^m, 7^h 52^m and 8^h 15^m light shocks were felt at San Francisco, Cal. and southward. At Watsonville, Santa Cruz County, nine shocks were felt; at Hollister, San Benito County, plate glass windows were broken, and brick walls cracked.

April 1.—At 1^h a smart shock at Hamilton, Ont.—*Canadian Meteorol. Serv.*

April 2.—At 8^h 50^m two light shocks, north to south, at San Francisco, Cal.—*U. S. Weath. Rev.*

April 12.—At 2^h 36^m a shock was felt at Cairo, Ill., lasting thirty seconds, vibration S.S.W. to N.N.E.

April .—Newspaper advices from Panama late in June, contain vague reports of seismic phenomena in the valley of the Atrato, States of Colombia, occurring during the last of April, by which Rio Sucio, forty miles from the Atlantic and Turbo, on the Gulf of Uraba, suffered injury; but reliable details of the phenomena have not come to hand.

May 1.—10^h and May 4.—14^h 30^m, earthquakes are reported to have occurred in connection with an eruption of the volcano Ometepe, on the island of the same name, in Lake Nicaragua. News of the occurrence first reached the New York papers, via Panama, on July 4, in a vague and probably exaggerated form. Although the fact of some eruption there seems to be confirmed by later advices, no reliable details are known.

May 4.—At 11^h 45^m a slight shock at Helena, Montana, from east to west.

May 10.—During the night of the 10th–11th a shock from north to south was felt in Victoria, British Columbia.

May 19.—A severe earthquake occurred in Ecuador, creating alarm in Quito and still more in Latacunga, fifty-five miles south of Quito, where a number of houses were overthrown. The neighboring villages also suffered very severely. An officer stationed in the village of Toacaso reported the first shock at 17^h 30^m, a second and more destructive one between 23^h and 24^h, and during that night *sixteen* shocks; while occasional shocks occurred during the succeeding days. An eruption of Cotopaxi was in progress at the time.

May 21.—"At 7 A. M. a slight earthquake was felt at Mompos, on the river Magdalena, in the State of Bolivar; which was followed by a sharper one at 2 A. M. on the 22d, on which day shocks were also felt at San Salvador and Guayaquil."—*N. Y. Herald.*

May 22.—At 23^h 30^m two distinct shocks were felt at Catlettsburg, Ky.

May 28.—At 21^h 55^m two earthquakes occurred in Valparaiso, Chili, in rapid succession.

June 3.—At daylight a strong and somewhat prolonged earthquake was experienced in Callao, Peru, but did no damage. At 1^h 30^m the same day, a much slighter movement was felt in Lima.

June 10.—At 9^h a shock lasting six seconds at Martinique, West Indies.—*J. M. B.*

June 19.—A new volcanic outbreak, accompanied by earth tremors, is reported to have occurred in the island of Ometepe, in Lake Nicaragua.

June 21 and 23.—Several earthquake shocks were experienced at Andes, Chili; and at 2^h 55^m of the 23d a sharp shock was felt at Valparaiso.

July 1.—At 3^h a slight shock at Carson City, Nevada.—*U. S. Weath. Rev.*

July 6.—At 11^h 15^m a light shock at Cairo, Ill., lasting five seconds.

July 7.—At 10^h 50^m a light earthquake at Los Angeles, Cal., direction not determined.—*U. S. Weath. Rev.*

July 7 and 9.—At midnight on the 7th and at 2^h on the 9th, sharp shocks were felt in San Salvador.—*N. Y. Times.*

July 14.—At 1^h 30^m a light shock, lasting eight seconds, at Cairo, Ill., reported also at Wickliffe, Ballard Co., Ky.

July 20.—At 16^h 48^m a severe shock was felt at Panama, direction west and east.—*N. Y. Times.*

July 30.—Two shocks, with rumbling sound, were reported at Gilroy, Cal.; hour not stated.—*N. Y. Times.*

Aug. .—Surgeon Main, at Brownsville, Texas, in a report to the Surgeon General of the Marine Hospital Service, says: "Early in August there was an earthquake shock at Pachuca, Mexico, causing twenty deaths and the destruction of twenty houses."

Aug. 4.—At 11^h and 12^h 50^m light shocks, east to west, at Oakland, Cal.—*U. S. Weath. Rev.*

Aug. 19.—At 2^h 55^m three slight shocks at Carson City, Nev. —*U. S. Weath. Rev.*

Aug. 27.—Prof. Geo. Davidson of San Francisco, reported to the U. S. Coast Survey, that at 1^h earthquake waves commenced to be recorded on the Saucelito tide gauge and continued to be observed during the 28th; height of waves one foot, time between crests about forty minutes. These waves were at first referred to the great explosion of Krakatoa in the Straits of Sunda, which took place on the same day about six or seven hours, actual time, before the time here stated. While this is possible, is it not more probable that they were due to some of the seismic phenomena vaguely reported as having occurred in the Aleutian Islands? (c. f. Oct. 6, this article).

Aug. 28.—At Talcahuano, Chili, earthquake waves were reported, commencing just before noon and continuing the rest of the day. These were very likely to be referred to the Krakatoa explosion on Aug. 27th.

Aug. 28.—At 22^h a sharp shock was felt at St. Thomas, West Indies.—*N. Y. Times.*

Aug. 29.—At 20^h a strong shock of earthquake lasting about fifteen seconds was felt at Guayaquil. At the same time there were reports of shocks felt in Salvador, Colombia and Ecuador, but no details are known to the writer.

Aug. 30.—Two shocks at St. Thomas, W. I., almost simultaneous; the first light, the second severe.—*N. Y. Times.*

Sept. 1.—At 8^h 25^m a light shock at Los Angeles, Cal., vibration north to south, followed by a second shock after four seconds.—*U. S. Weath. Rev.*

Sept. 5.—At 4^h 30^m, shocks were felt at Los Angeles, Santa Barbara (4^h 15^m) and Wilmington, Cal., the vibrations were N.E. to S.W. and were sufficient "to cause chandeliers to sway with considerable motion."

Sept. 6.—At 23^h prolonged shocks were felt at Lima, Peru.—*U. S. Weath. Rev.*

Sept. 10.—At 4^h 10^m a strong shock at Lima, Peru, duration 15 seconds, direction S. to N.

Sept. 13.—Panama advices of Oct. 28 say that a strong earthquake and rumbling noises occurred at Cucuta, Santander, on this date, and that on the previous day a movement had been felt at Santa Rosa, Manizales and Medellin.—*N. Y. Times.*

Sept. 13.—At 14^h 30^m a shock, lasting five seconds, at Santa Barbara, Cal.—*U. S. Weath. Rev.*

Sept. 21.—At 6^h 45^m a heavy rumbling noise followed by an earthquake shock, occurred at Greensborough, Guilford Co., N. C.—*U. S. Weath. Rev.*

Sept. 28.—About midnight two slight shocks were felt at Portland, Oregon.—*N. Y. Times.*

Oct. 6.—About 8^h occurred a heavy explosion at Mount St. Augustin, on the coast of Alaska, by which the mountain peak was split in two and a series of earthquake waves started in the neighboring seas. It was followed by a period of volcanic activity lasting for some weeks. For further details the reader is referred to an article by Professor Geo. Davidson of the U. S. Coast Survey, in Science, vol. iii, p. 186.

It may be added that there have been reports of volcanic activity at other points in the peninsula of Alaska, and in the chain of Aleutian Islands, notably at Bogoslov near Unalashka, during the summer and fall, but authentic details are not yet at hand. See articles by W. H. Dall, Science, iii, 89, and Geo. Davidson, Science, iii, 282.

Oct. 9–10.—At 23^h 3^m of the 9th, two light shocks, of about two seconds duration, were felt at San Francisco and vicinity. At 1^h 2^m of the 10th, a much more severe shock followed. It was felt somewhat widely through the surrounding country and was most severe on the bay of San Francisco, opposite that city, but only slight damage was done. At Oakland loud and prolonged rumbling noises accompanied the shock. The direction of vibration was north and south.

Oct. 13–14.—On these dates the tide-guage at Colon, Isthmus of Panama, indicated abnormal movements of the sea, which were referred to earthquakes at Santander and Guayaquil; but no other account of earthquakes at these places on those dates has reached the writer. The tide-guage of the island of Naos on the Pacific showed nothing abnormal.

Oct. 15.—An earthquake "at night" at Point des Monts, on the Gulf of St. Lawrence.—*Canadian Meteorol. Serv.*

Oct. 16.—At 3^h 15^m a slight shock at Cape Mendocino, Cal.—*U. S. Weath. Rev.*

Oct. 17.—At 3^h 30^m a shock at Contoocook, N. H.—*J. M. B.*

Oct. 20.—About 13^h 15^m a sharp shock was felt throughout the island of Bermuda, but no damage was done. The oscillation continued ten seconds, the direction being from west to east.

Oct. 24.—At 16^h 14^m a severe shock, continuing about fifteen seconds, occurred at Cape Mendocino, Cal., direction from S.S.W. to N.N.E.—*U. S. Weath. Rev.*

Oct. 30.—"In the morning" two light shocks at Oakland, Cal., from north to south.—*U. S. Weath. Rev.*

Nov. 4.—A shock at Cove Creek, Utah.—*N. Y. Tribune.*

Nov. 5.—A strong earthquake "at night" at Point des Monts on the Gulf of St. Lawrence.—*Canadian Meteorol. Serv.*

Nov. 11.—At 18^h 15^m a slight shock at Poway, San Diego Co., Cal.—*U. S. Weath. Rev.*

Nov. 13.—Panama advices of Nov. 17th say: "Slight earthquake shocks were felt on the Isthmus on the 13th inst., and a week earlier other shocks occurred." —*Newark* (*N. J.*) *Daily Advertiser.*

Nov. 22.—At 11^h two shocks at Point des Monts, Gulf of St. Lawrence.—*Canadian Meteorol. Serv.*

Dec. 5.—At 9^h 20^m shocks occurred at Melbourne, Izard Co., and Rovenden Springs, Ark., accompanied by a loud noise.

Dec. 12.—At 23^h 40^m a slight shock occurred at Los Angeles, Cal., and on the 13th another.—*U. S. Weath. Rev.*

Dec. 16 ?—At 15^h a slight shock at Poway, San Diego Co., Cal. —*U. S. Weath. Rev.*

Dec. 22.—At 20^h an earthquake at Point des Monts, Gulf of St. Lawrence.—*Canadian Meteorol. Serv.*

The foregoing notes include seventy-eight notices, of which nine are in small type. They are distributed by localities as follows:

Canada	8
New England	3
Atlantic States	2
Mississippi Valley	11
Pacific Coast	23
Mexico	1
West Indies	4
Central America, Colombia, Venezuela, Ecuador	14
Peru and Chili	10
Not counted (Feb. 27, June 19)	2
	78

The following may be selected as the more important earthquakes of those above noted: Jan. 11, Cairo, Ill.; Mar. 8, Panama; May 19, Ecuador; Aug. —, Mexico; Oct. 6, Alaska. The great majority of the shocks were very moderate and caused little or no damage.

Princeton, N. J., Mar. 26, 1884.

ART. XLIII.—*Thermometer Exposure;* by H. A. HAZEN.

[Read before the Philosophical Society, Washington, D. C., October 13, 1883.]

THE subject of thermometer exposure may be discussed under two general divisions. The first of these relates to the locality in any large region where the thermometer shall be exposed, in order that it may give the true air temperature of the locality. The second relates to the immediate environment of the thermometer which shall fulfill the same requirement.

Under the first of these divisions: height above ground; proximity of trees or houses; freedom of access of air; absence of local heat effects; character of ground, etc., are all important. A great diversity of opinion relative to many of these points exists, but it may be said that a good height above ground and no interruption of the wind seem essential. If a thermometer is too near the earth's surface it will be affected unduly by dampness and fog which has a tendency to settle at a low level, and moreover, unless exposed on the summit of a hill, there will be danger of an interruption to the wind, so that in hot, nearly calm weather the air will become stagnant, thus vitiating the result we seek. For example, mean monthly temperatures from a maximum thermometer 4½ feet above ground in New Haven, Conn., were from four to five degrees higher during the summer months, than from a maximum thermometer, having free access of the wind, on a roof 111 feet above the ground, and about 500 feet from the first thermometer.

Careful experiments upon an open scaffolding at heights up to 80 feet have been made under the direction of Professor Wild, of St. Petersburg. Little difference was found in the warmer months in the air temperature of different heights. In general also the relative humidity was higher near the ground with a few notable exceptions, for example, the following table exhibits the mean relative humidity for four months' observations.

Relative humidity at various heights.

Month.	1·9 Meters.	15·9 Meters	26·3 Meters.
June, 1873,	63·3%	59·0%	70·1%
July,	62·2	62·0	60·7
June, 1874,	57·6	56·8	55·7
July,	72·1	71·4	76·2

It seems impossible to explain these peculiar results which do not follow any law with respect to height; on the whole, however, the humidity has a tendency to increase with approach to the earth's surface.

In order to show the importance of obtaining a proper locality for exposing a thermometer, table I is given which shows temperature and humidity at various places in Washington, D. C. (These and many other experiments have been tried and introduced in this paper since its original presentation to the Philosophical Society).

TABLE I.

Date.	Time.	Locality.	Dry.	Wet.	R. H.	Dist.fr'm Roof.
1883.						
Nov. 17,	6.45 P. M.	Roof.	36·1	29·5	41	
	6.50 "	Roof.	35·7	29·5	44	
	6.55 "	Roof.	35·6	29·2	42	
	7.41 "	Pa. av. and 17th st.	35·0	28·3	39	½ block.
		Pa. av. and 16½ st.	33·1	27·5	45	½ "
	7.55 "	I and 15th st.	34·0	27·6	40	3½ blocks.
		K and 15th st.	33·9	27·5	39	4½ "
		M and 15th st.	32·9	27·3	45	6½ "
		R. Island av. and 15th st.	30·3	25·9	53	7½ "
		P and 15th st.	30·5	26·1	53	9 "
	8.14 "	Q and 15th st.	29·9	25·6	54	10 "
		Corcoran and 15th st.	29·5	25·4	57	11 " =1⅛ mile.
Nov. 19,	6.45 P. M.	Roof.	48·2	41·0	48	
	7.00 "	Roof.	48·1	41·0	49	
	7.15 "	On ground.	44·5	38·5	53	
		Pa. av. and 16½ st.	42·6	37·3	56	
		H and 16th st.	42·3	37·3	58	
	7.30 "	L and 16th st.	39·9	35·9	64	
		O and 16th st.	38·8	35·1	66	
		Corcoran and 16th st.	38·3	34·9	68	
	8.00 "	R and 16th st.	36·9	34·0	71	
		Corcoran and 15th st.	37·8	34·7	71	
Nov. 20,	6.30 A. M.	Corcoran and 16th st.	31·4	30·3	88	
		P and 16th st.	31·9	30·4	84	
		M and 16th st.	32·0	30·4	83	
		H and 16th st.	31·9	30·3	83	
		Pa. av. and 17th st.	33·1	31·3	82	
	7.03 "	Roof.	35·9	32·8	70	
	7.08 "	Roof.	36·3	33·1	69	

On November 19 there is a remarkable difference of over 11° between the extreme stations with a corresponding difference of 23 per cent in the relative humidity. The results are not strictly comparable owing to the difference in time between the observations, yet as the temperature was changing but slowly this consideration can have little weight. Experiments are still under way relative to this matter.

Taking up now the second division of the subject, we find that the necessity of an uniform and satisfactory shelter or screen for thermometers has long been recognized. The international meteorological council, at the Berne meeting, while not recommending any particular form of shelter, yet urged the desirability of more extended experiment. Thermometers suspended in free air, in the shade of a dwelling or wall during the day, will give an approximate daily local temperature though generally too low both day and night. If, however, it be desired to critically study the past records, or what is more important to compare observations, whether mean or daily, at different stations it will manifestly be necessary to eliminate from them all effects of improper exposure.

It may be argued that the most important consideration is that of uniformity and that constant errors may be neglected, provided they are the same in all the exposures. If, however, varying atmospheric conditions diminish or intensify constant sources of error, it is wise to avoid these as much as possible. The essential point to be regarded is that a shelter shall at any and all times give an air temperature influenced as little as possible by harmful causes.

To accomplish this the following conditions must be realized if possible. 1st. There should be a perfect access of the air, whose temperature we wish to ascertain, to the thermometer. It will be seen that under all circumstances this is necessary for even if, as is frequently done, an artificial means of ventilation is employed, yet if the shelter affects in any way the air temperature or prevents the free circulation of air, it must to a certain extent vitiate the result obtained from the air propelled to or stirred about the thermometer.

2d. The shelter should shield, from all reflected heat, from direct radiation from the sun by day, to the sky by night, and from radiation from surrounding objects.

3d. No moisture should reach the thermometer.

The questions to be answered by experiment then, are, which if any of these conditions may be neglected, and what is the best form of shelter for accomplishing the desired result.

The forms of shelters adopted by different countries have been exceedingly diverse. That of the French, the "Renou" stand, consisting of a nearly horizontal platform under which the thermometers are exposed at 6¼ feet above sod, very nearly fulfills the first condition above. The east and west side pieces however, employed for screening from the morning and afternoon sun, would seem to check very light winds on those sides, and there does not seem to be sufficient provision against soil or sod radiation. A shelter similar in plan to this has been adopted as a standard in Melbourne, Australia. This shed has 144 square feet of horizontal surface, two roofs, of galvanized iron, nine inches apart, the ridge of the outer roof eight feet above ground, the thermometers suspended in a wire cage one foot below the inner roof. On the east and west are louvres to shield it from the rising and setting sun. In calm weather it would seem as though this shed would give too much shade.

In England, the Glaisher stand has been largely used. This consists of an upright frame which is rotated with the sun's motion so as to keep one side, on which the thermometers are placed at about four feet above sod, continuously in the shade of the frame. Professor Wild has shown that this stand may give four or five degrees too high temperature by day from sod radiation, and at night the same number of degrees too low by radiation to the sky and from surrounding objects. The Stevenson shelter is also in great favor in England, and consists of a cubical screen, of double louvres, 18″ long and high and 10″ wide. This is placed at a height of 4′ above sod. Professor Mohn, of Christiania, has shown that in the sun this shelter gives too high values. It is undoubtedly too small and close to give good results. A shelter similar to the above has been devised by Rev. F. W. Stow, of England. (Quart. Jour. Met. Soc., vol. viii, p. 234.) This is somewhat larger than Stevenson's and has metallic louvres instead of wooden. It has the advantage of great ease in construction and of good ventilation.

In Spain a double metallic shelter has been used. This has an inside louvre box 14×14×17 inches, between the inside and outside louvres there is a free air space and connected with this there is a common vane ventilator. In Russia, Professor Wild has constructed a novel form of shelter which has attracted much attention. This consists of a large cubical frame of wood, having the south side and roof double boarded (the free air space between these boards is connected throughout), the east and west sides of single louvres and the north side entirely open. There is no bottom but upon a cross-piece inside is placed a metallic screen of four quarter cylinders upon a central spindle, with the top and bottom cone-shaped. These cones have their elements parallel, thus causing more or less draft. The two opposite, outside quarter cylinders are rotated upon the spindle so as to expose to view the thermometers. The latter are at a height of 11 feet above sod. This form of shelter is open to the objection that it prevents a free access of air, the double boarded south side cutting off all south wind is especially unsatisfactory in this regard.

It is of the utmost importance that there should be a standard of comparison in all experiments, and this we have in the swung thermometer, called by the French thermometer fronde, which is a common thermometer attached to a string or wire, and rapidly swung through a circumferance whose radius is the length of the string. After experimenting some time a form of dry and wet bulb "fronde" was devised, which has been in constant use since and has given good satisfaction. The thermometers were lashed together, the stem of one two inches longer than the other, in such a manner as to bring the wet bulb about two inches below the dry. This permits of immersing the wet bulb without wetting the dry. A few swings only are needed in making an observation, it is swung perhaps forty or fifty times, then read, swung again and read, etc., it seldom requires more than three attempts except in very cold weather, 0° and below. This "fronde" is especially commended for experiments upon temperature and hygrometric conditions at any place where it is proposed to establish a meteorological station.

The theory of this thermometer is that since it is rapidly brought in contact with a large mass of air it must give its temperature unless the results are vitiated by other causes. It has been objected, for example, that friction with the air will tend to raise the temperature, and that the centrifugal force will on the contrary tend to depress the mercury column. Repeated experiments at low and high velocities (3 and 18 miles per hour), have invariably given the same results, showing that these causes do not produce harmful effects at any velocities possible by hand. This standard has been compared by Professor Wild with his shelter just described, and he concludes that during the day it shows about 0·7° too high a temperature, while at night it gives the same amount too low. It may be regarded as an open question whether this does not show that the difficulty was in the shelter rather than in the so-called standard. In order to make comparisons with any thermometer by day, it is essential to determine the effect of the sun or to shield from it. One of the difficulties met with in the use of "fronde" has been its extreme sensitiveness to the slightest air current, requiring several trials at each observation the mean of these giving the temperature sought. To determine the effect of direct sun heat, trials were made in the shadows of high isolated trees and in the shade of Washington monument, when the air was still or had very little motion, with the result that at midday with a clear sky, in the summer time, the temperature given by "fronde" may be ·7 to 1·0 degree higher in the sun than in the shade. It cannot be considered however, that such a shade temperature as was used represents the exact air temperature, but it was nearly correct, perhaps the true value of the air temperature was somewhat higher, and that the effect of the sun heat is a little less than 0·7°.

Since a thermometer exposed to the clear sky reads at times one degree lower than if sheltered, we might conclude that the "fronde" will be liable to the same effect unless entirely overcome by its rapid motion through a large body of air. Observations on clear nights in September and October have shown the "fronde" sometimes ·2 or ·3 degrees higher and sometimes the same amount lower than a thermometer from which all radiation was cut off. Experiments are still needed in summer and in different situations to fully settle the question, but it seems probable that the "fronde," if shielded from direct sun heat during the day, will give at all times the most accurate temperature that can be obtained.

The following brief description of some of the previous experiments in this field, will serve as an introduction to subsequent work. Possibly the most complete results hitherto published are those from observations taken, under the auspices of the English Royal Society, upon a large open field at Strathfield Turgiss. The observations were taken at 9 A. M., 3 P. M., and 9 P. M., from November, '68 to April, '70 inclusive, January, '70 only being omitted. The stands tested consisted of eight forms ranging between the open stand like Glaisher's and the closed like Stevenson's. As a result of these tests it was decided that the Stevenson was least faulty, though it was not claimed that even this was all that could be desired, and especially as regards hygrometric observations.

Another series of tests has been published in a Quarterly Report for 1880. These consisted in readings at Kew, at 9 A. M. and P. M., from June '79 till November '81, of thermometers in a Stevenson stand 4′ 4″ above sod and in a Wild's shelter near the former but 12′ above sod. The published cut of the photograph of the outside wooden structure of the latter, however, shows louvre work on the south side and indicates that Professor Wild's idea was not fully carried out. The result would have been somewhat different if the south side of the Wild shelter had been closed. The means showed nearly identical temperature in the two shelters, the Wild reading ·1° lower. The mean of the maximum was ·3° higher and of the minimum ·6° lower in the Wild. The monthly mean relative humidity ranged from one to two per cent lower in Wild's. Comparing individual differences between the two the highest that Wild's read above the other was 1·9° while the lowest was 3·5° (it would be a matter of much interest if the atmospheric conditions giving such large differences between two shelters so near each other could be studied). These comparisons would seem to show a lack of ventilation in the Wild shelter as that was so much higher than the other that the wind should have had freer access to it. Also a mere agreement between the two cannot be regarded as proving the accuracy of either, but since there are manifest defects in the Stevenson we may conclude that neither is satisfactory. Comparisons are also given between the Stevenson shelter and the Kew thermograph records which show the latter ·49° higher at 9 A. M. and ·82° lower at 9 P. M. Possibly these differences may be due in part to a freer exposure of the thermograph to the air.

In entering upon a series of experiments it was deemed best to construct a so-called Pattern shelter, whose main points should be good size and a free access of air to the interior. This shelter is 4×3×3 feet with single louvre work on all sides three inches wide and inclined at an angle of 30° to the horizontal. The roof is double and the bottom close. The north side is a door which can be removed. By the kindness of Mr. Clark, opportunity was granted for conducting the experiments upon the roof of one of his buildings in a thickly settled part of Washington. This roof is about 60 feet above ground, and is free to air currents save from the southeast. There were three shelters employed. A "Stow" about 12 feet above the roof and two "Patterns" at heights of 12 and 16 feet. At first the door of the lower "Pattern" was removed and a Wild metallic screen inserted, after several weeks' comparison this screen with its thermometers was placed in the upper "Pattern," its door having been removed.

The following plans and precautions were taken to determine the adaptability of these shelters, and to check the thermometers:

1st. The relative air circulation in the interiors has been obtained by comparison between dry and wet bulb thermometers and the effect of thorough ventilation has been learned by comparing the wet bulb in the shelter with the "fronde."

2d. The relative amount of reflective heat entering the shelter has been ascertained by using a black bulb thermometer, i. e. an ordinary thermometer with its bulb coated with lampblack.

3d. The readings of the three thermometers in each shelter were checked by using similar traveling thermometers which were placed in each shelter in succession, and numerous comparisons made.

4th. The thermometers used had cylindrical bulbs, with the exception of two in "Stow," and have been twice carefully compared with a standard, once at temperature 6° below zero. All readings have been corrected for instrumental error.

5th. All the observations have been made by one person, and it has been the practice to read forward and back, at nearly all times, in order to eliminate as much as possible effects of changes in temperature between the first and last observation.

6th. In making comparisons it has been deemed best usually to make a continuous series of readings for an hour or more, as a single reading a few times each day will hardly give what we wish except for the mean; while continuous observation, under known conditions which are slowly changing, will enable us to follow effects due to gradually rising or falling temperature, the increase or decrease of wind velocity, the shifting of the wind, slowly changing humidity, etc.

The following are a few of the results collected from the observations since September 1, 1883.

To determine the least size of a shelter necessary to overcome the effects of heat from the sides, there were arranged from east to west in the upper "Pattern," nine thermometers at equal distances. Observations were made in the early morning and in the afternoon. Under the most favorable conditions the inside of a shelter farther from the sun will undoubtedly give a slightly too low temperature in the morning owing to the fact that it is farther from the sun, but this effect will be exceedingly slight, and in fact will be entirely overcome if there is any breeze. Oftentimes with a still air and hot sun on one side of the shelter, if a slight breeze happened to spring up on that side the temperature would be brought even lower than on the opposite side; in fact so much difficulty was encountered from such gusts that it was found necessary after a while to fasten a test tube to each thermometer to shield it.

Table II shows the results of these observations.

Considering the difficulty of comparing thermometers hung side by side in free air, the accordance of these results is very satisfactory. In the morning there is a mean difference of 1·8° between the east and west sides; a fall of ·55° or nearly $\frac{1}{3}$ the whole amount, in the first 9 inches, and one of 1·2° or $\frac{2}{3}$ in the first 18 inches. In the afternoon there is a fall of 1·5° from west to east, in the first 9 inches it was about $\frac{1}{4}$ the whole fall and in the first 18 inches it was nearly $\frac{1}{2}$, i. e. in September a thermometer at 9 inches from the side of a shelter would indicate in calm sunny weather a temperature uniformly about 1·2° too high. Experiments are still needed in midsummer, with larger shelters, with double louvres, with metallic louvres and with traveling thermometers. We may conclude that a single louvred shelter exposed directly to the sun's rays should have the clear inside length not less than 36 inches.

Table III shows observations in the three shelters "Stow" (A), "Russian" (B) and "Pattern" (C); there are also added results from dry and black traveling thermometers and from a thermometer exposed on the *outside* of "Pattern."

Column 1 gives the mean time of each set or of five successive observations, the next five columns give, the dry and wet thermometers, the relative humidity from these, the black thermometer and the difference between this and the dry, in (A); the next five give the same values for (B); the next five for (C); the next three give the dry and black and their dif-

TABLE II.—*Comparisons of thermometers placed in a "pattern" shelter 4·5″ apart in an east and west direction, the outside ones being 4·5″ from the sides.*

Each figure represents the mean of five consecutive observations.

Date.	Time.	Thermometers. I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	Wind.	Weather.
	MORNING OBSERVATIONS.											
Sept. 6, 1883,	7.23 to 7.29 A. M.	57·74	56·96	56·60	56·40	56·42	56·02	56·04	55·88	55·98	Calm.	Sun bright.
" 7,	7.09 to 7.14 "	57·20	56·42	56·02	55·90	55·82	55·48	55·38	55·28	55·28	Lt. S.W.	"
" 7,	7.14 to 7.20 "	58·66	57·98	57·72	57·42	57·46	57·12	57·14	56·86	56·96	"	"
" 15,	7.07 to 7.12 "	69·34	69·08	68·72	68·26	68·10	67·94	67·78	67·54	67·70	Calm.	"
" 15,	7.12 to 7.18 "	70·30	70·00	69·60	69·14	68·98	68·82	68·56	68·24	68·40	"	"
" 26,*	6.51 to 6.55 "	51·80	51·20	[50·84]†	50·68	50·24	50·00	50·00	50·00	49·90	Lt. N.	"
" 26,*	7.10 to 7.15 "	52·76	52·36	[52·00]†	51·86	51·24	51·06	51·32	51·06	50 98	"	"
	Mean..........	59·69	59·14	58·79	58·52	58·32	58·06	58·03	57 84	57·89		
	AFTERNOON OBSERVATIONS.											
Sept. 6, 1883,	4.31 to 4.43 P. M.	72·36	72·66	72·58	72.76	72·92	73·18	73·22	73·36	73 86	Lt. S.	Sun bright.
" 6,	4.45 to 4.50 "	72·50	72·60	72·56	72.98	73·12	73·26	73·32	73·42	73·94	"	"
" 26,*	4.27 to 4.32 "	63·24	63·38	[63·38]†	63·38	63·56	64·04	64·36	64·66	64·76	Calm.	"
	Mean..........	69·37	69·55	69·51	69·71	69·87	70·16	70·30	70·48	70·85		

* These observations were made after first inserting each thermometer in a test-tube in order to cut off fluctuations due to slight gusts of wind.

† Thermometer III was needed in another place; bracketed values have been interpolated.

TABLE III.—*Temperature observations in Stow, Russian and Pattern shelters, and in free air.*

Each reading represents the mean of five observations, October 10, 1883.

Time.	A—Stow.					B—Russian.					C—Pattern.					Traveling Thermometers in Pattern.			Ther. Free Air.
	Dry.	Wet.	Rel. Hum.	Black.	Black minus Dry.	Dry.	Wet.	Rel. Hum.	Black.	Black minus Dry.	Dry.	Wet.	Rel. Hum.	Black.	Black minus Dry.	Dry.	Black.	Black minus Dry.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
12.32 P.M.	72·7	62·8	54	73·1	·4	73·4	63·6	56	73·6	·2	71·9	62·4	56	72·7	·8	71·8	72·5	·7	73 3
12.38	72·8	62·9	55	73·2	·4	73·6	63·8	56	73·8	·2	71·8	62·4	56	72·6	·8	71·9	72·4	·5	73·9
12.48	72·6	62·9	55	73·0	·4	72·9	63·3	56	73·2	·3	71·2	62·0	57	72·1	·9	71·5	71·9	4	73·9
12.53	71·9	62·7	57	72·3	·4	72·9	63·2	56	73·2	·3	71·2	61·8	56	72·0	·8	71·4	71·8	·4	73·3
1.00	71·8	62·0	55	72·1	·3	73·1	63·2	55	73·5	·4	71·2	61·7	55	71·9	·7	71·2	71·8	·6	73·4
2.47	74·6	63·0	49	74·9	·3	75·6	64·3	51	76·0	·4	74·0	63·0	51	74·8	·8	74·0	74·8	·8	76·7
2.54	74·6	63·1	50	74·8	·2	75·6	64·4	51	75·8	·2	74·2	63·0	50	75·0	·8	74·3	74·8	·5	76·5
2.59	74·7	63·1	49	74·9	·2	75·3	63·9	50	75·4	·1	74·1	62·9	50	74·7	·6	74·1	74·7	·6	76·0
3.06	74·6	63·5	51	74·9	·3	75·6	64·4	51	75·8	·2	74·2	62·8	50	75·0	·8	74·4	74·8	·4	76·3
3.12	75·3	64·1	51	75·6	·3	75·8	64·7	52	76·0	·2	74·6	63·4	51	75·5	·9	74·8	75·2	·4	76·8
Mean....	73·6	62·0	52·6	73·9	·32	74·4	63·9	53·4	74·6	·25	72·8	62·5	53·2	73·6	·79	72·9	73·5	·53	75·0
																In Russian.			
3.31 P.M.	75·9	64·3	50	76·2	·3	76·3	65·0	51	76·6	·3	74·8	63·5	50	75·6	·8	76·4	76·4	·0	77·4
3.38	75·3	63·8	50	75·7	·4	75·8	64·6	52	76·0	·2	74·7	63·3	50	75.5	·8	75·8	75·9	·1	76·8
3.46	75·0	63·4	49	75·4	·4	76·0	64·7	51	76·2	·2	74·6	63·1	50	75·4	·8	76·0	76·1	·1	77·0
3.52	74·8	63·1	49	75·1	·3	75·6	64·2	51	75·8	·2	74·1	62·6	49	75·0	·9	75·6	75·6	·0	76·5
4.26	74·6	63·0	49	74·8	·2	75·3	64·0	51	75·4	·1	74·4	62·6	49	75·0	·6	75·2	75·1	·1	76·1
4.32	75·0	63·1	48	75·3	·3	75·4	63·9	50	75·5	·1	74·4	62·7	49	75·1	·7	75·4	75·3	·1	76·0
4.38	74·6	63·4	51	74·8	·2	74·8	64·2	53	75·0	·2	74·2	62·8	50	74·9	·7	74·8	74·8	·0	75·2
4.44	74·2	62·8	50	74·3	·1	74·6	63·9	53	74·8	·2	73·5	62·1	49	74·5	1·0	74·6	74·7	·1	75·1
4.49	73·8	63·3	53	73·9	·1	74·2	64·0	54	74·4	·2	73·4	62·7	52	73·8	·4	74·0	74·0	·0	74·3
4.56	73·6	63·4	54	73·6	·0	73·6	64·1	57	73·8	·2	73·0	62·8	54	73·5	·5	73·6	73·6	·0	73·3
Mean....	74·7	63·4	50·3	74·9	·23	75·2	64·3	52·3	75·4	·19	74·1	62·8	50·2	74·8	·72	75·1	75·1	·01	75·8

NOTE.—Weather calm and clear.

ference as determined from traveling thermometers placed successively in (B) and (C); the last column gives the temperature from a free thermometer.

Comparing these, we see from columns (7) (10), (12) (15), and (17) (18) that observations of dry and black in (B) and (C) are directly comparable. We find the black in (B) more than ·5° lower than in (C), though (C) shows the dry at the same time more than 1·0° lower than (B). This would seem to indicate that the free black bulb thermometer cannot aid in determining the true air temperature in a shelter, and also that, if a free circulation of air is provided for, the effect of reflected heat may be neglected. We also find that (C) gives a relative humidity ·2 per cent in one group and 2·1 per cent in the other *lower* than (C), while (A) agrees well with C.

Table IV gives a comparison of all observations of dry and wet thermometers from Sept. 20 to Oct. 11, and from Oct. 31 to Nov. 7; between these two sets the "Russian" screen was put in the upper "Pattern."

TABLE IV.—*Comparative observations in Stow A, Russian B and Pattern C shelters.*

Date.	No.	Wind.	Weath.	Stow.			Russian.			Pattern.		
				Dry.	Wet.	R. H.	Dry.	Wet.	R. H.	Dry.	Wet.	R. H.
Sept. 20,	25	Light.	Clo.	71·4	57·4	37·3	71·2	57·3	37·4	71·1	57·0	36·6
" 21,	95	Light	Fair.	73 4	59·1	37·9	73·0	58·9	38·3	72·9	58·7	37·8
" 26,	140	Brisk.	Clear.	59·0	48·4	40·1	58·3	48·7	44·6	58·3	48·5	43·6
" 27,	65	Brisk.	Fair.	71·3	61·8	55·5	71·3	62·1	56·9	70·9	61·7	56·6
" 28,	100	Light	Haze.	77·5	67·6	57·6	77·5	67·5	57·2	76·8	67·1	58·0
" 29,	75	Brisk.	Fair.	68·8	61·7	64·7	68·6	61·3	63·7	68·1	61·1	64 8
Oct. 3,	45	Light.	Clo.	63·5	56·2	60·7	63·6	56·5	61 6	63·3	56·3	62·1
" 5,	50	Light.	Fair.	55·0	45·5	41·6	54·9	46·1	45·5	54·4	45·4	43·8
" 10, A. M.	140	Light.	Clear.	69·2	60·7	58·5	69 1	61·3	61 7	67·8	60·0	60 9
" 10, P. M.	95	Light.	Clear.	74·0	63·1	51·5	74·5	63·9	53·1	73·5	62·7	51·6
" 11, A. M.	80	Brisk.	Clear.	69·8	59·5	51·1	70·0	59·9	52·0	69·8	59·2	49·7
" 11, "	75	Brisk.	Clear.	78·6	62·0	34·2	78·3	62·2	35·7	78·3	61·1	32·0
Total -------	985											
Mean -------	----	------	------	69·3	58·6	49·2	69·2	58·8	50·6	68·8	58·2	49.8

OBSERVATIONS WITH RUSSIAN AT 16 FEET AND PATTERN AT 12 FEET.

Date.	No.	Wind.	Weath.	Stow.			Russian.			Pattern.		
				Dry.	Wet.	R. H.	Dry.	Wet.	R. H.	Dry.	Wet.	R. H.
Oct. 31,	15	High.	Clear.	67·1	52·8	31·7	67·0	53·0	32·7	67·2	52·8	31·1
Nov. 1,	25	Light.	Clear.	43·3	35·4	37·4	43·0	35·8	38 4	43·0	34·9	34·6
" 3,	65	Brisk.	Clear.	51 2	41 8	37·5	50·1	41.6	41·8	50·9	41·4	36·7
" 5, A. M.	40	Calm.	Clear.	55 4	48·7	59·6	55·5	49·0	60·1	56·2	49·1	57·2
" 5, P. M.	20	Calm.	Clear.	63·2	53·2	47·5	62·4	52·9	50·0	62·8	52·8	47·2
" 7,	20	High.	Clear.	50·1	42·2	46·5	49·7	42·2	48·5	50·1	42 2	46·5
Total -------	185											
Mean -------	----	------	------	55·0	45·7	43·4	54·6	45·8	45·2	55·0	45·5	42·2

In the first series we find "Pattern" giving a mean temperature ·4° lower than "Russian" with a mean relative humidity ·8 per cent lower. In the second series we find the "Pattern" which is now twelve feet above roof giving ·4° higher temperature and a relative humidity 3·0 per cent lower. Taking the mean of the two series we find no difference in the temperature, while the "Pattern" gives a relative humidity nearly 2·0 per cent lower.

The lack of ventilation in the Russian may be best shown by taking observations of the wet bulb when its temperature is below freezing. As shown in "Science," June 8th, 1883, it is under these conditions that ventilation is most needed.

Table V exhibits individual readings of dry and wet thermometers. 1st, "fronde;" 2d, "Russian;" and 3d, "Pattern."

TABLE V.—*Comparison of dry and wet "fronde" with Russian and Pattern.*

	"Fronde," 14 ft.			Russian, 16 ft.			Pattern, 12 ft.			Time.	Wind.	Weather.
	Dry.	Wet.	R. H.	Dry.	Wet.	R. H.	Dry.	Wet.	R. H.			
Nov. 13	31·7	26·3	45	31·5	31·5	--	31·6	26·9	52	7.23 A. M.	Calm.	Clear.
	32·0	26·7	47	31·9	31·4	95	32·3	26·8	44	7.31	"	"
	32·8	26·9	42	32·9	30·5	75	33·2	27·3	43	7.44	"	"
	34·4	28·7	47	34·7	30·6	62	35·1	29·7	50	8·09	"	"
Nov. 14	32·8	26·4	38	33·1	27·1	42	32·8	26·7	40	7.03 P. M.	Brisk N.W.	"
	33·1	26·3	34	33·2	28·0	49	32·9	27·1	43	7.16	"	"
	32·9	26·2	35	33·0	27·3	44	32·7	26·5	39	7.25	"	"
Nov. 15	22·8	20·4	68	23·0	31·2	--	23·0	22·7	96	7.05 A. M.	Calm.	"
	23·5	20·7	63	23·3	30·0	--	23·2	21·2	73	7.15	"	"
	23·8	21·4	68	23·5	24·2	--	23·7	21·7	74	7.25	Light S.	"
	35·4	27·9	32	35·3	30·4	55	36·2	31·8	58	11.03 A. M.	Light S.S.W.	"
	35·1	28·5	40	35·3	31·6	58	36·0	29·6	43	11.19	"	"
	35·1	28·1	36	35·4	30·6	56	36·6	30·5	46	11.30	"	"
	35·1	28·2	37	35·4	30·1	51	36·2	29·8	43	11.35	"	"
Nov. 17	41·1	31·7	23	40·5	33·3	38	42·7	33·2	24	3.00 P. M.	Calm.	"
	41·6	31·1	20	41·1	32·3	27	41·4	31·7	21	3.17	Light S.S.W.	"
	36·1	29·5	41	35·4	30·6	56	35·2	30·3	54	6.45	"	"
	35·7	29·5	44	35·4	30·4	54	35·3	30·1	52	6.50	"	"
	35·6	29·2	42	35·2	30·3	55	35·2	30·1	53	6.55	"	"
Nov. 20	35·9	32·8	70	35·0	34·4	94	34·9	33·9	86	7.03 A. M.	Calm.	"
	36·3	33·1	69	34·9	33·3	84	34·9	33·0	81	7.08	"	"
	35·2	32·7	75	35·1	33·4	83	34·8	33·2	84	7.18	"	"
	35·9	33·1	72	35·3	33·7	86	35·2	33·3	81	7.30	"	"
	36·1	33·4	73	35·6	33·8	82	35·4	33·6	81	7.35	"	
Mean ..	33·8	28·3	48·4	33·5	30·8	...	33·8	29·2	56·7			
Mean, omitting the four observations in which wet was higher than dry in Russian.												
	35·4	29·5	45·8	35·2	31·2	62·3	35·4	30·4	53·3			

The mean results in Table V show nearly identical air temperatures by the three methods, but a relative humidity more than 16 per cent too high for "Russian" and over 7 per cent for "Pattern."

The following conclusions are advanced:

1st, Thermometer shelters when exposed to direct sun heat should be at least 36″ long.

2d, With proper precautions the thermometer "fronde" both dry and wet will give the most correct air temperature and relative humidity.

3d, The interposition of a second louvre seems hardly necessary; it not only prevents the free access of air, but also if ventilation is used it must affect the air which is propelled to the thermometer.

4th, While the thermometers in a single louvred shelter may in heavy storms be wet, yet it takes but a moment to wipe the bulb dry, besides in rainy weather both dry and wet indicate nearly the same temperature.

5th, For obtaining even approximate relative humidity in calm weather single louvred shelters are necessary, and for the best result an induced air current is essential especially in the winter in northern countries.

At the same time that the above experiments were being carried on, another series of observations was made in window shelters. These have shown, as is well known, that in summer the temperature is slightly too low by day and too high by night, and that no satisfactory hygrometric observations can be made without artificial ventilation. As many are not in a situation to use any but a window shelter the following suggestions are added for places north of 35° lat. N.

1st, There should be a free air space of 6 to 12 inches between the shelter on the north side of the building and the wall.

2d, The simplest form of screen would be four pieces of board 10 to 12 inches square, nailed together box fashion, leaving the bottom and side toward the window open; the thermometers dry and wet should be placed five inches apart near the center of this screen, with their bulbs projecting below the plane of the lower edge. In the summer months, when the sun shines on the north side, the window blinds can very easily be brought at right angles to the wall of the house and fastened there, thus shielding from the sun. As to a more elaborate arrangement it may be said that nothing extensive is needed; probably a shelter made after the "Stow" pattern, as just described, thirty inches long, eighteen inches wide and twenty-four inches high with closed bottom would answer perfectly in latitudes north of 35°. A shield with half shut blinds can be easily arranged as mentioned above, the blinds being widened if necessary to cover the shelter with their shadow. Experiments are still being carried on upon this matter. The Chief Signal Officer has kindly permitted the publication of these results preparatory to a more exhaustive study.

ART. XLIV.—*Hillocks of Angular Gravel and Disturbed Stratification*; by T. C. CHAMBERLIN.

MUCH interest has been awakened in recent years in the peculiar gravel mounds and ridges—in part embraced under the terms Kames, Eskers and Osars—which are disposed in varying frequency over a large part of the drift areas of both the eastern and western continents. Numerous writers, foreign and native, have made descriptive and theoretical contributions to the literature of the subject.* With increased attention there has

* Among these the following may be cited as having more or less immediate relevancy to the present topic: Edw. Hitchcock, Geol. of Mass., 1841, Trans. Assoc. Am. Geol. and Nat., 1840–42, Smith. Cont. ix, 1857; W. W. Mather, Geol. of N. Y., 1st Dist., 1842; J. Hall, Geol. of N. Y., 4th Dist., 1842; L. Vanuxem, Geol. of N. Y., 3d Dist., 1842; Ch. Martins, Bulletin de la Société Géologique de France, 1845–6; Robert Chambers, Tracings in the North of Europe, 1850, also, Edinburgh New Phil. Journal, 1853, liv, 229; T. F. Jamieson, On the Drift and Rolled Gravels of the North of Scotland, Quar. Journal Geol. Soc., 1860, xvi, p. 347, also, ibid, 1865, xxi, p. 161, also ibid, 1874, p. 329; C. H. Hitchcock, Agri. and Geol. of Maine, 1861, pp. 271–274, 1862, pp 388–391; Geol. of New Hampshire, iii, 1878; G. H. Kinahan, On the Eskers of the Central Plain of Ireland, Jour. Geol. Soc. Dublin, 1863, x, p. 109, also Dublin Quar. Jour. Sci., 1864, iv, p. 109, and Geol. Mag., 1875, p. 86; C. Whittlesey, Fresh Water Glacial Drift of the North Western States, Smith. Contrib's, 1866; L. Agassiz, Glacial Phenomena in Maine, Geol. Sketches, 1876, p. 101 (originally in Atlantic Monthly, xix, Feb., 1867); A. Erdmann, Exposè des formations quaternaires de la Suède, 1868; N. H. Winchell, Surface Geol. of Northwestern Ohio, Proc. Am. Assoc., 1872, xxi, p. 65, also Geol. Reports of Minn. and Ohio; D. Hummel, Om Rullstensbildningar; K. Svenska, Vet. Akad. Handlingar, 1874; James Geikie, The Great Ice Age, 1874, pp. 201–237, Riv. Ed., 1876, Kames, pp. 210–225, Eskers, 395–6, Åsar, 407–409; J. S. Newberry, Geol. Survey of Ohio, vol. ii, 1874, p. 41, vol. iii, 1878, p. 40; N. O. Holst, Om de Glaciala rullstensaarne, Stockholm, Geol. fören. Förh, 1876–77, iii, 97; T. C. Chamberlin, Trans. Wis. Acad. Sci., iv, 1876–77, p. 201, Geol. of Wis., ii, 1877, p. 207, Comptes Rendus, Congrès International de Geologie, Paris, 1878, p. 254; Warren Upham, On the Origin of Kames or Eskers in New Hampshire, Proc. Am. Assoc., 1876, Modified Drift, Geol. of New Hampshire, vol. iii, 1878; G. F. Wright, Some Remarkable Gravel Ridges in the Merrimac Valley, Proc. Boston Soc. Nat. History, 1876–8, xix, 47, also, The Kames and Moraines of New England, Ibid., 1879–80, xx, 210; A. S. Packard, Glacial Marks on the Pacific and Atlantic coasts compared, Am. Nat., 1877, xi, 674; E. Orton, Geol. Surv. of Ohio, vol. iii, 1878, p. 646; A. C. Lindmuth, Geol. Surv. of Ohio, vol. iii, 1878, p. 503; W. J. McGee, On the Complete Series of Superficial Geol. Formations of Northeastern Iowa, Am. Assoc., 1878; G. H. Stone, Kames of Maine, Proc. Am. Assoc., 1880; M. N. Elrod, Geol. and Nat. Hist. of Indiana, 1881, p. 154; J. D. Dana, On the relations of the so-called "Kames" of the Connecticut River Valley to the Terrace formation, Am.

been progress in analytical delineation, classification and nomenclature. That there is still abundant room for amplification in these regards is broadly manifest.

As a minor contribution to the subject it is the object of this paper to direct attention to a class of hillocks whose characteristics have some significance.

By way of approach to their taxonomic relations, we may set aside the entire classes of gravel hills and ridges that are formed by *degradational processes*—the chief agency of which is erosive sculpture—not because they are unimportant, but because they are widely distinct in real character from those to be here considered, as will appear from their description.

From the *constructive* classes we may also eliminate those which are formed by littoral and subaqueous agencies, whether these are waves, currents or floating ice, since they are distinguished by characters of their own, and may usually be satisfactorily discriminated from the class in question. We may also disregard those which are obviously caused by violent fluviatile currents in the eddies and angles of river troughs, when their relationship to the valley drift and topographical environment clearly indicate their origin. If we also set aside some less frequent classes of other possible origins and limit our attention to those gravel heapings whose position, constitution and distribution point to an origin springing from the mutual relations of glaciers and glacial waters, we must still distinguish between two somewhat broad classes. (1.) The first predominantly take the form of linear ridges which lie essentially *parallel* to the course of drift movement, notable exam ples of which are the osars of Sweden and Maine. (2.) The second class more commonly assume the form of mounds—either clustered or dispersed—and when disposed in chains or belts, which is their predominant habit, they lie *transverse* to the lines of glacial movement.

If we correlate these two classes somewhat more widely with glacial phenomena, the first falls into association (*a*) with the linear axi-radiant drift hills so prevalent in many regions (of which the "drums," "drumlins," "lenticular," or "elliptical hills" of New Hampshire, Massachusetts, New York and Wisconsin are special shapely examples), (*b*) with the longitudinal crevasses of the glaciers, and (*c*) with superglacial and, to a measurable extent, sub-glacial drainage.

The second class drop into comparison (*a*) with terminal and

Jour. Sci., vol. xxii, Dec., 1881; N. S. Shaler, Illustrations of the Earth's Surface, Glaciers, 1881, p. 66, On the Origin of Kames, Boston Soc. Nat. Hist., 1884, Feb. 6 (unpublished and contents unknown to the writer); A. Geikie, Text-book of Geology, p. 892; L. C. Wooster, Kames near Lansing, Mich., Science, 1884, Jan. 4; Robert Bell, Report of Progress Geol. Surv. of Canada, 1880–81–82, C. vi, p. 9.

recessional moraines, and all forms of peripheral ridging, (*b*) with transverse crevasses, and (*c*) with marginal drainage. By marginal drainage I mean either that which was intimately associated with the ice-margin, or was essentially limited in its action as a genetic agency to the periphery of the glacier. The waters may have had their ulterior origin back from the margin, either upon or beneath the ice, and, of course, they flowed away from it to the sea, but their efficiency in constructing gravel hills was essentially peripheral.

If correlated with rock topography, it may be observed as a broad and somewhat loose generalization that the first class usually conform, with measurable divergences, to the general rock slopes, while the second are disposed in much negligence of associated rock contours, and often stand in seeming independence if not antagonism to them. If, however, the study of their relationships be carried into detail, the subjacent topography will be found more or less influential in determining the special disposition of both classes, but it will lead aside from the present purpose to pursue this phase of the subject.

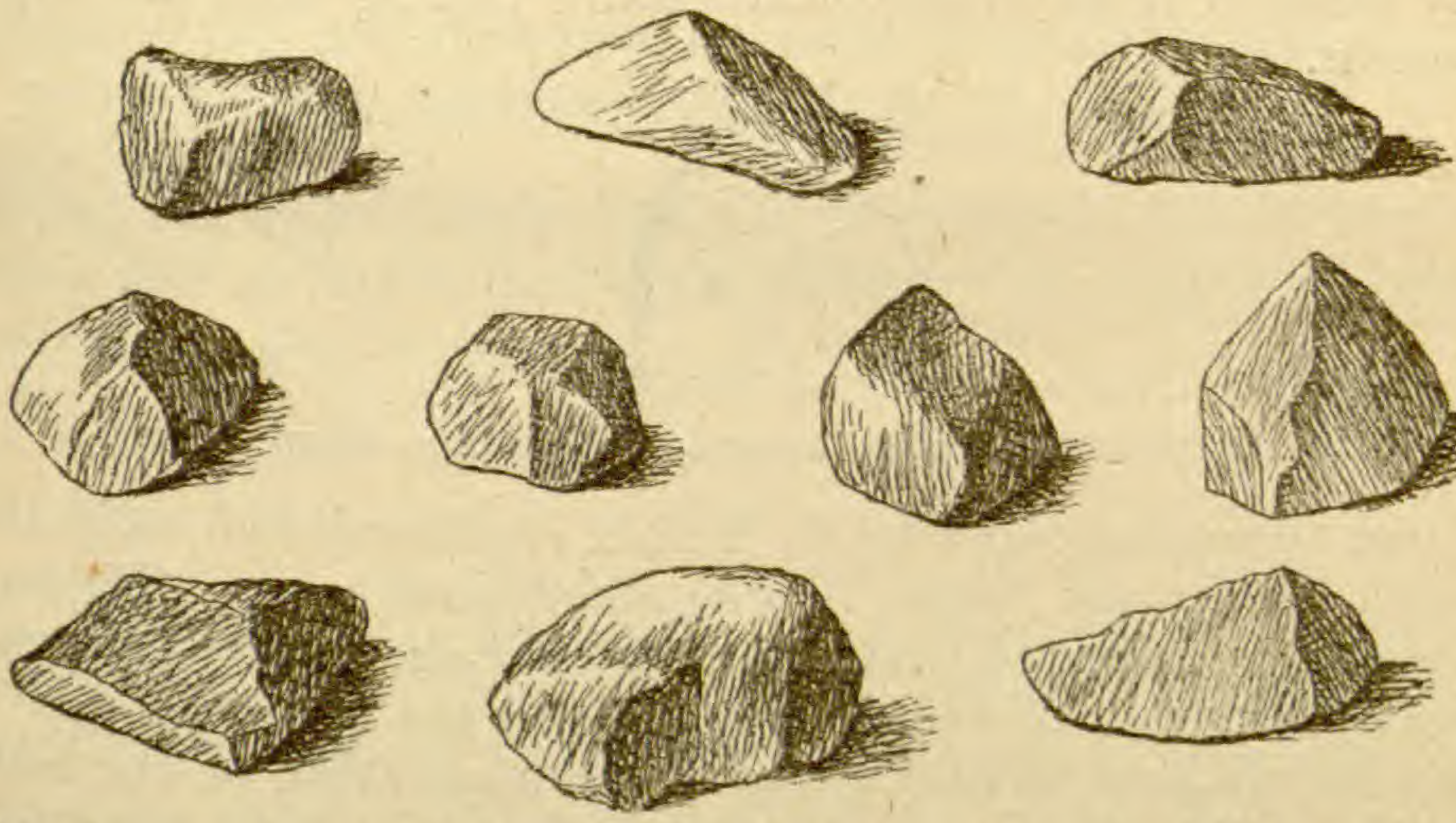
Those of the second class are the almost constant associates of the terminal moraines of this continent, and are, like them, disposed variously, but not altogether indifferently, over summits, slopes and valleys. It is several years since I called attention to the habitual association of gravelly accumulations with the Kettle moraine of Wisconsin, and its correlatives in the interior States.* These vary in form and structure through a somewhat wide amplitude, and as structural classes are not limited to association with well defined marginal moraines, though themselves indirectly peripheral glacial phenomena. It is only to a sub-class of this order that attention is here directed. They became subjects of special interest in tracing the margin of the later drift across the plain tracts between the hilly regions of Wisconsin and those of eastern Ohio, over which reliefs are relatively feeble, and therefore compel the more critical attention. Illustrative examples will be chosen from that region. They are not, however, confined or even predisposed to plain tracts, but frequent also hilly regions, perching upon slopes and summits, and nestling in valleys.

Surface aspects.—The surface contours of these hillocks are somewhat various and probably have no sharply defined limitations. Very commonly they are simple isolated mounds, not conspicuously unsymmetrical, and range from flatter forms not exceeding ten or twelve feet in height to more sharply

* Geol. of Wisc., vol. ii, pages 207 to 211—Le Kettle moraine et les mouvements des glaciers qui lui ont donnés naissance. Comptes Rendus, Congrès International de Géologie, Paris, 1878.—Extent and significance of the Wisc. Kettle Moraine. Trans. Wisc. Acad. Sci., 1876–77.

peaked examples reaching up to forty and fifty feet or occasionally beyond. These simple tumulous forms are more common in the plainer tracts. When clustered they usually assume a rapidly undulatory knob-and-basin contour. Not infrequently they are appendages of more massive ridges of till or till-covered rock in which case they constitute unsymmetrical embossments of varying forms.

1.



Angular gravel, natural size; from a hillock one mile north of Midway, Madison County, Ohio.

Internal Constitution.—They are built up chiefly of gravel and subordinately of sand, clay and bowlders. Special interest attaches to the form and composition of these constituents and their associations with each other. The gravel is largely formed of limestone fragments,* which, instead of having been reduced to the rounded form common to gravel, retain a high degree of angularity. Their surfaces are, however, worn to a greater or less degree, but it is of the type produced by forceful rubbing rather than rolling. There are not infrequent examples of undoubted glacial striation. The whole aspect of the attrition suggests the common form of glacial abrasion which the stony fragments of till present, modified by slight subsequent rolling. Indeed it is easy to demonstrate that the gravel is directly derived from the till and has suffered little modification in the assortment, for numbers of the hillocks show in certain portions of their diverse material true till, in other portions, till from which most of the clay has been removed; still other portions consist of the rock-fragments of the till with a meagre amount of clay in the interstices; while yet other portions consist of the subangular gravel above described, quite thoroughly separated from the clay and slightly

* The illustrative examples are here described, not the whole class.

worn; and in even yet other portions, the gravel is more notably worn but rarely well rounded. The process of assortment is thus exemplified in all its stages, within the narrow limits of a single hillock. The angularity of the fragments that constitute this gravel is illustrated by the preceding figures, *natural size*, which represent with a fair degree of truthfulness the character of the originals. The selection, it will be observed, is from the smaller grade of gravel, which presumptively suffered more transportation and rolling than the larger fragments.

2.

Striated limestone fragment, natural size, from the above locality.

These specimens were taken from a representative collection seriatim under the limits in size determined upon. Figure 2 represents a glaciated fragment, *natural size*, which happened to be drawn out of the collection with the above group. It would be difficult to find a clearer demonstration of the slight attrition which these gravels have suffered in their assortment from the parent till. It is to be remarked, however, prudentially that so slight a degree of attrition is not universal to the material of the hillocks under consideration, though the above specimens were taken from well assorted and thoroughly stratified beds and were intended to represent the average character of a very considerable number of these hills. There are usually some portions of each mound in which the material is more rounded and there are other accumulations of a similar nature in other respects and similarly situated, whose material is considerably more worn.

The character of the sand and clay comports perfectly with the derivation above indicated. The sand, instead of the familiar well worn grains of quartz, consists, in large part, of particles of limestone with which are mingled minute fragments of shale and some rounded grains of quartz. Numerous acid tests of these sands made in the field invariably elicited prompt and active effervescence, which indicates unleached limestone particles. Under the lens, the grains present, in the main, clean fresh surfaces of characteristic texture.

As an approach to a more accurate determination of their character, 130 grains, selected indiscriminately from the smallest particles that could be conveniently handled (mainly less than 1^{mm} in diameter) were dropped in succession into dilute hydrochloric acid slightly warmed. These were taken from a quantity gathered from the face of an excavation (one mile north of Midway, Madison Co., Ohio) in such a way as to represent fairly the average of six feet vertical depth and twenty feet face, lying between six and twelve feet from the surface. Of the grains so treated, 95 gave notable effervescence, and mainly dissolved; 18 light-colored grains gave no action and were manifestly quartzose; 17 dark-colored grains gave no perceptible response. After digesting twelve hours, 16 dark grains remained and 18 light colored ones. There were in addition a few minute quartz particles, probably nuclear points or particles that adhered unobserved to larger ones when dropped in the acid.

From the same sample 107 grains, selected indiscriminately, except that a larger grade was chosen (1 to 4^{mm} in size) were treated in a similar way. Of these 94 gave notable effervescence, 9 dark colored grains gave slow or feeble action, and four light colored particles gave no response. This confirmed what a general inspection seemed to indicate, that with increasing size of the grains there was increased proportion of limestone particles, and inspection of the finer gravel stones fully bears out this law. A magnet drawn through the sand brought forth a few bristles of magnetite. Examined under a polarizing microscope the associated dust is seen to be largely quartz, and the finer grains to be mainly quartz and fragments of granular limestone and dolomite, to which are added a few splinters of clean crystalline calcite, an occasional grain of magnetite, and not infrequent dark or black, nearly or quite opaque grains, whose character was not determined.

An analysis of the leading ingredients by Professor E. G. Smith gave:

Insoluble in HCl.		Soluble in HCl.	
SiO_2	= 21·157	$CaCO_3$	= 44·294
Al_2O_3	1·057	$MgCO_3$	26·070
Fe_2O_3	·839		
CaO	trace, undetermined		70·364
MgO	" "		
	23·053		

P_2O_5	undetermined	6·583 subject to correction for loss or gain.
H_2O	"	
Fe_2O_3	"	
Al_2O_3	"	
		100·00

A second sample of finer grain gave :

Insoluble in HCl.

SiO_2	=	21·507
Al_2O_3		2·480
Fe_2O_3		·409
MgO		undetermined
CaO		"
		24·396

Soluble in HCl.

$CaCO_3$	undetermined	75·604 estimated by loss; subject to correction for loss or gain.
$MgCO_3$	"	
Fe_2O_3	"	
Al_2O_3	"	
P_2O_5	"	
H_2O	"	
		100·00

These, in the light of the preliminary inspection, may be interpreted roundly to signify about 70 per cent of magnesian limestone particles, less than 20 per cent of quartzose sand and less than 5 per cent of shale particles. In another aspect they seem to disclose that 70 per cent certainly, and probably 90 per cent, were derived by mechanical action, while probably not more than 10 per cent arose from decomposition.

A similar analysis of a much more worn sand taken from a hill about 6 miles southwest of Bellefontaine, Logan County, Ohio, gave the following results:

Insoluble in HCl.

SiO_2	=	29·341
Al_2O_3		14·516
Fe_2O_3		1·964
CaO		trace, undetermined
MgO		" "
		45·821

Soluble in HCl.

$CaCO_3$	=	31·079
$MgCO_3$		7·885
		38·964

Fe_2O_3	undetermined	15·215 subject to correction for loss or gain.
P_2O_5	"	
H_2O	"	
Al_2O_3	"	
		100·00

This shows a much less, but still large proportion of limestone derivatives and a much greater ingredient of a clayey or shaley character.

The clays, associated with some portions of the gravelly mass of these hills, have not been analyzed, but acid tests in the field indicate the abundant presence of the carbonates. Two conditions of the clay may be recognized, linked by intermediate gradations. The one, in which it constitutes a matrix embracing the stony fragments after the manner of bowlder clay—indeed the mass is indistinguishable from pebbly till—the other, in which it is only a coating of the angular gravel, or a partial filling of its interstices, giving the impression that it is a secondary inter-deposition. These two varieties are connected by intermediate gradations, giving rise to an interesting series of clayey gravels and gravelly clays.

3.

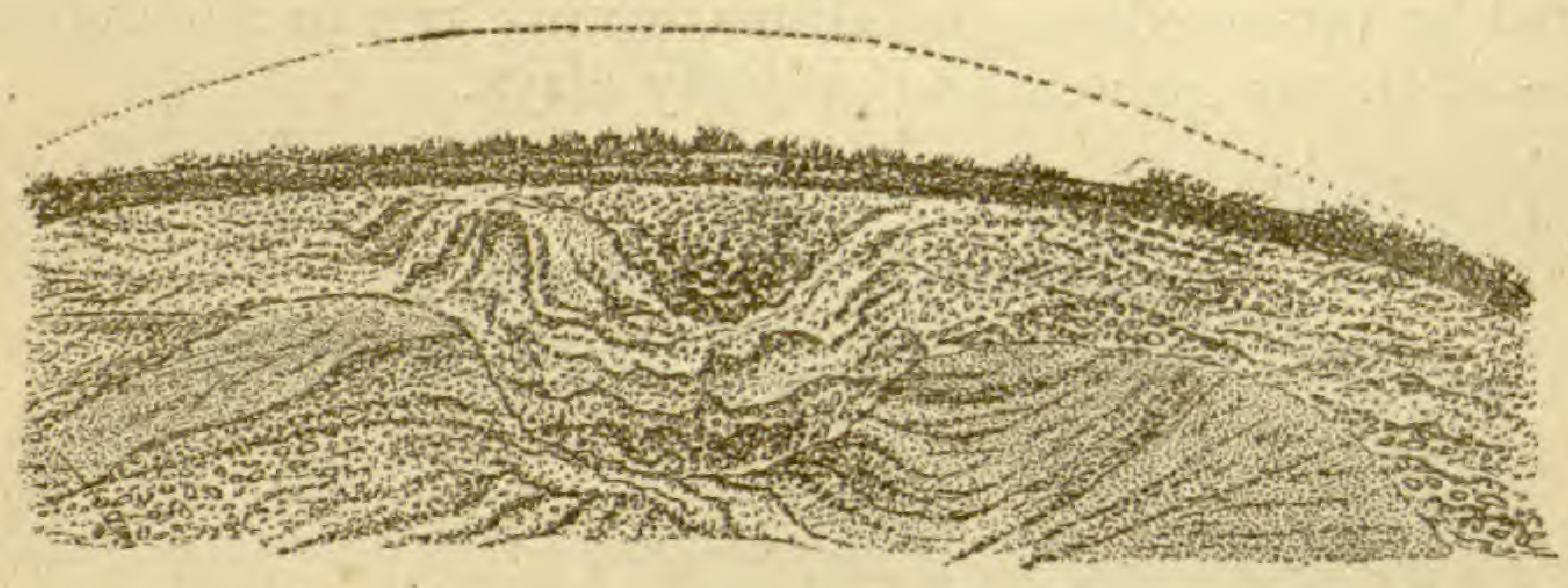
Section of a portion of a gravel hill, showing highly inclined and contorted stratification. East line of Sec. 28, T. XXI, R. 5 W., Jackson, Tippecanoe Co., Indiana.

Stratification.—The gravel in certain portions of these hills is completely assorted and stratified in horizontal layers. A larger proportion assumes various inclined attitudes, and examples of curved and discordant stratification appear in the greatest abundance and variety. But it is to be observed that the slope of the inclined beds is not limited to the moderate inclinations to which such material is confined when deposited under running water, but stands at all inclinations, even up to verticality. Moreover the beds are often twisted and contorted, or crushed into confusion, and occasionally, though rather rarely, broken and disjointed. The partially assorted portions partake most of these anomalous attitudes, being pushed into various irregular shapes and curiously inwrought among the better assorted portions. It is in association with these disturbed beds that the till-like portions are found. Vertical and inclined *veins*, more or less irregular, and filled with a very fine silt, occasionally present themselves. The accompanying figures very imperfectly represent the general aspect of the interior structure of these hillocks. To fully appreciate their real complexity, it is necessary that the study of the actual section should be carried into detail.

It thus appears that these hills present gradations (1) of material from mixed stony clays to finely assorted sand and gravel; (2) of attrition, from that of the glaciated till fragments to moderately worn sand and gravel, and (3) of stratification, from contorted and disturbed beds to almost complete horizontality. The interesting fact is that this occurs within the limited compass of a single hill, it may be a mere hillock, scarcely exceeding in size an artificial tumulus.

Inferences.—The following inferences are drawn, if not altogether from the brief statements above made, at least from the wider range of facts observed.

4.



Section of a portion of a gravel hill near Midway, Madison County, Ohio, showing discordant and contorted stratification.

I. *The angular gravel is an immediate derivative from the adjacent till.* This is manifest from its passage into till through a complete series of gradations, and from the identity of its stony constituents with those of the till.

II. *The material is of extremely local derivation*—considered as a secondary formation—(1) because it is so little worn in its extraction, (2) because it is so imperfectly and so variously assorted, and (3) because of the intimate stratigraphical associations above indicated. Considered as to its ultimate genesis through its parent till, it is at least not of remote origin, in the main; for, aside from the lithological and paleontological evidence that is applicable to the coarser material, and by inference, and to some extent by microscopic inspection, to the sands and clays, it is manifest that material containing from 40 to 70 per cent of limestone was not derived from the crystalline rocks of the Canadian highlands, nor from these combined, in the ratio of surface exposure, with the Lake-basin series of sandstones, limestones and shales, nor even from these combined ratably with the formations adjacent to the deposits. If a uniform shaving were cut from the face of the successive strata from the Canadian heights to the locality of the deposits, it would not give the higher percentage of calcareous and magnesian material, even if no account were taken of surface-leached material, which must inevitably have become mixed with the drift. The character of the material indubitably indicates that, while a minor portion was brought from distant sources, the great mass was gathered from the adjacent limestones.

III. *These hills were formed in the presence of an intermittent disturbing agency.* It seems quite impossible to explain the curious relations of the disturbed and undisturbed portions of the mounds by postulating a single thrust, or even a succession of disconnected sudden impulses. It seems necessary to assume the continued presence but intermittent action of the disturbing agency. This is strengthened by the following consideration.

IV. *Their formation required a special localizing agency.* This is most apparent in the cases of isolated mounds on broad plain tracts of till, or of embossments on the slopes or crests of ridges. No existing agency, by any extension of its magnitude, is at all competent to account for their localization. The formative agency, or combination of agencies, must have produced, at once, local assortment and local heaping of the assorted material, or, in other words, the assorting waters must have been confined and concentrated in their derivative action, and likewise constrained so as to heap their material into tumuli, whose location was determined by the constraining agency more than by any feature of the local topography or other present condition.

V. I infer, therefore, that these hills could not have been produced by any form of beach action, whether assisted by ice or not, because, in addition to what has been previously implied, their external forms, their irregular dispersion, their varying altitudes, defying reduction to horizontality, as well as their otherwise irreconcilable topographic situations, are incompatible with such an origin.

VI. Their inherent characteristics, taken in connection with their association with morainic belts, supports the opinion that they were formed along the edge of the great ice sheet by numerous marginal streams. The disturbance of bedding and the intrusion of the till masses are attributable to the oscillatory action of the ice, while the partial assortment, feeble attrition of the gravel and the multiform phases of stratification, were accomplished by the issuing streams. The localization of these streams was of course determined by the special conditions of glacial drainage then existent, but now largely past determination. The heaping of the gravels is thought to have been aided by the ice which restrained both the stream and the dispersion of its products. The special phases of accumulative action were probably somewhat variable, being sometimes purely marginal, the heaping being at the *debouchure* of the streamlets, sometimes within the walls of subglacial tunnels * or small marginal ice cañons,† and sometimes, perhaps,

* Hummel, loc. cit. † Upham, loc. cit.

at the base of moulins, so near the edge of the glacier that their products did not suffer obliteration by subsequent mechanical action of the ice. I have been unable to satisfactorily picture the precise process of formation of all forms of the accumulations under the conditions of any one of these methods alone, but as all were presumptive attendants of glacial action, the various forms seem explicable by their several, or their joint, agencies.

The hypothesis of formation in this manner is in complete harmony with the local character, the angular forms and the chemical constitution of the sands and gravels.

If they had been formed by superglacial streams, it seems necessary to suppose: (1) that a much larger proportion of distant material would have been present, even if it is maintained that subglacial material rises promptly to the surface of the ice, a view which I do not entertain; (2) there must have been a more complete assortment of the material, since superglacial streams are necessarily rapid and have great selective power; (3) there would probably have been more notable attrition and (4) a greater rarity of small glaciated stones, since these are very rare, if not altogether wanting, in superficial debris.

Significance of Calcareous Character.—The highly calcareous composition of this material is worthy of special note and, independently of other considerations, is very significant of the mechanical origin of the drift. The residuary material which covers non-glaciated areas within and about the drift-bearing territory is essentially non-calcareous even when derived from limestone, as I have satisfied myself by numerous field tests over a wide area and as is being demonstrated more thoroughly by special investigations in the hands of my assistant, Mr. R. D. Salisbury, undertaken with a view to develop more precisely the important truths that lie along this line of approach to the problems of the drift. Calcareous sands of the nature above described, are, so far as I can learn, wholly unknown in non-glaciated regions and are a product quite irreconcilable with the pre-glacial conditions that prevailed in the region where they are now found.

Nomenclature.—It would be quite within the sanction of prevalent practice to dub these hillocks *kames*, and there make an end of it. But at the outset of this article the manifest need of a stricter classification was alluded to. This must necessarily carry with it, or at least eventuate in, a more precise use of terms. These terms should be either simply structural or simply genetic, or else indicative of a given structure having a given origin. At present the term, *kames*, is applied broadly to embrace, on the one hand, mounds, hummocks and peaked hills, and, on the other, extensive branching gravel ridges, the two classes standing to other glacial phenomena in the contrasted relations I have previously pointed out; to say nothing of the probable inclusion under the term of fluviatile and littoral accumulations or degradational relics having no direct relationship to land ice. It is doubtless much too early to determine a final classification and nomenclature, but I think it will be a wholesome advance in that direction to restrict the term *kames* to mound-like and short-ridged accumulations whose distribution is obviously or apparently peripheral to the formative ice, and to distinguish from them under the name *osars* the extended linear and branching ridges that lie parallel to the lines of glacial movement and that belong to the longitudinal class of glacial features.* We may need to carry our distinctions much beyond this It is to be hoped that it will be possible to draw discriminations close enough ultimately to distinguish between the accumulations of (1) peripheral, (2) subglacial, (3) superglacial, and (4) ice-cañon streams, and (5) moulin cataracts, and also between the products formed in connection with (1) glacial advances, (2) glacial halts, and (3) glacial retreats. It is not improbable also that it may become important to distinguish between the drainage products (1) of active, and (2) of stagnant glaciers or glacial remnants. It is, for me at least, very difficult to form a clear and satisfactory conception of the formation of osars, one or two hundred miles in length and forty to one hundred and eighty feet or more in height, with lateral branches and meandering courses, like those of Sweden and Maine, in connection with active moving glaciers. The time requisite for the accumulation of so considerable an amount of worn and assorted material was by no means trivial when reckoned in terms of ordinary glacial motion. This motion of the ice seems incompatible with the meandering courses, and the branching forms, if not with the structure and definition of the ridges. Nor is complete satisfaction afforded by the view that they were formed progres-

* By reference to the discussions of thirty and forty years since, it will be found that the term *osars*, in its Anglicized form, was in common use as the accepted name of this class of deposits, and on this account has claims to retention. See, among other possible references, Am. Jour. Sci., xlv, 1843, p. 322, where Dr. Jackson identifies the gravel ridges of Maine as *osars;* also, Hitchcock's Elementary Geology, where *osars* are specifically defined and the term repeatedly used as one of common acceptance; also, Geol. of Lake Superior Land Dist., p. 236, where Desor likens certain gravels to "those curious ridges in Sweden, familiar to European geologists under the name osars." Also, Murchison's Geol. of Russia, vol. i, pp. 542-556, where the use of the term implies its adoption even among English writers.

But a more important reason for the retention of this term lies in the fact that the Swedish *osars* are a thoroughly typical and distinctive class, while the Scottish *kames* are comprehensive and need differentiation. The descriptions of Dr. James Geikie, which have done so much to foster interest in them, give precedence to the mound type, and justify us in restricting the term to that dominant class.

sively in channels cut back into the retreating edge of the ice by superglacial streams.*

Not to enlarge upon the subject here, suffice it to say that there are many features of the great branching osars that strongly invite the belief that they are the products of the drainage system of practically stagnant glaciers.† If this view be sustained—and that will depend, of course, not so much upon its aptness as an explanatory hypothesis, as upon collateral and independent evidence that the dissolving ice sheet, in its closing stages, became stationary in the areas involved—there will be room for a wide dynamic distinction between these by-products of ice under minimum motion, and the kames associated with terminal moraines, which are the offspring of glaciers at a stage of nearly maximum activity.

To what an extent it may be found serviceable to use distinctive genetic terms for these several classes, can only be adjudged when their respective prevalence, and the success with which they can be trustworthily discriminated, shall have been determined. Meanwhile the general structural distinction between elongated osars and hummocky kames is needed to avoid in some measure confusion of types, and to secure convenience of expression. This restriction and special application of the terms, kames and osars, is in accordance with the predominant, but not by any means uniform, foreign use of the terms, which is indeed not discriminative. Beyond question difficulties arise in the strict application of the terms, since the elongated ridges occasionally break up into clustered hillocks, and the transverse belts are attended by linear ridges, so that, structurally considered, the two types merge into close association. So also, genetically, they are related in the fact that they spring alike from the mutual relations of glaciers and glacial waters, but it seems more important to recognize the wide general distinction, than to employ a terminology so broad as to embrace phenomena that are diverse in such an important sense.

Under this restriction of terms the hillocks under discussion would be classed as kames, and would constitute one of their most distinctive, though perhaps not most common, types.

* Upham, Origin of Kames or Eskers in New Hampshire. Proc. Am. Assoc., 1876, xxv, 216.

† Prof. Stone, who has studied these special forms more extensively than any one else in this country, expresses the conviction that the flow of the ice as a whole had ceased at the time of their deposition. (Kames of Maine, p. 469.)

ART. XLV.—*Extinct Glaciers of the San Juan Mountains, Colorado*; by R. C. HILLS.*

THAT portion of the Rocky Mountain range which, for the purpose of this paper, will be considered as the San Juan Mountains, includes the whole of the elevated region embraced in the Counties of Hinsdale, San Juan, Ouray, San Miguel, Dolores, Rio Grande and La Plata.

The drainage east of the Continental Divide constitutes the source of the main branch of the Rio Grande, while that to the westward includes the principal tributaries of the San Juan and the southern tributaries of the Grand and Gunnison. The volume of water conveyed into the Rio Grande is small compared with that which, flowing westward, furnishes more than half the total volume of the Colorado River. In fact the volume of the Rio Grande from this source only does not exceed that of either the Dolores or Animas, streams which are simply tributaries of the Grand and San Juan.

The extent of glacial action in the past seems to have been, in a great measure, proportional to the magnitude of the existing river systems, and it is found that not only was there a greater thickness of ice on the western slope but the area of glaciation was many times more extensive. Evidence of the former existence of glaciers in the Rio Grande drainage area is most decided in the region lying west of Wagon Wheel Gap. For a distance of twenty-eight miles above the Gap, the river bottom, which is seldom less than half a mile wide, is a continuous deposit of drift. Above this for some distance the fall of the river is considerably increased, and the surface of the eruptive rock here forming the river bed is, where exposed, usually smooth and rounded. There are no accumulations of drift, or if such ever existed they have since been carried away. Succeeding this is a swampy bottom about four miles long, extending nearly up to Lost Trail Station, and terminated at its lower extremity by a moraine. It is separated from a third and smaller valley, lying between Lost Trail and Timber Hill, by a few well-rounded hills cut by the river. Timber Hill is equidistant about seven miles from the semi-circular ridge dividing the Atlantic from the Pacific drainage and enclosing a section of country that, with the exception of the higher peaks, appears to have been thoroughly glaciated.

Of the lateral ice streams flowing into the Rio Grande Valley, the greatest was probably that of Clear Creek. It originated in the country lying above Clear Creek Falls, and which is at the present time mostly below an elevation of 10,500 feet.

*A paper read before the Colorado Scientific Society, October 1, 1883.

A short distance down the valley from the Falls the ice stream was divided, one portion entering the Rio Grande Valley at Antelope Park and the other portion at Antelope Springs, three miles to the eastward. The latter branch formed the depression known as Santa Maria Lake, and, during its retreat, the huge terminal moraine one mile above the springs.

From the Continental Divide at the head of the Rio Grande to Wagon Wheel Gap the distance is about fifty-two miles. Below the Gap there is evidence that glaciers flowed in from the Divide to the southward, but it does not appear that the main glacier extended east of the Gap. Judging from the glaciation on the hills flanking the valley, the main glacial stream did not exceed five hundred feet in thickness, and its extraordinary extension eastward must have been due to additions from lateral sources. In comparison with the country west of the Divide the glacial features of the Rio Grande Valley are of secondary interest, and it is to the Pacific slope of the mountains more particularly that I wish to direct attention. That a long continued period of extensive glaciation existed there is shown by the frequent occurrence of drift along the western margin of the undulating plateau region, lying near the base of the main range, and by the scratched and fluted surface of the crystalline schists and such eruptive rocks as have resisted disintegrating action in and around the main range itself. In addition, morainal deposits are a conspicuous feature in the flat swampy bottom, known as parks, of frequent occurrence along the principal streams. It does not appear that the glaciers were always confined to the existing valleys, but that, at some remote period, the entire western slope of the mountains, except probably the higher peaks, was covered with an unbroken sheet of ice. The extension of this sheet westward was doubtless aided to a considerable degree by additions of glacial material from three more or less isolated groups of mountains, viz: the Tongue Mesa, Mount Wilson and La Plata groups.

The western limit of the ice sheet at the period of greatest extension is not always well marked, yet sufficiently so at intervals to admit of its being defined with some approach to accuracy. From the Rio Navajo northward to the Mancos Valley the ice plowed down through the Fox Hills sandstone into the Colorado shales, sometimes to the level of the Dakota, leaving an irregular line of escarpments and low hills facing the Needle and La Plata Mountains. These escarpments are especially noticeable between the Animas and Mancos rivers where the depth of erosion from this cause alone is from 250 to 500 feet. Similar escarpments occur fronting the Mount Wilson and Lone Cone groups of mountains. In the Animas

River region bowlders of quite large size, usually granite, are distributed over the country five miles west of the town of Durango and nearly sixty miles from the source of the Animas River. No rocks are exposed in the vicinity older than the Colorado Cretaceous, and the nearest exposure of granite is at Elbert, eighteen miles up the river.

In the Rio San Miguel region the ice moved westward with the general course of the San Miguel River, and crossed diagonally the course of the south branch of that stream. To what distance it extended I am unable to say, but I have observed erratic bowlders of eruptive rock on the mesas flanking the San Miguel, thirty-five miles from the source of the river.

In the country immediately south of the Uncompahgre River, it does not appear that the ice extended west of the mouth of Dallas Creek. In the region between the Uncompahgre and Cimarron the extension was much greater. For several miles west of Tongue Mesa the country is covered with coarse bowlder drift, composed largely of eruptive rocks derived from the Tongue Mesa Mountains. The western limit of this area is marked by a long ridge of Archæan rocks running diagonally from the Cimarron southwesterly to the Uncompahgre Valley and known as the Vernal Mesa. Consequently, the greatest extension of drift is toward the latter, where erratic bowlders may be observed twelve miles west of the extremity of Tongue Mesa and within a short distance of Montrose. Similar features are observable in the section of country lying between the Cimarron and the mouth of Indian Creek on the Lake Fork of the Gunnison.

As the ice sheet retreated it became divided and finally separated into distinct glaciers corresponding to the principal valleys. Of these the Animas glacier was probably the largest. It formed the beautiful and fertile Animas Park in La Plata county and Baker's Park in San Juan county. It was augmented by large additions of glacial material from the Needle and Cascade Mountains, and a short distance above Elbert was probably at one time nearly three miles wide. Between Elbert and Silverton the rounded surfaces of the crystalline schists exhibit glacial scratches 1200 to 1500 feet above the old glacier bed. Two parallel terminal moraines cross the lower end of Animas Park at Animas City. There is a moraine at the lower, and another at the upper end of Baker's Park.

Next in importance was probably the Hinsdale glacier, occupying the upper valley of the Lake Fork of the Gunnison. It formed the basin of Lake San Cristobal, and, as shown by the drift covering the low hills northeast of Lake City, was at one time nearly a mile wide. Lake City is about twenty-four miles from the source of the river and about fifteen miles from the nearest point on the Continental Divide. Owing to kaolinization and other causes the rocks bordering the lower portion of the district have not retained the characteristic glacial scratches, and the only indication of the probable thickness of the Hinsdale glacier is the presence of drift material which is abundant 800 feet above the level of Lake San Cristobal.

The Uncompahgre glacier was eighteen miles long, extending to the foot of Uncompahgre Park and to within a short distance of the mouth of Dallas Creek. It deposited the huge moraine, over 150 feet high, which crosses the lower end of the park. Below the town of Ouray only friable sandstones and shales are exposed and glacial striæ are absent. Above Ouray the quartzites and schists are scratched and polished 800 feet or more above the bed of the Uncompahgre River.

On the La Plata the local glacier was about 15 miles long, and, in places, three-fourths of a mile wide, extending more than six miles below Parrott City. A glacier of about equal dimensions occupied the valley of the Mancos. The drift forming the substratum of the Mancos Valley is largely mixed with clay, probably owing to the enormous amount of shale eroded by the glacier.

On the North Fork of the San Miguel was a glacier eight miles long, and about 200 feet thick towards its western extremity. It extended to the lower end of what is known as Gold Run, a swamp valley terminating in a moraine about thirty feet high. The glacier of the South Fork of the San Miguel was about fifteen miles long and debouched into the main valley a short distance below the lower end of Gold Run. It was augmented by the Lake Fork glacier, the latter forming the depression occupied by Trout Lake. The only indication of the probable thickness of the South Fork Glacier is the occasional occurrence of fluted surfaces on the precipitous granite exposures below the town of Ophir, which can be observed 400 feet above the smooth granite bed of the old glacier and on both sides of the river.

On the San Juan, Navajo, Los Piños, Piedra, Florida and Dolores, all of which streams I have visited, local glaciers of greater or less extent once existed; but those I have described were probably the most important, at least their history is the best preserved.

During the period of the extension of the ice sheet the Upper and Middle Cretaceous rocks were eroded from 200 to 500 feet, in some places more, the amount of erosion being greater where shales predominated, as for instance, in the section of country immediately north of Animas City.

That a long period of time elapsed between the retreat of the ice sheet and the final retreat of the local glaciers is shown by the depth of erosion in the South Fork of the San Miguel. As before remarked, the course of this stream is diagonal to the direction of movement of the San Miguel portion of the ice sheet, which was approximately that of the main valley. The South Fork glacier cut down through not less than 800 feet of Cretaceous sandstones and shales, forming a cañon nearly half a mile wide bordered at intervals by escarpments of sandstone. The erosion of this cañon must have taken place since the retreat of the ice sheet and before the retrograde movement of the local glacier had reached the junction of the South Fork with the main stream. However, the South Fork cañon does not represent the average depth of erosion by local glaciers, but rather the maximum, for in most instances it has not exceeded half this amount.

Since the retreat of the local glaciers to the upper valleys the rivers have excavated chasms, or, what are usually termed "box cañons," fifty to one hundred feet deep, according to the velocity of the current and character of the eroded rock. Evidence of this nature is shown in the Uncompahgre cañon near Ouray, in the cañon of the Animas above Elbert, on the Dolores above Rico, and on the Lake Fork of the Gunnison above Lake City. The depth of these chasms gradually decreases toward the heads of the streams, notwithstanding that the fall gradually increases, and around the sources of all the rivers rising in the San Juan Mountains we find localities where the water is flowing but a few feet below the striated rock surface of the old glacier bed.

It is not unusual to find in these mountains limited accumulations of *névé* that never entirely disappear. There are two of these at the head of Henson Creek, near the point where the Animas Forks wagon road crosses the divide, at an elevation of 13,000 feet. They are seldom less than fifty feet thick, from 100 to 300 feet wide and from 400 to 600 feet in length. I visited the smaller of the two on the 20th of September of the present year and found a stream of water, caused by the melting of a recent fall of snow, running the whole length of its trough-like surface. Scraping away some of the loose snow I discovered that the mass was solid ice, into which light was transmitted some distance. It seems moderately certain that the Glacial period of this portion of the Rocky Mountains extended nearly up to the present time and that the *névé* accumulations found on the head of Henson Creek, and elsewhere, are the remnants of the ice envelope, which, at a remote period, covered nearly the whole of the habitable portions of Hinsdale, San Juan, Ouray and San Miguel Counties, and a large portion of the Counties of La Plata, Dolores and Rio Grande, extending over a territory of more than 4,500 square miles, or about equal to the area of Arapahoe County.

Regarding the comparative excess of ice on the Pacific slope of the mountains, I think some explanation may be found in the cause producing an excess of water on that slope at the present time. Inspection of one of the official maps of this region shows that the Continental Divide forms a long elliptical curve opening to the eastward, enclosing the country drained by the Rio Grande, and in general conforming to the contour of greatest mean elevation. An examination of the eruptive rocks of different localities indicates that the present curve represents approximately the trend of the Continental Divide at the close of the last period of disturbance, for we find rocks belonging to the more recent overflows dipping from the Continental Divide into the Rio Grande valley, so that the rocks occurring between Del Norte and Wagon Wheel-Gap are contemporaneous with those found near the divide, north, south and west. As a result, nearly four-fifths of the region circumscribed by the contour of 8,000 feet is thrown west of the divide, and this fact sufficiently explains why there is such a limited volume of water flowing to the east as compared with that flowing to the west, which is to be referred to topographical rather than to meteorological conditions. There can be no doubt that the last period of disturbance antedated the period of glaciation and that therefore the greater accumulation of ice on the western slope was due to substantially the same cause that now determines the greater flow of water in that direction.

ART. XLVI.—*Gender of Names of Varieties;* by ASA GRAY.

AMONG other subordinate questions in Natural-history Nomenclature, it has been asked whether names of varieties, like those of species, should conform in gender to the genus, or whether they may not as well conform to the word *varietas*, and so always be feminine.

Linnæus introduced the current practice of numbering varieties by the letters of the Greek alphabet, α, β, γ, etc. But to some varieties, evidently to the more important, he gave names. These names, when adjectives, were always (so far as we know) made to agree in gender with the generic name: ex. gr.—

Viburnum Opulus, β roseum.
Asparagus officinalis, α maritimus, β altilis.
Mesembryanthemum ringens, α caninum, β felinum.

In our days named varieties play a more and more important part; and all botanists, as a rule, appear to have followed the Linnean model, with now and then a divergence which is readily explained, and which may be said to be accidental, such as

Ripogonum album, var. *leptostachya*, Benth.

This is as one writes "forma *albiflora*" or "Var. *albiflora*," a white-flowered form or variety. But that this is not the pattern nor the true construction of varietal names appears at once on reference to ordinary cases. Thus, for example, in "*Nasturtium amphibium*, *α indivisum*, DC. Syst.," it is not an undivided variety of the species that is meant, but a name which stands in the same grammatical relation to *Nasturtium* that *amphibium* does, and to write *N. amphibium*, *α indivisa*, is obviously wrong. We should say that it makes no difference whether the word variety, or its abbreviation *var.* is expressed or understood. When the conditions of the case seem to call for it, we should write *N. amphibium*, var. *α indivisum*, just as, if it were ever needful, we might write, "*Nasturtium*, spec. *amphibium*," and just as L. C. Richard (a good model), in Michaux's Flora writes,

Viburnum dentatum, var. *α glabellum*, *β semitomentosum*.
Rhus Toxicodendron, var. *α vulgare*, *β quercifolium*.

The editor of the Gardener's Chronicle (March 22, p. 373), having put this kind of question to M. Alphonse de Candolle (whom we should consider the highest living authority upon nomenclatural matters), understands him to reply that "the insertion of the abbreviation *var.* for *varietas*, which is feminine, demands a feminine termination; but if the word *var.* be omitted, then the rule would be for the variety to follow the specific name;"—meaning probably the generic name, for in one of the examples given, "*Thymus Serpyllum*, *β montanus*," it does not follow the specific.

From this point of view, viz: that where the nature of the group (in this case, variety) is expressed the adjective name should be feminine, but where only understood, it might be masculine or neuter—we must commend the editor's closing remark:—

"Perhaps the simplest and most easily recollected rule, would be to make the varietal name feminine in all cases, whether the *var.* or *varietas*, were expressed or understood. This at least would be intelligible, and would conduce to uniformity of practice."

It would also be logical, and the logic also would require all specific names to be feminine; for the word understood, *species*, is feminine.

Now we do not suppose that M. de Candolle would tolerate a double set of genders for the names of varieties. His doctrine is that the "var." should be discarded and the Greek letters only employed, not only for numbering the varieties, but for designating the fact that the name they are prefixed to is a variety.

It is not difficult to perceive why it has come to pass that "English writers generally use the abbreviation *var.*," and that some continental botanical writers follow the practice. One reason is, that it enables us to cite an author's variety by its name without having to concern ourselves with its Greek number, whether it is β or γ or δ, which otherwise we should have to attend to. Another is, that our sense of good form revolts at beginning sentences and paragraphs without capitals. In our books, varieties usually stand in independent paragraphs. Even in Latin we do not like to begin a paragraph:—

"*a indivisum* foliis omnibus integerrimis serratisve, non aut vix basi auriculatis."

In English we can still less abide it. So we prefix "Var.," and either number our varieties with Greek letters or, preferentially, leave them out.

But, we did not suppose that by the employment of the word "Var." we had interfered with the relation of the name of the variety to that of its genus. Var. *indivisum*, in this case, we should construe the phrase: "Varietas cujus nomen est *indivisum*. 'Var. *indivisum*' stands on the same ground as 'species *amphibium*.'" The latter rank we rarely need to express, because we always prefix the generic name or its initial. The former may often come in a shape which renders the designating prefix *var.* necessary, or at least most convenient.

We may, indeed, quite correctly write, *var. albiflora*, a white-flowered variety, *var. longifolia*, a long-leaved variety: but that is not according to the Linnean pattern nor to the regular practice, nor to the strict analogy of the varietal name with the specific.

Moreover, if the gender of the word which designates the grade of the name is to govern the gender of the name, at least when expressed, as by *var.*, then all *subspecies* must be made feminine. Now, this term *subspecies* is coming largely into use. And it has to be expressed in every case, in this wise:—

Ranunculus aquatilis, L.
Subsp. *heterophyllus*.
Subsp. *hederaceus*, etc.

If the proposition which we deprecate is adopted these names would have to be written *heterophylla* and *hederacea* by an author who ranked them as subspecies but *heterophyllus* and *hederaceus* by one who took them as varieties and simply numbered them by Greek letters. Obviously the propositions in the Gardeners' Chronicle had not been thoroughly worked out.

ART. XLVII.—*On Secondary enlargements of Feldspar fragments in certain Keweenawan sandstones;* by C. A. VANHISE.

RECENT observations by Sorby,* Irving,† and others‡ have shown the occurrence in sands and sandstones, and even in the most indurated quartzites, of a secondary quartz, so placed upon each one of the original grains of quartz as to be crystallographically continuous with it. This occurrence and the explanation afforded by it of the change of a sandstone to a quartzite, naturally lead the lithologist to query whether similar enlargements may not occur in the cases of other minerals found as particles in rocks of fragmental origin, and thus still further light be thrown upon the origin of some of the crystalline schists. Bonney, for instance, in speaking of certain of the crystalline rocks of Cornwall, England, conjectures the possibility of such occurrences in the following words.§ "These larger feldspar grains, for instance, may have as their nuclei feldspar grains which were original constituents, and may have survived the dissolution of the finer sedimentary materials in which they were imbedded. Then in the process of re-constitution, feldspar (not perhaps always of the same species) may have been added to feldspar, quartz to quartz, mica to mica and hornblende to hornblende or altered augite."

Of the minerals mentioned by Bonney, quartz and the feldspars, because of their abundance, are evidently by far the most important. For some time past, during my microscopic studies, I have been on the outlook for evidences of the existence of enlargements of feldspar fragments. In the slate conglomerates of the north shore of Lake Huron, I have found what seem to be enlarged feldspar grains, but the evidence that any of the material is of secondary origin is not sufficiently satisfactory, the lines of separation between the supposed new material and the nuclei being ill marked. However, I have found what seem certainly to be additions to grains of that mineral, in certain of the Keweenawan feldspathic sandstones. The specimens in which these supposed enlargements were first found are taken

* Presidential Address before the Geological Society of London, Q. J. G. S., vol. xxxvi, 33.

† On the Nature of the Induration in the St. Peters and Potsdam Sandstones, and in certain Archæan Quartzites in Wisconsin, by R. D. Irving, this Journal, III, xxv, 401.

‡ Young, this Journal, III, xxiv, 47; Wadsworth, Bost. Soc. Nat Hist., Feb. 7, 1883; Philips and Bonney, Q. J. G. S., xxxix.

The same occurrence was noted in the quartzites of Eureka, Nevada, by Iddings and Arnold Hague as long ago as the summer of 1881, although these observations are not yet published.

§ The Hornblendic and other Schists of the Lizard District with some additional notes on the Serpentine, by T. G. Bonney, Q. J. G. S., xxxix, 19.

from those portions of the sandstones almost in contact with overlying basic eruptives. This location is evidently a favorable one for the development of such enlargements, the heated alkaline waters which would naturally descend from the overlying lavas supplying appropriate conditions. Then too, quartz enlargements when most easily found, are shown by lines of ferrite about the nuclei, and are ordinarily best seen in the less indurated quartzites. The Keweenawan sandstones are highly ferruginous, and are of an open texture; hence, if among them feldspars have taken new growths, the conditions for their detection are favorable.

1.

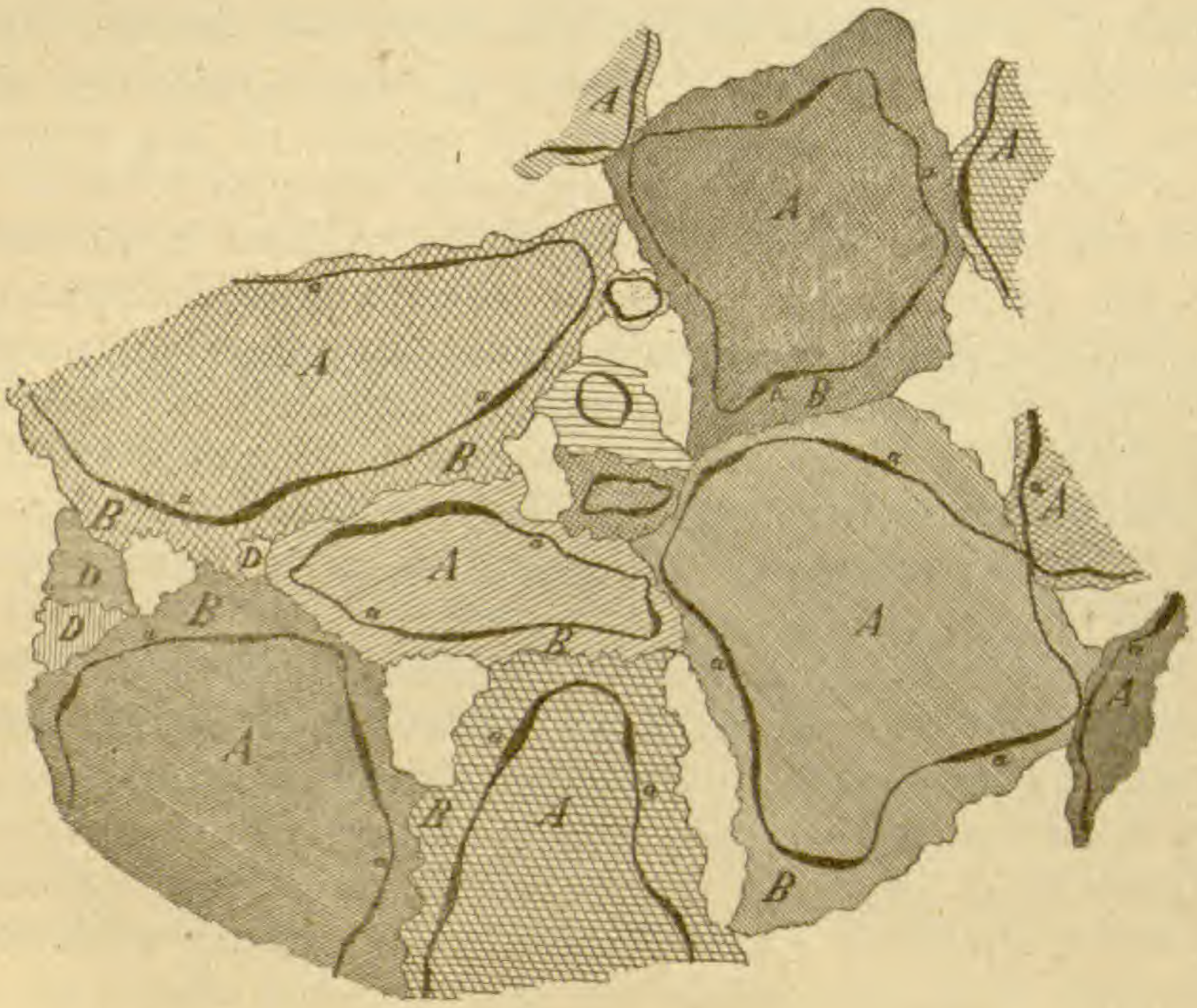


Fig. 1. Part of section of sandstone from Eagle Harbor, Mich., × 100; in polarized light. AAA, fragments, each from a single feldspar individual; *aaa*, films of iron oxide on the borders of the original grains; BBB, secondary enlargement of the original grains; C, quartz grains; DD, unfilled spaces; EE, secondary feldspar grains polarizing independently of the original grains.

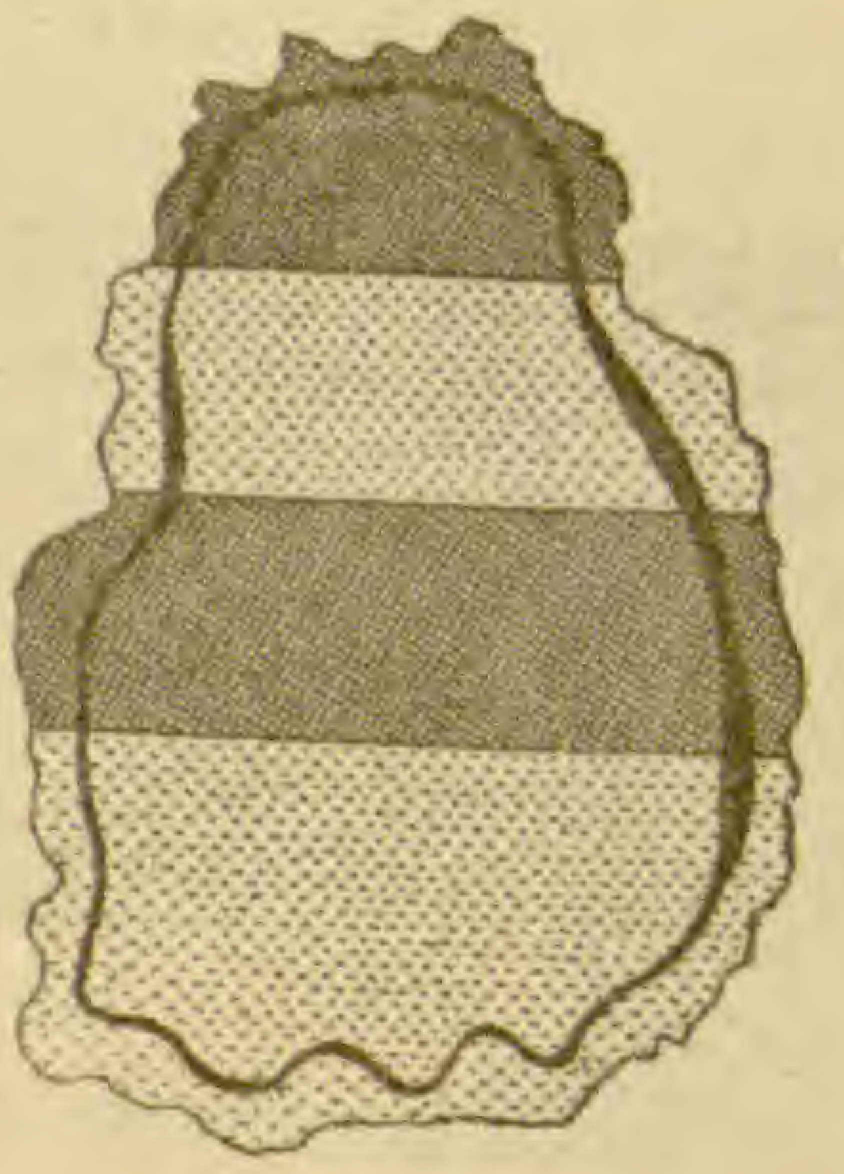
The feldspathic sandstone immediately underlying the diabase of Eagle Harbor, Michigan, is of a uniform medium grain, a magnifying glass showing but little quartz. The feldspar grains are stained red with iron oxide. Hydrochloric acid gives with the powder a slight effervescence. In thin section the sandstone is seen to be composed largely of grains of different feldspars, next to which in abundance are rounded complex fragments derived from a granitic porphyry,* consisting of

* The Copper Bearing Rocks of Lake Superior; by R. D. Irving. Third Annual Report United States Geological Survey, p. 114.

feldspars penetrated by a saturating quartz. Next in order of abundance are complex fragments of some altered basic rocks. Finally a few grains of quartz and a little secondary calcite are noted.

The feldspars are frequently somewhat kaolinized, but most of the grains are fresh enough to give quite uniform colors in polarized light, and, in the case of the plagioclases, well defined twinning bands. The grains are all rounded, their boundaries being marked by broad lines of ferrite. However some subsequent mineral has used these grains as nuclei, about which to deposit, and now each individual appears in the polarized light to extend beyond its original limits. These newly formed borders, as compared with the interiors, are different, in that they show no decomposition, and are freer from iron stains. When the borders from different feldspathic grains have extended so far as to come in contact, as they usually have done, they form sharply serrate, nicely fitting junctions, which are roughly comparable to the suture of a skull (fig. 1.)

2.



3.

Fig. 2. In polarized light; × 100. Plagioclase from Eagle Harbor sandstone, showing crystallographic continuity of original grain and secondary enlargement.

Fig. 3. In polarized light; × 100. Fragment of a grain of a granitic porphyry from Eagle Harbor sandstone.

This newly added material appears to be feldspar which has coördinated crystallographically with the grains about which it has deposited. It possesses no optical properties which would exclude that mineral, but cleavage and decomposition being absent, no comparison with the feldspars can be made as to those characteristic features. The belief that the new material is feldspar is, however, supported by the following facts.

When the enlarged feldspar is orthoclase, the deposited substance polarizes uniformly with the nucleus about which it is seen (fig. 1), exactly as quartz enlargements polarize with the grains on which they have grown. Further, when plagioclase is enlarged, as it frequently is, the new material has twinned uniformly with the old, the twinning bands in polarized light running continuously across cores and the added borders (fig. 2). This phenomenon was observed in many different grains and in different sections.

Again, the complex fragments above mentioned as derived from a granitic porphyry, and as containing quartz and feldspar, often have borders of new material and the added portions resemble, and usually polarize with, the feldspars instead of with the quartz, with which they would naturally coördinate, if with either, were they composed of silica. Frequently the exteriors of this class of grains are apparently all of feldspar, even when a third or more of the edges of the original fragments (and in some places for considerable spaces continuously) are of quartz (fig. 3). The grain figured consists of part of a single, orthoclase individual, including several areas of quartz. The secondary enlargement polarizes with the feldspar throughout its area.

4.

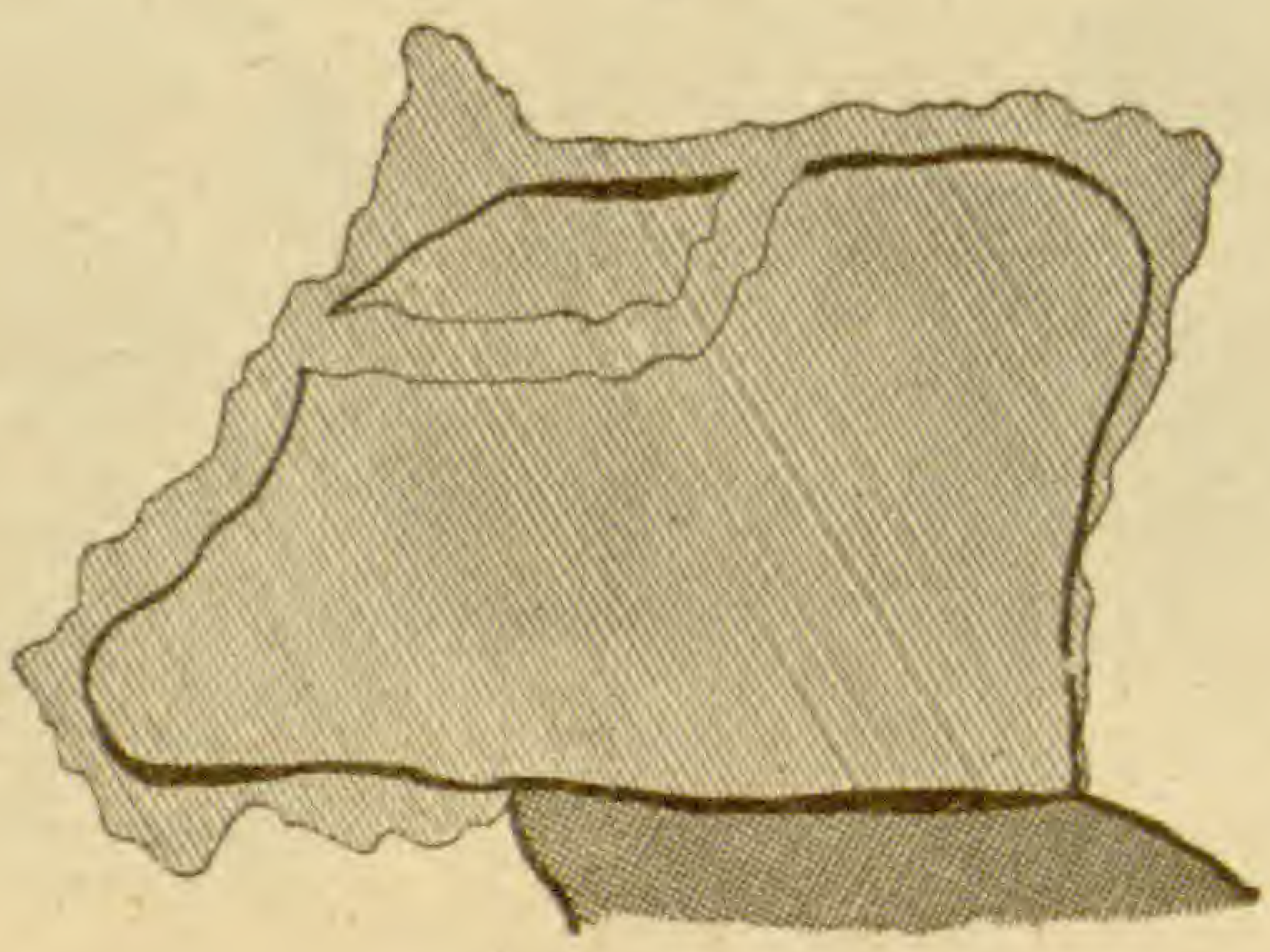


Fig. 4. In polarized light; × 100. Part of section of Eagle Harbor sandstone, showing an orthoclase fragment broken and re-cemented by a secondary material crystallographically continuous with the original fragment and with the border of newly deposited material.

Finally, the complex basic fragments also have their borders of new material. These basic grains are often very feldspathic, the feldspar individuals being, however, small. Here an enlargement instead of being a unit, as it commonly is in the preceding cases, consists of several or many individuals. The feldspars at the edge of the nucleus have ordinarily controlled the new growth, so that the new material polarizes in parts with the old interior grains. These parts have, however, often extended upon each side beyond the adjacent feldspars, and thus at times overlapped other feldspars—whose conditions were less favorable for renewed growth—or other minerals, if such chanced to be in contact with the division line between the clastic fragment and its border of new material.

The change which has taken place in one grain of orthoclase is of some interest. The grain has been broken into two parts, which have spread somewhat, and is now cemented with a new material which extinguishes with the original fragments, and also with the exterior second growth, with which it is continuous in one place (fig. 4).

In some cases the new material deposited on a grain, instead of continuing as a single individual until it meets a similar growth from another grain has crystallized independently in small interlocking grains (fig. 1). This independent feldspar (if we are correct in so considering it) is more plentiful about the basic fragments than about the feldspar grains or those of the granitic porphyry.

Uncovered thin sections were prepared and the supposed feldspar enlargements tested—so far as practicable—as to hardness with a needle and as to solubility in hydrochloric acid. With difficulty some of them were scratched, and they were not affected by the acid. The results of these tests accord well with the idea that the borders are feldspars, and show that they cannot be a carbonate.

Most of the sections of the Eagle Harbor sandstones also show quartz enlargements, but in one none were seen.

This same secondary material has been found in other sandstones in the Keweenawan series, and in two cases the sandstone directly underlies "greenstone." Descriptions of these, however, will not be given, as they furnish no additional points of interest.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Metasulphites.*—Berthelot has investigated the formation and properties of a salt which he calls the metasulphite of potassium. It was prepared by saturating a cold or hot concentrated solution of potassium carbonate with sulphurous oxide gas, and drying at 120° the salt which separated by crystallization. Though called anhydrous bisulphite by Muspratt and Marignac, it was found to have the formula $S_2O_5K_2$. It is characterized by the heat of its formation, by its stability, by its capacity of forming hydrates and even solutions distinct from those of normal bisulphite, and by its pyrogenic reactions. The direct formation of bisulphite evolves 16·6 calories at 13°; and,

if it reacts at once upon a second equivalent of potassium hydrate it evolves 15·2 calories more. But if the solution be carried to 100° in a closed vessel out of contact with the air, it is found that on saturating with potash only 12·9 calories are evolved in place of 15·2. Hence the bisulphite undergoes this change to metasulphite even in solution. If now the metasulphite be dissolved directly in water and saturated with potash 12·7 calories are evolved. Dissolved directly in a solution of caustic potash 6·9 calories are evolved; and this added to the 5·7 calories due to the solution, gives 12·6 as before. Even if the solution of metasulphite be heated to boiling and preserved three days, it still evolves 12·5 calories on being saturated with potash. Solutions of bisulphite on the contrary recently prepared, give 15·2 calories when saturated with potash; while after standing for a while, or on heating, they evolve only 12·6 calories when thus treated. The formation of the metasulphite then from the bisulphite evolves 15·2−12·6=2·6 calories. This evolution of heat explains the stability of the metasulphite and its production in solution. These results are the reverse of those which occur with sulphates. The anhydrous bisulphate $S_2O_7K_2$ is transformed into normal bisulphate in presence of water, with evolution of heat (1·45 calories). Deeming it of importance to ascertain whether the metasulphite is really converted into neutral normal sulphite by potash in excess, the experiment was tried and, immediately after measuring the resulting heat, one equivalent of dilute hydrochloric acid was added to the solution, and the heat again determined. The sum of the two effects was found to equal precisely that of the heat of neutralization of hydrogen chloride by potassium hydrate, 14·0 calories at 10°; thus proving that there had been no auxiliary reaction of the sort supposed. Further the author finds that on precipitating with alcohol a solution of potassium carbonate saturated with sulphurous oxide gas, he obtained compounds which were not normal bisulphite, but contained less water. Hence the hydrate formed is capable of losing its water without losing any sulphurous oxide. This view is confirmed by the heat of solution, which is the same for the anhydrous and the hydrated metasulphite. Under the action of heat, the dry metasulphite does not change at 150°; but toward a dull red heat it evolves sulphurous oxide though without producing any neutral sulphite; the reaction being $(S_2O_5K_2)_2=(SO_4K_2)_2+SO_2+S$. Hence the metasulphite has relations to the normal bisulphite resembling those which distinguish the ethylsulphites properly so called $(C_2H_5)_2O.K_2O.S_2O_4$ produced by the decomposition of sulphurous ether by alkalies, from the ethylsulphites $(C_2H_5)_2S_2O_5.K_2O$ (otherwise called hydrethylsulphates) obtained by the oxidation of ethyl sulphides. The author gives the relations of the acids of sulphur as follows together with the heat of their formation: 1st list. Ratio S: K. Sulphide K_2S_2+53; hyposulphite $S_2O_3K_2$,+133·7; metasulphite $S_2O_5K_2$,+184·6; hyposulphate $S_2O_6K_2$+205·7; bisulphate (metasulphate) $S_2O_7K_2$,+236·6; persulphate $S_2O_8K_2$: 2d list, ratio S : K_2. Sulphide SK_2,+102·2 ; sulphite K_2SO_3,+272·6 ; sulphate SO_4K_2,+342·2.—*Ann. Chim. Phys.*, VI, i, 81, Jan. 1884.

G. F. B.

2. *On the Hyponitrites.*—DIVERS and HAGA have replied to the criticisms of Berthelot and Ogier upon the hyponitrites. The latter chemists, finding a low percentage of silver in the silver hyponitrite prepared by them, assigned to it the formula $Ag_4N_4O_5$ instead of AgNO given by Divers. The former chemists point out that a trifling admixture of nitrite or nitrate would have produced the observed result, that there is nothing to show that the substance analyzed was not thus admixed, and that the formula is antecedently quite improbable. However, to establish the existence of the body AgNO, they prepared various samples of the hyponitrite, using various methods of purification. As a result, they were able to increase the percentage of silver from 75·5 the highest value obtained by Berthelot and Ogier, to 77·69; the percentage required by the formula AgNO being 78·3. The experiments are still in progress, the authors expecting to improve upon these results in the future.—*J. Chem. Soc.*, xlv, 78, March, 1884.

G. F. B.

3. *On Ferric ethylate and colloidal Ferric hydrate.*—GRIMAUX has succeeded in producing a colloidal ferric hydrate by a new method. If 3·25 grams ferric chloride be dissolved in 25 c.c. of absolute alcohol, and a solution of 1·4 grams sodium in the same weight of alcohol be gradually added, a precipitate of sodium chloride is at once formed and the dark brown liquid contains all the iron in the state of ferric ethylate with not a trace of chlorine. On distilling off the alcohol, a black pasty mass of unaltered ferric ethylate is left, which is soluble in absolute alcohol, in benzene, chloroform, petroleum ether and methyl alcohol. A trace of water, however, transforms it into ferric hydrate. Its alcoholic solution is not precipitated by a current of dry ammonia gas; though dry carbon dioxide throws down a dark brown precipitate and hydrogen sulphide gives ferrous sulphide. Exposed to the atmosphere, the alcoholic solution absorbs moisture and gives a thick coagulum of ferric hydrate. If however the ethylate solution be poured into an excess of water, a limpid liquid is obtained which presents all the appearance of the colloidal ferric hydrate described by Graham. It coagulates spontaneously after a longer or shorter time, or on the application of heat. At the temperature of 19°, half its volume of water produces immediate coagulation while 15 volumes produces a coagulum only after three days. With ten volumes of water, the solution coagulates at once only on ebullition. This variety of colloidal ferric hydrate, which is always slightly alkaline, is considerably less soluble than that of Graham, which is feebly acid. The author calls attention to the similarity of coagulation in the case of these mineral colloids with that of the nitrogenized colloids of the organism. The coagulation in both cases is retarded by cold; a blood which coagulates in five minutes at

11·5°, requiring only two minutes at 35° and one minute at 48·8°. With the inorganic colloids the author regards the phenomenon as simply a polymerization.—*Bull. Soc. Ch.*, II, xli, Feb., 1884.
G. F. B.

4. *On the Synthesis of Piperidine and its Homologues.*—By treating pyridine with sodium in alcoholic solution LADENBURG succeeded some months ago in preparing piperidine. Since that time he has improved the method so as to obtain nearly the quantitative yield. He has also prepared some interesting homologues of this base. Picoline from animal oil, boiling between 134° and 139° and hence a mixture of α-methyl-pyridine with some β-methyl-pyridine, was treated as above, distilled, saturated with HCl and evaporated to dryness. The residue was converted into the nitroso-compound, extracted with ether and decomposed with HCl. The hydrochlorate, distilled with HKO, and purified, gave a colorless oil boiling at 121–124°, consisting essentially of α-methyl-piperidine $C_5H_9(CH_3)NH$ isomeric with the methyl-piperidine prepared by Hofmann $C_5H_{10}NCH_3$. The author has also prepared ethyl piperidine from γ-ethyl-pyridine by the same reaction.—*Ber. Berl. Chem Ges.*, xvii, 388, March, 1884.
G. F. B.

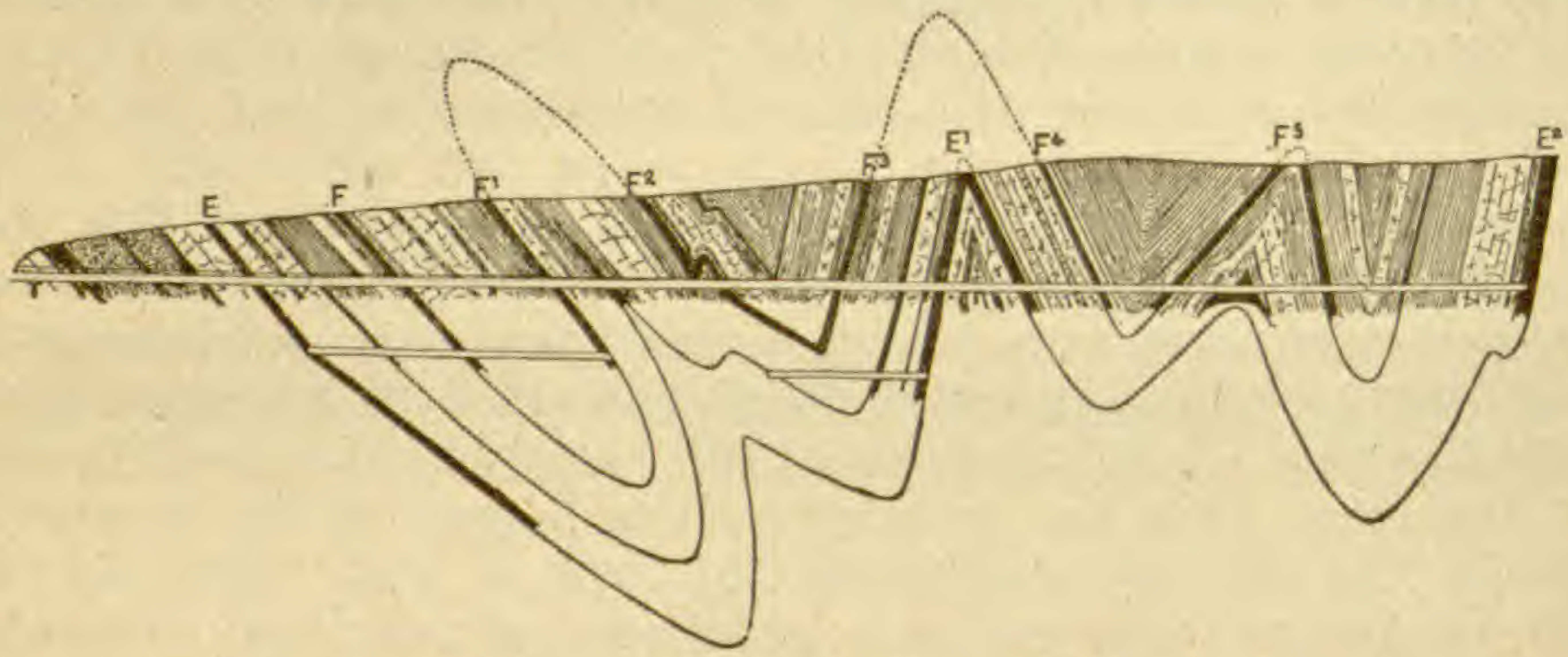
5. *On a Vacuum regulator for fractional Distillations.*—GODEFROY has described a simple and efficient regulator for preserving constant the vacuum employed in fractional distillations. The apparatus—whose size may be varied according to the purpose intended—consists of two somewhat large vertical glass tubes united at their lower ends by a fine tube. One of these (A) terminates above in a stopcock and funnel; the other (B) is extended above by a tube over which a rubber tube is passed to connect the regulator with the distilling apparatus; the lower end is closed by a three-way cock, on the side of which is the fine tube connecting with A. On the side of the tube B are two openings one above the other and about a centimeter apart, each having a tube two millimeters in diameter, bent at right angles and rising parallel to the tube itself. The lower one of these terminates above by a bulb and tube, to which the rubber tube is attached leading to the exhaust. The lower tube passes through the side of this bulb and is recurved. When not in use A is entirely filled with mercury and B contains more or less according to the vacuum desired. On working the exhaust, as soon as the pressure in B is less than will support the mercury column in A, this column falls and the mercury rises in B, cutting off first the lower and then the upper lateral tube. The exhaustion can now proceed no farther, until air enters from the distilling apparatus; then the mercury level falls below the opening of the lateral tube and the air is drawn through this tube into the exhaust. A graduation permits the difference of level of the mercury in the two tubes A and B to be read off, and thus the pressure under which the distillation is effected, to be determined.—*Ann. Chim. Phys.*, VI, i, 138, Jan., 1884.
G. F. B.

6. *On a new Temperature-regulator.* — LOTHAR MEYER has devised a modified form of temperature-regulator which is exceedingly sensitive. It consists of a brass tube, to be immersed in the air bath, within which is a glass rod. Supported on the upper end of this tube is one end of a lever 40 cm. long, the support acting as the fulcrum. Near this end is a screw, the lower end of which rests upon the end of the glass rod. Since the expansion of glass is only about half as great as that of brass, the outer end of the lever is moved down as the heat rises and up as it falls. To this arm of the lever, and adjustable as to distance, is hung by means of a chain, an apparatus like the upper part of a Kemp-Bunsen regulator. The gas passes down a central tube of sheet iron, having a slit at the lower end immersed in mercury; it then passes through the slit into an outer tube of glass, and so on to the burner. Obviously as the temperature rises the lever falls, the iron tube sinks deeper in the mercury, shortens the slit and diminishes the flow of gas. The lateral tubes for the entrance and exit of the gas are similarly movable and sealed with glycerin. On the thirtieth of June the temperature of an air bath thus regulated varied only five degrees in an experiment lasting six hours.—*Ber. Berl. Chem. Ges.*, xvii, 478, March, 1884. G. F. B.

II. GEOLOGY AND MINERALOGY.

1. *Geology of the Panther Creek Basin or eastern end of the Southern field;* by C. A. ASHBURNER. 208 pp. 8vo, with an atlas of 13 sheets of maps.—Report AA, Geological Survey of Pennsylvania. Harrisburg, 1883.—The Atlas of this report is noticed at length in the last volume of this Journal. The report gives details with regard to the sections—their strata, flexures, anthracite beds, the topography and other characters of the different basins, the variations of the beds in thickness, etc.; also the working and production of the mines, the constitution of the coals, the contents of the anthracite beds of the whole region, and other points of economical and scientific importance. The sections have much geological interest as illustrations of the subject of flexures in rocks. We here reproduce one of them, but much reduced in scale and with the omission of the statements as to the kinds of intervening strata and the parts of the coal beds that have been worked. It is the section from Neshequehoning Valley to Mauch Chunk through Rhume Run (No. 1) Tunnel (sheet No. 1 of the atlas and page 47 of the Report). Mr. Ashburner observes that Prof. Rogers' Report of the first survey of the State gives a diagram of the same section from surveys in 1840, and others have since been constructed. This latest has the advantage of being based on all explorations made to the present time and the newest identifications of the coal beds. In the section E, E^1, E^2, are outcrops of the "Mammoth bed," 13 to 27 feet thick; F to F^6, of the overlying Red Ash coal bed, 8 to 23 feet thick. The whole

thickness of the anthracite beds, from the mouth of the tunnel through the Mammoth bed, E, to F inclusive (the lower Red Ash coal bed), is 56 feet. The section illustrates (1) the doubling of a bed on itself, so doubling its thickness; (2) the uncertainty of determinations of the thickness of beds of rock in a region of flexures (the two parts of F at F^5 being separated by only a thin



outcrop of the thick strata, wholly unlike what intervenes between F^1 and F^2, and between F^3 and F^4; (3) the increase in the vertical depth of a bed where it is doubled up in the central part of a steep fold.

In an introductory chapter to the volume, Prof. Lesley suggests that some abrupt thickenings of the Pottsville conglomerate (from 300 feet, the average, to 900 and 1700 feet) may perhaps be accounted for on the principle alluded to in (3). He states also his conclusion that the Archæan regions of eastern Pennsylvania and probably also of the New Jersey Highlands were wholly covered "by the Paleozoic sediments at the time of the deposit of the Pottsville conglomerate." Prof. Cook gives for the height of the highest point of the New Jersey Highlands (2½ miles south of Vernon) (Rep. for 1883) 1,496 feet; what the Archæan rocks lost in height during the long interval since the Carboniferous era is without record.

2. *Geological Survey of New Jersey; Report for* 1883, G. H. Cook, State Geologist. 188 pp. 8vo.—Like all of Professor Cook's Reports, this new one is valuable both from a scientific and an economic point of view. The facts of practical bearing relate chiefly to the character and exploration of iron ores, and at less length, of other ores and mineral products, and those of special geological interest are mostly from observations on the Triassic sandstone, the trap rocks, and the Archæan rocks and iron ores.

The conclusions of Professor W. M. Davis that, while the Bergen Hill and Palisade range of trap is intrusive, the first and second ranges of the Watchung Mountain are probably overflows; that the overflows occurred before the sandstone formation was completed and before its beds were tilted; and that the amygdaloidal feature of a trap is evidence of overflow, are discussed, and various facts adduced sustaining the opposing opinion—that all the trappean ranges are alike of a later age than the Red sandstone formation, and were intruded after the beds were raised to their present inclined position. Many instances are mentioned of *unaltered* sandstone adjoining the trap; but while such facts occur at many points in the Watchung Mountains where the rock is sandstone, at other points, and especially wherever it is shale, it is hard baked and altered in color, and sometimes contains crystallized minerals as a result of the heat. Such effects of heat are found on both the eastern and western sides of the Watchung Mountains, leaving no doubt as to intrusion. Sands would not be baked or new minerals formed where there was no moisture to aid the heat. Professor Cook states that the dip of the Triassic sandstone is not everywhere westward, as has often been said, but that over a considerable tract of country in the valley of the Raritan there is eastward dip.

The kinds, positions and other characteristics of the Archæan formation are briefly considered, and interesting sections are given showing the conformable relations of the iron-ore beds (magnetite) to the enclosing rock. Professor Cook states that the beds of ore "partake with the associated gneissic strata of all the essential and accidental features or elements belonging to stratified rocks. They possess dip, strike and pitch, and are folded, faulted and pinched, as are the rocks about them. . . . Hence, when viewed in connection with the associated stratified rocks, the conclusion is unavoidable that they were deposited as sediments and are of the same age with them."

On page 162, an account is given of the detection of *native iron* in the Triassic shale and earth in Raritan township, about three miles east of New Brunswick. An analysis by Dr. T. B. Stillman obtained 76·12 per cent of metallic iron. This is the only case yet known of native iron from the sandstone formation. The Report for 1874 (p. 56), mentions its detection in the trap rocks of New Jersey.

3. *Locomotary Appendages of Trilobites.*—In the Journal of the Cincinnati Society of Natural History for October, 1883, Dr. John Mickleborough describes a specimen of trilobite of the large species *Asaphus Megistos*, which has great interest on account of the preservation of the ventral surface, with the attached appendages. His article is illustrated by a lithographic plate.

The specimen has been studied also by Mr. C. D. Walcott, and the general result of Mr. Mickleborough confirmed, but with new developments as to the structure. Mr. Walcott's article, which is published in Science of March 7, is illustrated by a woodcut of natural size, showing the parts in strong relief a little more strongly than they would have been represented in a good lithograph, as we judge from an examination of a cast—though of one that was made before the specimen had been thoroughly cleaned by Mr. Walcott. The number of pairs of appendages "clearly discernable" is 26, 9 of them beneath the thorax, one beneath the posterior margin of the head, and 16 beneath the pygidium.

"The legs beneath the thorax show seven joints in two instances." The general arrangement and position of the appendages are very much as they were represented by Mr. Walcott in his restoration of *Calymene senaria* (Bull. Mus. Comp. Zool., viii, 1881). Mr. Walcott also states that, on a careful examination, numerous fine slender filaments were discovered, both beneath the thorax and pygidium and also near the posterior end of the latter, slender jointed appendages not half a millimeter in diameter, and he appears to regard these as branchial, as he did the spiral and ribbon-like filaments discovered in his dissections of specimens of Calymene.

Mr. Walcott, after an examination of the specimen of *Asaphus platycephalus*, described by Billings as having remains of ambulatory legs, sustains Mr. Billings's conclusion. There is a pair of these appendages to each segment of the thorax. No indications of abdominal legs are visible.

4. *The Glacial Boundary in Ohio, Indiana and Kentucky;* by Professor G. F. Wright. 86 pp. 8vo. With map illustrations. 1884. Published by the Western Reserve Historical Society.—Through the labors of Professor Wright the southern limit of the glacier has been traced westward from Pennsylvania into Illinois; and in Pennsylvania, the work now carried on by Professor Lewis, was at first the joint work of him and Mr. Lewis. His conclusions as regards Ohio, Kentucky and Indiana, have already been given in this Journal, (xxvi, 44, 326). The paper now published contains the results of his latest explorations, and especially the details for the State of Ohio. It is to be noted that the expression "terminal moraine," is not here used, the fact being, as stated by him, that the limit, while in general distinct, is not always marked by true moraine depositions.

5. *Report on the Geology and Natural History of Canada for* 1880–81–82. A. R. C. Selwyn, Director. With many maps and plates.—Mr. Selwyn states, in his Summary Report, that he had examined during the past season several of the mines on the north shore of Lake Superior. In the 800 miles, he found only seven mines and one stone quarry that were worked, and only one, the Silver Islet Mine, that was profitably so.

The Reports in the volume are as follows: on the geology of the southeastern part of Quebec, by Dr. Selwyn; on the Bow and Belly River region and coal deposits, by Dr. G. M. Dawson; on the geology of the basin of Moose River and Lake of the Woods, by Dr. Bell; on northern and eastern New Brunswick, and on the Gaspé peninsula, by R. W. Ells; notes on some of the mines in the province of Quebec, by G. W. Willimott; and chemical report, by G. C. Hoffmann.

Part I of volume III on Paleontology, consists of a paper on Paleozoic fossils by J. F. Whiteaves, illustrated by 8 plates.

6. *Cretaceous and Tertiary Floras of British Columbia and the Northwest Territory.*—Dr. J. W. Dawson has a memoir on this subject in the Transactions of the Royal Society of Canada,

for May, 1883. It is illustrated by 7 plates. He states that the anthracite beds of the Queen Charlotte Islands are now known to be Middle Cretaceous, and equivalent of the upper part of the Shasta group of California, and that the coal beds of the Nanaimo and Comos basins, Vancouver Island, are Upper Cretaceous, equivalent to the Chico and Tejon groups of California. The Lignitic or Laramie group is admitted to be a transition group between the Upper Cretaceous and Eocene. The paper reviews the previously described species, and describes others that are new.

7. *Bertrandite: a new mineral.* — MM. DAMOUR and BERTRAND have recently published an account of a new mineral from the neighborhood of Nantes, to which M. Damour has given the name of *Bertrandite*. An analysis by him yielded:

SiO_2	BeO	Fe_2O_3	H_2O
49·26	42·00	1·40	6·90 = 99·56

for which the formula $2(Be_2SiO_4) + H_2O$ is proposed; in other words it is near phenacite but differs in containing water. According to Bertrand it crystallizes in the orthorhombic system with a prismatic angle of 121° 20′; the crystals are generally tabular in habit through the extension of the basal plane or of the brachypinacoid, they are sometimes twins. The crystals are transparent, colorless or slightly yellowish, luster brilliant, vitreous, hardness a little less than six, specific gravity 2·586—2·593. The mineral occurs in cavities in pegmatite implanted on quartz or feldspar with apatite, arsenopyrite, pyrite.—*Bull. Soc. Min.*, vi, 248, 252, 1883.

8. *Tin ore* (*Cassiterite*) *in the Blue Ridge in Virginia.*—The "Virginias" of October last, contains a note by Prof. H. D. Campbell, of Washington and Lee University, on the discovery of tin ore in the eastern corner of Rockbridge County, Virginia, on Painter Mountain branch of Irish Creek, about a mile and a quarter from the line of Nelson County. The vein runs east and west at the place and immediately about the ore consists of quartz. The thickness of the band of ore is small, and it is as yet uncertain whether the ore will prove to be sufficiently abundant for profitable working. In an incomplete analysis of a specimen from the vein Professor Campbell obtained tin 63·58, iron 1·68, silver 0·67, arsenic 0·30, silica 8·41.

9. *Meneghinite and Tennantite from Canada.*—Dr. B. J. Harrington has described the occurrence of several minerals new to Canada. One of these is meneghinite. It occurs in massive form near Marble Lake, township of Barrie, Ontario. Its specific gravity was 6 33. An analysis afforded

S	Sb	As	Pb	Cu	Fe	Ag
16·81	19·37	tr	61·45	1·36	0·07	0·08=99·14

The tennantite occurs massive at the Crown mine, Capelton, Quebec, associated with pyrite, chalcopyrite, quartz, etc. Its specific gravity was 4·622. An analysis yielded

S	As	Sb	Cu	Fe	Zn	Pb	Ag	insol.
27·99	15·34	4·52	42·09	3·77	4·56	0·25	0·21	0·09=98·82

Strontianite occurs sparingly in cavities in concretionary masses of limestone contained in the Utica shales of St. Helen's Island, Montreal. Acmite is shown by Dr. Harrington to be an important constituent of the nepheline syenites of Montreal and Belœil.

10. *Materialien zur Mineralogie Russland*, von N. VON KOKSCHAROW.—The first eighty pages of the ninth volume of this great work have recently been published. They are largely devoted to a memoir on the species caledonite, but supplementary notices are also given of monazite, rutile, pachnolite and xanthophyllite.

11. *On Allanite from Topsham, Maine;* by F. C. ROBINSON. (Communicated.)—Some time ago there was brought to my notice a peculiar, and to me then unknown mineral which a student had discovered in the granite on what is known as "Sprague's Hill," Topsham, Me. We have just completed an analysis of it, and proved it to be allanite. It occurs in the above locality in considerable abundance and in the form of brownish crystals partially decomposed, and looking like rusty nails driven into the granite. Occasionally fair crystals are found. Up to the time of its discovery no cerium mineral was known to occur here, but recently we have found in small quantities another cerium mineral which is now under examination. This latter does not occur in the same locality as the allanite, but is associated with columbite and gahnite. Other minerals of this locality are also being analyzed by us and notices of them will be published from time to time. The analysis of the allanite was made under my supervision by J. Torrey, Jr.

SiO_2	Al_2O_3	Fe_2O_3	CeO	LaO DiO	CaO	H_2O	Na_2O K_2O*
37·20	10·24	24·46	8·66	9·57	6·84	1·74	1·26=99·97

This analysis gives the approximate ratio for R : R̶ : Si=1 : 1 : 3. Different samples seemed to vary somewhat in composition, perhaps owing to the difficulty of obtaining pure pieces because of its being so much decomposed. Thus some gave small amounts of Mn and less Fe; some also gave little Mg. H_2O was also slightly variable.

12. *On Cuprodescloizite from Mexico.*—On the 29th of November last, Prof. Rammelsberg read a paper before the Berlin Academy on a variety of descloizite from San Luis Potosi, Mexico, to which he gave the name cuprodescloizite. He describes it as occurring in blackish reniform masses imperfectly crystalline on the surface and within showing a fibrous structure. The powder is brown; the specific gravity is 5·856. An analysis gave the result stated below (1). It is interesting to note that what was without doubt the same mineral was at a somewhat earlier date described by S. L. Penfield in this Journal for November. The description as given by Penfield agrees in most respects with that of Rammelsberg, only the specific gravity was found to be 6·202.

* There was only a trace of K_2O. Its exact amount will be hereafter determined.

The analyses are as follows: (1) by Rammelsberg, (2) by Penfield.

	V_2O_5	As_2O_5	P_2O_5	PbO	CuO	ZnO	FeO	H_2O	SiO_2	
(1) $(\frac{2}{2})$	22·47	0·28	0·17	54·03	8·13	12·62	....	2·52	....	= 100·22
(2) $(\frac{3}{3})$	18·95	3·82	0·18	54·93	6·74	12·24	0·06	2·70	0·12	= 99·74

As was shown by Penfield, the mineral is essentially identical with descloizite. Whether the fact that it contains copper replacing part of the zinc entitles it to a new name is a point about which there may be difference of opinion.

III. Botany and Zoology.

1. *Bulletin of the California Academy of Sciences*, No. 1. Feb. 1884, pp. 59, 8vo.—With this issue the California Academy begins a new series of its proceedings and publications, superseding the Journal, as we suppose, though there is no announcement of this.

The contents are distributed under the heads of Zoology, (a single paper, by Miss Rosa Smith, characterizing *Squalius Lemmoni*, a new fish), Botanic Section, five papers; Microscopic Section, five papers upon *Fungi*, which, there is a certain relief in finding outside the domain of botany; Astronomy, six papers, or rather notes, by the worthy President, Professor Davidson. The title of one of these upon the cover suggested a straying botanical paper, yet it was easy to make out that "Intra-Mercurial Plants" were planets which had dropped a vowel. Lastly Mineralogy, a paper on Colemanite, a hydrous borate of lime, by Mr. Evans.

The first botanical paper may also seem to have wandered afield. It is a very short one, on *Veatchia* (*V. Cedrosensis*) a new genus of *Anacardiaceæ*, by Asa Gray, remarkable for its utricular fruit. It had been described by Dr. Kellogg in the Academy's Journal, long ago, as *Rhus Veatchiana*, and as Dr. J. A. Veatch was either one of the founders or very early members of the California Academy, upon which he bestowed his collections in Lower California, it was most proper that the genus which is to honor his memory should be published there. Any botanist who has occasion to read the Latin character will be able to correct certain faults of punctuation and the single misprint which more or less mar the sense.

Dr. Behr and Dr. Kellogg have joined forces in the publication of an *Anemone Grayi*, which grows on Tamalpais, and which seems to be a plant, several times collected in the California Coast Ranges, which Dr. Torrey first and other botanists since have taken for a mere form of the Linnæan *A. nemorosa*, probably with good reason.

Dr. Kellogg follows with two new species of Lower California: *Astragalus insularis*, on which we have no opinion to offer, and *Phacelia ixodes*, a well marked species, which has also been recently collected by Mr. Orcutt.

Mr. Greene describes a dozen Californian species, one of them a re-publication of Dr. Kellogg's *Brickellia multiflora*, and another, *Sparganium Californicum*, "from three to nine feet high," said to be "perhaps too near *S. eurycarpum*, Engelm." Our lamented associate was unable to distinguish it from that species.

Mrs. Curran's contribution is of three species, of which the most curious is a second species of *Acanthomintha* (*A. lanceolata*), differing from the other in a 2-lobed upper lip of the corolla (contrary to the generic character: only a single specimen collected, which is unfortunate.

Of the Fungological papers, by Messrs. Cooke and Harkness, Messrs. Phillips and Harkness, Messrs. Plowright and Harkness, Messrs. Ellis and Harkness, and a larger number of new species and genera by Dr. Harkness alone, it is not for us to discourse. Mycology is becoming, as it were, a kingdom of its own. A. G.

2. *Darwinism stated by Darwin himself. Characteristic Passages from the writings of Charles Darwin: selected and arranged* by NATHAN SHEPARD. New York: Appleton & Co. 1884. pp. 350, 12mo.—A thoroughly correct and unbiased idea of Darwinism is to be obtained only from Darwin's own writings. But in a book of extracts very much depends upon how these are put together. A glance at the present volume gives the impression that the selection and arrangement have been done with good judgment. There is no daubing with untempered mortar, for there is not a word of note or comment. A. G.

3. *Wild Flowers of America, with Fifty colored plates from original drawings* by ISAAC SPRAGUE. Text by GEORGE L. GOODALE, M.D., Professor of Botany in Harvard University. Boston: Cassino, 1882, imp. 4to.—We probably noticed the earlier fasciculi of this volume of changeful fate and early interruption. But, as it now lies before us, a beautiful volume of 200 pages of letter-press and fifty portraitures, in which the chromo-lithographic printer has really done justice to Mr. Sprague's elegant and faithful paintings, we wish to call attention to it. We believe that the copies were so promptly taken up that it is entirely out of print; and we are uncertain if the publisher can reproduce it, though that, and the continuance of the work, were greatly to be wished. While all the plates are of very high order (except that a few are rather meagre), the following are among the most exquisite: *Aquilegia Canadensis*, *Gerardia flava* with *G. tenuifolia*, *Lilium Philadelphicum*, *Iris versicolor*, *Rudbeckia columnaris*, *Clematis Virginiana*, *Arethusa bulbosa*, *Kalmia glauca*, the most rare *Shortia galacifolia*, *Echinacea angustifolia*, and Skunk cabbage, though that needs a leaf to be sketched in as a back-ground; also Indian turnip, the pink Azalea, or wild honeysuckle, our sweet water-lily and the May-flower. A word must be said for the letter press, which has avoided poetry and thread-bare sentiment, and has managed to combine, in a readable and interesting narrative, much good descriptive matter, curious information,

and a series of lessons in botanical morphology. Finally there is a full index of all the technical terms and of the subjects treated, as well as of the flowers figured. A. G.

4. *A Catalogue of the Native and Naturalized Plants of the City of Buffalo and its Vicinity;* by DAVID F. DAY. Buffalo, 1883. pp. 215, 8vo.—This is published by the Buffalo Society of Natural Sciences, of which the compiler of this catalogue was one of the founders (in the year 1861), and the venerable Judge Clinton the leading spirit and first president. "That devoted naturalist and accomplished scholar," and most genial man, having removed his residence from Buffalo, "where he passed so many years of his useful and honorable life," to his native city of Albany, the editing of the present catalogue has devolved upon his associate. It has been a good while in hand, and both in form and in substance it is a most creditable production. It "presents the names of all the plants which have been detected within a radius of fifty miles of Buffalo," is accompanied by a map of the region, a sketch of its physical geography and climate, and other interesting details. It has set a good example by including, upon the basis of real investigations, all the cryptogamous plants of the region which have been fairly determined. A supplement brings in additions and corrections nearly up to date of publication. The phænogamous species are 1,217, in 106 orders. Almost exactly half of them are in the ten larger orders, and are distributed as follows:

Compositæ, 143.	Labiatæ, 39.
Cyperaceæ, 105.	Ranunculaceæ, 36.
Gramineæ, 88.	Cruciferæ, 36.
Rosaceæ, 52.	Orchidaceæ, 34.
Leguminosæ, 45.	Liliaceæ, 31.

Labiatæ would not hold this position except for its adventive and naturalized representatives, which make up one-third of its quota. Owing to its situation, its relation to railroads, and its cattle yards, Buffalo is a trap for adventive plants from the west, and one great use of this catalogue is to mark their coming, for future comparison. The portion of the catalogue devoted to the *Musci*, 165 species, *Hepaticæ*, 24, *Lichenes*, 204, *Fungi*, 869 and *Algæ*, 204, is of particular interest. There is a complete index of generic names. A. G.

5. *Die Pflanzenkrankheiten;* by Professor Dr. B. FRANK. (In vol. i of Schenk's Handbuch der Botanik, Trewendt, Breslau.) 243 pp., 46 ills.—This is one of the important monographs referred to in our last number as forming a part of the Encyclopedia of Natural History now publishing in Germany.

The results of the numerous investigations in regard to the maladies of plants are scattered through a wide range of botanical, pharmaceutical, horticultural, and agricultural journals. Some of these investigations have been of the most superficial and untrustworthy character, and the conclusions must be received with great caution. In the volume now before us, the more important facts have been carefully brought together, and conveniently arranged, but with too little critical remark. Hence, although of the greatest use to one in search of the literature of the subject, the work does not sufficiently aid one who does not have access to the original authorities.

Candidly giving up the difficult task of trying to draw a line between pathology and teratology, Professor Frank describes as diseased conditions, all variations from the normal condition of the species. He confesses that the subject is surrounded with difficulties, upon the consideration of which we cannot now enter, except to say they mostly spring from the transfer to such simple organisms as plants, of the terms which are in ordinary use in Medicine and Veterinary Medicine. The provisional working classification of plant-diseases proposed by Frank is plain and reasonably comprehensive. Four groups are made, viz:

Effects of injurious mechanical influences, as distortions through lack of room for growth, and the many forms of wounds. 2. diseases induced by inorganic nature, such as come from too little or too much light; from too low or too high a temperature; from an unfavorable medium, and unpropitious climatic influences. 3. Diseases brought on by parasitic plants. 4. Diseases caused by animals.

As might be expected, the chapter on wounds and their healing, takes up some of the most interesting questions in Morphology and Physiology. The different modes of repair are well considered, and the illustrations very telling. The injuries produced by frost, and by low temperatures which do not quite reach the freezing point of water, are treated of with some detail, but in a less satisfactory manner than the other parts of the work. The chapter on Parasitic Fungi deals with the effects produced by them rather than with their morphology. He speaks of three general effects produced by these parasites: 1. a consumption of the living matter and its stored food. 2. Destruction of tissues. 3. Irritation inducing abnormal growth. The Essay throughout is painstaking, which makes it of great utility as a work of reference, the citations being given with extraordinary accuracy.

G. L. G.

6. *Researches on the Structure of Diatomaceæ*, from the "Cemenstein" of Jutland, by Messieurs W. PRINZ and E. VAN ENMENGEM, of the Belgian Microscopic Society. (Ann. Soc. Belg. de Microscopie, t. viii).—The authors give the results of their examinations of *sliced* Diatoms in descriptions and in excellent plates, and also facts of geological interest connected with them. The diatoms are filled usually with calcite, but contain sometimes minute crystallizations of pyrite inside or as a coating; and the pyrite occurs commonly in the parts of the diatom (the perforations, especially) where the organic matter existed, to provoke the chemical reaction necessary for its precipitation. The author discusses also the origin of the pseudo-

morphs of pyrite after diatoms that had been described from the London clay, and explains their formation by first a coating of pyrite and then a substitution of pyrite for the silica as it is slowly removed, molecule for molecule. By dissolving away the pyrite he found still a delicate siliceous skeleton remaining.

7. *Report of the Entomologist*, Dr. C. V. RILEY, for the year 1883; from the Report of the Department of Agriculture. 80 pp. with plates.—Dr. Riley's report contains much important information on insects injurious to vegetation, and the best means of preventing their destructive work; and the plates contain figures of apparatus which have been devised for the latter purpose, besides illustrations of the insects. A valuable chapter on the destruction of evergreen forests in Northern New England and New York is by Professor A. S. Packard.

8. *Results of Dredging under A. Agassiz in the "Blake." Report on the Isopoda*, by OSCAR HARGER.—The species of Isopod Crustacea here described and figured by Mr. Harger come from depths of 500 to 7,000 feet and are in part new to the American coast. They include species of *Cirolana*, *Æga*, *Rocinela* and *Syscenus*.

9. *Exploration of the Surface Fauna of the Gulf Stream;* by A. AGASSIZ. Vol. viii, No. 2 of the Memoirs of the Mus. Comp. Zool. Harvard College.—This memoir describes the *Porpitidæ* and *Vellelidæ*, and is illustrated by 12 plates.

10. *Selections from Embryological Monographs.* Compiled by A. AGASSIZ, W. FAXON and E. L. MARK.—II. Echinodermata, by A. Agassiz, with 15 plates (Mem. Mus. Comp. Zool., vol. ix, No. 2), consists chiefly of plates illustrating the embryology of Comatula, Ophiuroids, Asteroids, Echinoids, and Holothurioids, as made out by the researches of different zoologists. They are here brought together under the supervision of Mr. Agassiz, for the aid of students in zoology, and make a very instructive series.

11. *Cruise of the Revenue Steamer Corwin in Alaska and the N. W. Arctic Ocean, in* 1881. 120 pp. 4to, with many plates. Washington, 1883.—This Report contains an illustrated memoir on the Birds of Behring Sea and the Arctic Ocean, by E. W. NELSON; Anthropological Notes, with plates, by Dr. I. C. ROSSE; Botanical Notes, by JOHN MUIR.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—At the recent meeting of the National Academy, held at Washington from April 15th to 18th, the following papers were entered for reading:

On the photographs of the Transit of Venus taken at the Lick Observatory: by SIMON NEWCOMB.

Whether there is a minimum perceptible difference of sensation: by C. S. PEIRCE and J. JASTROW.

The character of the heat radiated from the soil: by S. P. LANGLEY.

Progress in making a new photograph of the spectrum: by H. A. ROWLAND.

Some experiments upon the spectra of oxygen: by A. W. WRIGHT.

On the depth of the western part of the Atlantic Ocean and Gulf of Mexico, with an exhibition of a relief model;—On the relative levels of the western part of the Atlantic Ocean and Gulf of Mexico with respect to the Gulf Stream;—An account of some recent pendulum experiments in different parts of the world, made in connection with the U. S. Coast and Geodetic Survey; by J. E. HILGARD.

Reduction of barometric observations to sea level; by ELIAS LOOMIS.

The Krakatoa atmospheric waves, and the question of a connection between barometric pressure and atmospheric electricity: by H. M. PAUL. (By invitation.)

On the volcanic sand which fell at Unalaska, Oct. 20, 1883, and some considerations concerning its composition: by J. S. DILLER. (By invitation.)

The quantitative estimation of carbon in ordinary phosphorus;—Redfiction of halogen derivatives of carbon compounds: by IRA REMSEN.

On the Fritts selenium cell;—On a lantern voltmeter: by GEO. F. BARKER.

Recent progress in electrical fuses: by HENRY L. ABBOT.

The sufficiency of terrestrial rotation to deflect river courses: by G. K. GILBERT.

The origin of crystalline rocks: by T. STERRY HUNT.

On the occurrence of mercury in native silver from Lake Superior: by GEO. J. BRUSH.

On the existence of tin ore in the older rocks of the Blue Ridge: by B. SILLIMAN.

Jade implements from Alaska: by F. W. CLARKE.

Zoological results of the deep-sea dredging expedition of the U. S. Fish Commission Steamer Albatross: by A. E. VERRILL.

On the structure and affinities of Didymodus, a still living genus of sharks of the Carboniferous period;—On the North American species of Mastodon: by E. D. COPE.

The characteristics of the lyomerous fishes;—On the classification of the apodal fishes: by THEO. GILL and JOHN A. RYDER.

On the ichthyological peculiarities of the Bassalian realm: by THEO. GILL.

Memorandum on composite photographs in craniology: by JOHN S. BILLINGS.

On the application of trinomial nomenclature to zoology: by ELLIOTT COUES.

Some recent results of the oral and aural teaching of the deaf, under the combined system: by E. M. GALLAUDET.

The study of comparative biography: by C. S. PEIRCE.

Memorial addresses were delivered by General H. L. Abbot on the late General G. K. Warren; by Professor C. A. Young on Professor Stephen Alexander; by Professor Silliman on Professor J. Lawrence Smith; and by Dr. Samuel H. Scudder on Dr. John L. LeConte.

The following new members were elected: Professor W. K. Brooks of Baltimore; General C. B. Comstock, U. S. Army; Professor Edward S. Dana of New Haven; Captain C. E. Dutton, U. S. Army; Professor Sidney I. Smith of New Haven.

2. *Report of the New York State Survey* for the year 1883, JAMES T. GARDINER, Director.—This Report, besides giving details and maps relating to the topographical work done, presents some facts in illustration of the subject of the *relations of drainage to rainfall and the removal of forests.* From observations at Rochester University since 1830, and at Buffalo and Rochester by the U. S. Signal Service since 1870, the rainfall (snow being included) increased, during the period from 1830 to 1880, from 27·7 to 38 inches; and from 1868 to 1881, the mean-fall was 38·73 inches. The forests were extensively removed in this interval. On the contrary, the mean annual rainfall of Auburn, Cazenovia Potsdam and Albany, places in the center, northern and eastern parts of the State, taken by periods of ten years, show that little

change has taken place; but at Pierrepont Manor and Oswego there is an indication of some increase. The last two places with Buffalo and Rochester, are near Lake Ontario; and Mr. Gardiner concludes that excepting in the vicinity of Lake Ontario little change in amount of precipitation has taken place, notwithstanding the large removal of forests.

With regard to the relation between drainage and rain-fall the report states that the average flow of the west branch of the Croton for four years was found to be 63 per cent of the rainfall. The basin covers about 20 square miles, is mostly wooded, and the subjacent rocks are metamorphic. In Massachusetts the same average for the Cochituate basin, west of Boston, for the interval 1852 to 1875, is 45 per cent; and for the Sudbury basin, which has an area of 77·76 square miles, about 50 per cent. In both of these cases also the rocks are metamorphic, but the basins are only partially wooded.

The maximum precipitation at Rochester and Buffalo, for the two months, March and April, is stated to be about 10·42 inches. The total amount of water to be disposed of during March and April—the time of maximum flow—is therefore often 10 inches, *plus* the water produced by the melting of snow accumulated before March 1st. Mr. Gardiner adds the remark that on unwooded areas, that are similar to the above mentioned regions in climate and other conditions, any channel capable of carrying off the spring flow is not liable to be flooded between May and November.

At the receiving reservoir in New York, between 1864 and 1880, the evaporation amounted to 80 per cent of the rain-fall, it being so great because wholly from a water-surface, and one in no part protected by forests from winds and the direct sun's rays.

3. *Note on the condition occasioning the Ohio River flood of February*, 1884; by J. D. DANA.—The unusual height of the flood of February last on the Ohio River, in which the water reached at Cincinnati a level of 71 feet ¾ inches above the guage mark (which is 2 feet above low water), has had different explanations. The right one is brought out in a paper (apparently editorial) giving an excellent review of the facts as to this and other Ohio floods, in Science of February 22.

The only floods which are known to have passed the 60-foot mark at Cincinnati, as stated in this paper, are the following: February,1832, 64 feet 3 inches; December, 1847, 63 feet 7 inches; February, 1883, 66 feet 4 inches. Speaking of the flood of 1883, it says: "The flood was due to two storms, the first from Feb. 3 to 5, in which about 3½ inches of rain fell at Cincinnati, and the second, on Feb. 10, 11, in which the rain-fall was about 2 inches. These storms extended to the head waters of the Ohio *and fell upon frozen ground—so that the water was carried at once into the water courses.*" Further, "the flood of 1884 rose from a single storm on Feb. 4 to 6, in which the precipitation was 4·46 inches in eight hours less than three days. This storm combined with the warm weather caused a general thaw over all the region from which the feeders of the Ohio come." The condition as to frozen ground, which was true of a large part of the drainage area is not in the latter sentence, but is implied by the connection. The floods also of 1880, 1881, 1882, 50 to 58 feet in height, occurred in February; and 19 out of the 27 between 1858 and 1884 were within the four months, December, January, February and March.

Facts bearing on this subject are given by the writer in his paper of 1882, on the "Flood of the Connecticut River from the melting of the Quaternary Glacier."* It is there deduced from the tables of precipitation kept at different points in the Connecticut valley, and from the amount of discharge of the river as carefully measured by General T. G. Ellis, of the U. S. Engineer Corps, at Hartford for the years 1872 to 1877, that in 1874, a year of great floods in January and May, the amount discharged, 733,103,000,000 cubic feet, was 69·5 per cent of the precipitation, while in 1877, a year of minimum discharge (only 526,261 millions, or five-sevenths of that in 1874) it was 50 per cent; and the conclusion is stated that the floods are dependent partly on the large amount of snow and ice over the country for melting, and to "a considerable extent on the frozen state of the ground over the hill slopes and much of the country, this favoring an easy slipping of the waters over the surface without absorption by the soil."

In 1874, when the discharge of the Connecticut was so great, the two months of largest discharge were January (135,491 millions of cubic feet, and May, 139,213 millions), the precipitation over the drainage area of the Connecticut for January, taking the average from observations at Amherst 35 miles north of Hartford, Hanover 135 miles north of Hartford, and Lunenburg on the river 200 miles north of Hartford and 60 to 70 from the most northern sources of the Connecticut, was 4·02 inches, and for May, 3·81 inches; yet in April with a mean precipitation of 4·49 inches, the discharge was only 62,031 millions; and in July, with a mean precipitation of 3·74 inches, the discharge was only 55,018 millions. April is usually a month of frozen ground over the northern half of the valley, but not always to so great an extent. Again, in February, the discharge amounted to 96,674 millions (half more than in April and two-thirds that of January), although the mean precipitation for the valley in that month was only 1·93 inches, showing that thawing was the chief cause, not the precipitation of that month.

Further, in 1877 (the year of minimum flood), during the month of October—too early for frozen ground except on the high mountain tops and yet always a cool month—the amount of discharge of the river was only 31,772 millions of cubic feet, although the mean precipitation in the valley for the month was 5·45 inches, which is *greater by one third* than in the months of greatest discharge in 1874.

* This Journal, III, xxiii, 368.

It is here evident that the frozen condition of the earth's surface has a vast deal to do with the height of the winter floods, and the extent of the forest region very little.

The conditions affecting the amount of discharge are (1) the loss by evaporation; (2) the loss by absorption.

Loss by evaporation becomes greater (1) as the seasons advance from cold to warm; (2) as forest regions become changed into dry fields of earth, or earth and rock; (3) as obstructing dams are multiplied, making the stream more or less a string of ponds. It is least, other conditions equal, when streams are deep in proportion to their breadth; and when the velocity is great, the time used for discharge being thereby diminished.

Loss by absorption becomes greater as the season advances from cold to warm, but only after the ground of the drainage area has become unfrozen; (2) the more the area is forest-covered; (3) the more porous, fissured, or cavernous the underlying strata; as vegetation develops with the advancing spring. It is least where the rocks are non-absorbent, as in most regions of metamorphic rocks; where the cold has produced a frozen surface—rock-like—over the drainage area.

Hence the best conditions for a great flood are a frozen drainage area and a great thaw after a large accumulation of snow, or a great rain and thaw. But for summer floods, the cause is a great and sudden rain-fall; and the steeper the slope of the tributaries and main stream, the vaster the discharge, since evaporation and absorption then fail largely of their usual perquisites.

4. *Publications of the Cincinnati Observatory, No.* 7.—The observations of Messrs. Stone and Wilson upon nine comets in 1880–2, both for positive and physical, are given in this valuable contribution. Ten plates illustrating the physical observations are added.

5. *Geological Society of London.*—At the annual meeting, the 15th of February, the Wollaston Gold Medal was given to Prof. A. Gaudry; the balance of the Proceeds of the Wollaston Donation fund, to Mr. E. Tulley Newton; the Murchison Medal to Dr. Henry Woodward; the balance of the Murchison fund to Mr. R. Etheridge; the Lyell Medal to Dr. Joseph Leidy of Philadelphia; the balance of the Lyell fund to Prof. C. Lapworth; a portion of the proceeds of the Barlow-Jameson fund to Dr. J. Croll; a second portion of the proceeds of the Barlow-Jameson fund, to Prof. Leo Lesquereux.

6. *Hermann Mueller Fund.* — The citizens of Lippstadt in Westphalia have formed a committee to collect funds for a memorial to the late Hermann Mueller, professor in the Real Gymnasium of that town, and one of the most distinguished investigators of the mutual relations of insects and flowers. Our announcement of his death, in August last, accompanied the notice of the English edition of his latest work. The proposed fund is "to preserve the memory of Professor Mueller, and aid his family by creating a foundation, whose revenues shall be

enjoyed by the widow of the deceased during her life-time, and after her death preferentially by some descendant of Professor Mueller's that shall be desirous of studying natural philosophy, or else by some other needy and worthy student of that science who shall have been educated at the public school of Lippstadt." Gifts to this fund may be forwarded to the treasurer of the Committee, Herr Stadtkaemmerer Wilhelm Thurmann, at Lippstadt.

7. *Rainfall returns.*—A circular has been issued by A. R. Binnie, M. Inst. C. E., F. R. Met. Soc., F.G.S., expressing his desire to receive copies of records of rainfall extending from as early a date as possible. It states that the observations should give annual falls only, and be continuous for a single locality for at least 15 years; that the results should be expressed in millimeters; that the name of the observer and the place of observation be attached. Mr. Binnie's address is Town Hall, Bradford, Yorkshire, England. Contributors are promised in return, a copy of the results of the enquiry. For a copy of the circular this Journal is indebted to the Signal Service Office, Washington.

8. *Monument to the great Paleontologist, Barrande.*—No more faithful or successful worker in Paleontology has lived than Barrande. Subscriptions to a monument to his memory will be forwarded by Professor A. Hyatt, Technological Institute, Boston.

OBITUARY.

SIGNOR QUINTINO SELLA, President of the R. Accademia dei Lyncei, of Rome, and for many years Minister of Finance in Italy, died on the 14th of March. His scientific researches were chiefly in crystallographic mineralogy, in which department his papers are of the highest excellence. His able statesmanship on the one hand brought order and system to the finances of United Italy, and on the other promoted the progress of the nation in literary and scientific culture and in whatever tended to contribute to the elevation of the people. Signor Mancini, in an address at a memorial session of the Chamber of Deputies, connects his name with three great achievements in the recent progress of his nation: "La restaurazione finanziaria della sua patria; la liberazione di Roma papale con la caduta del potere temporale; la grandezza intellectuale ed anche materiale di Roma moderna divenuta Italiana." He took an active part in the arrangements with reference to the geological survey of Italy and its geological map, and was President of the International Geological Congress at Bologna, in 1881. The Chamber of Deputies has appropriated 20,000 dollars for a monument to his memory.

A letter from Mr. T. McKenny Hughes, in Nature of March 27, dated Woodwardian Museum, Cambridge, March 25, states that "it is proposed to place a bronze wreath on the tomb of the distinguished Italian geologist and statesman, Quintino Sella," and that "English geologists are invited to express their sympathy with their Italian fellow-workers by sending their names with a small subscription."

APPENDIX.

ART. XLVIII.—*Principal Characters of American Cretaceous Pterodactyls;* by Professor O. C. MARSH. Part I. *The Skull of Pteranodon.* (With Plate XV.)

THE first remains of Pterodactyls discovered in this country were found by the writer, in the autumn of 1870, near the Smoky Hill River, in Western Kansas. These belonged to a gigantic species, which was described by the writer in 1871, and is now known as *Pteranodon occidentalis.* The geological horizon of these fossils was in the Middle Cretaceous, in the same deposits that contain the *Odontornithes*, or Birds with teeth. In the following year, additional specimens were secured by the writer in the same region, and referred to two new species of the same genus.*

In 1872, the writer again visited this region, and made a careful search for other specimens, and for several subsequent years had parties exploring the same deposits systematically, with good results; so that at the present time the remains of more than six hundred individuals of these reptiles have been secured from this horizon, and are now in the museum of Yale College.

The most of these remains represent gigantic species, the largest having a spread of wings of nearly, or quite, twenty-five feet. These all belong to the genus *Pteranodon*, and pertain to five species. One species referred to this genus was comparatively small, having a spread of wings of not more than three feet. A few specimens were found, intermediate in size, and these represent the genus *Nyctodactylus*, of which only a single species is known.

* This Journal, vol. i, p. 472, June, 1871; vol. iii, p. 241, April, 1872, and p. 374, May, 1872.

All these Cretaceous Pterodactyls, so far as known, differ widely from the members of this group in the old world, especially in the *absence of teeth*, and hence have been placed by the writer in a new order, the *Pteranodontia*, from the typical genus, *Pteranodon*.* Other important characters of this order have since been made known by the writer, showing that these strange reptiles constitute a well marked group, much more specialized than any hitherto discovered.

In the present paper, the skull of one species of *Pteranodon* is described and figured as typical of the order, and the remaining part of the skeleton will be discussed in subsequent communications.

The Skull.

The skull in the genus *Pteranodon* is very large, and much elongated. The facial portion is greatly produced forwards, and an enormous sagittal crest extends far backward, and somewhat upward, as shown in Plate XV, figures 1, 2, and 3. Seen from the side, the jaws project forward like a huge pair of pointed shears. They are very long, sharply pointed in front, and entirely destitute of teeth. In no specimens examined, young or old, have any indications of teeth been detected. The margins of the jaws are smooth and thin, as in many species of recent Birds. The jaws were probably encased in a horny sheath.

The bones of the skull are nearly all of extreme tenuity. With the exception of the occipital condyle, and the lower ends of the quadrates, all seem to have been pneumatic.

Seen from above, the skull appears extremely narrow. A sharp ridge extends from the end of the premaxillaries along the median line to the true cranium, and is continued backward by the thin elevated crest. The large antorbital openings thus seem near the middle of the skull, and, as they are directly over the posterior nares, they form part of the vertical apertures in the cranium, seen in Plate XV, figures 2 and 3.

The palate is deeply concave, and covered with bone, as far back as the posterior nares.

The bones of the skull are nearly all firmly ankylosed together, and this makes it very difficult to determine the different elements.

* This Journal, p. 507, vol. xi, June, 1876; p. 479, vol. xii, Dec., 1876, and vol. xxi, p. 342, April, 1881. See also vol. xxiii, p. 251, April, 1882.

The premaxillaries are very large, and have coalesced with the maxillaries. They appear to extend backward to the large antorbital vacuities. These apertures apparently include both the anterior nares, and the lachrymo-nasal fossæ, which are separate in most recent birds.

The orbit is of moderate size, and oval in outline, the apex being below. There was apparently no ring of bony sclerotic plates, since in the best preserved specimens no traces of this have been found.

The quadrate is firmly coössified with the other cranial bones, and projects strongly forward. Its distal end is one of the most characteristic parts of the skeleton.

The sagittal crest is of enormous size, and serves to balance the elongated jaws. It is very thin transversely, and during life was probably more or less flexible. In form and direction, it resembles the corresponding crest in the recent genus *Basilicus.*

The occipital condyle is very small, and nearly hemispherical in form. It is directed backward, and but slightly downward, thus differing from this part in most of the members of the group.

The Lower Jaws.

The lower jaws are very long, and quite sharp in front, corresponding closely in this respect with the end of the upper jaws. The rami are closely united by a symphysis which extends from the apex to beyond the posterior extremity of the dentary bone, as in the mandible of *Rhynchops*, and some other birds. Behind the symphysis, the rami are comparatively slender. The upper face is strongly concave. The articulation for the quadrate is deeply grooved obliquely, and the joint is a very strong one. The front portion of this mandible during life was evidently protected by a horny covering, like that of the beak above.

The nearly complete skull here described may be regarded as a type of the genus *Pteranodon.* Its principal measurements are as follows:

Length, from extremity of sagittal crest to end of premaxillary, about 30 inches, or	760· mm
Tranverse diameter of occipital condyle,	8·4
Distance from occipital condyle to distal end of quadrate,	105·
Length of lower jaw, about, 23 inches, or	585·
Greatest depth,	62·
Depth at articulation for quadrate,	23·

The skull of *Pteranodon ingens*, described by the writer from the same geological horizon, is about four feet in length.

The skull of *Pteranodon* differs especially from that of the other known *Pterosauria*, in the following particulars: (1) the absence of teeth; (2) the absence of anterior nasal apertures distinct from the antorbital openings; (3) the presence of the elongated occipital crest; (4) the whole jaws were apparently covered with a horny sheath, as in recent birds.

Yale College, New Haven, April 24th, 1884.

EXPLANATION OF PLATE XV.

FIGURE 1.—Skull and lower jaw of *Pteranodon longiceps*, Marsh; side view.

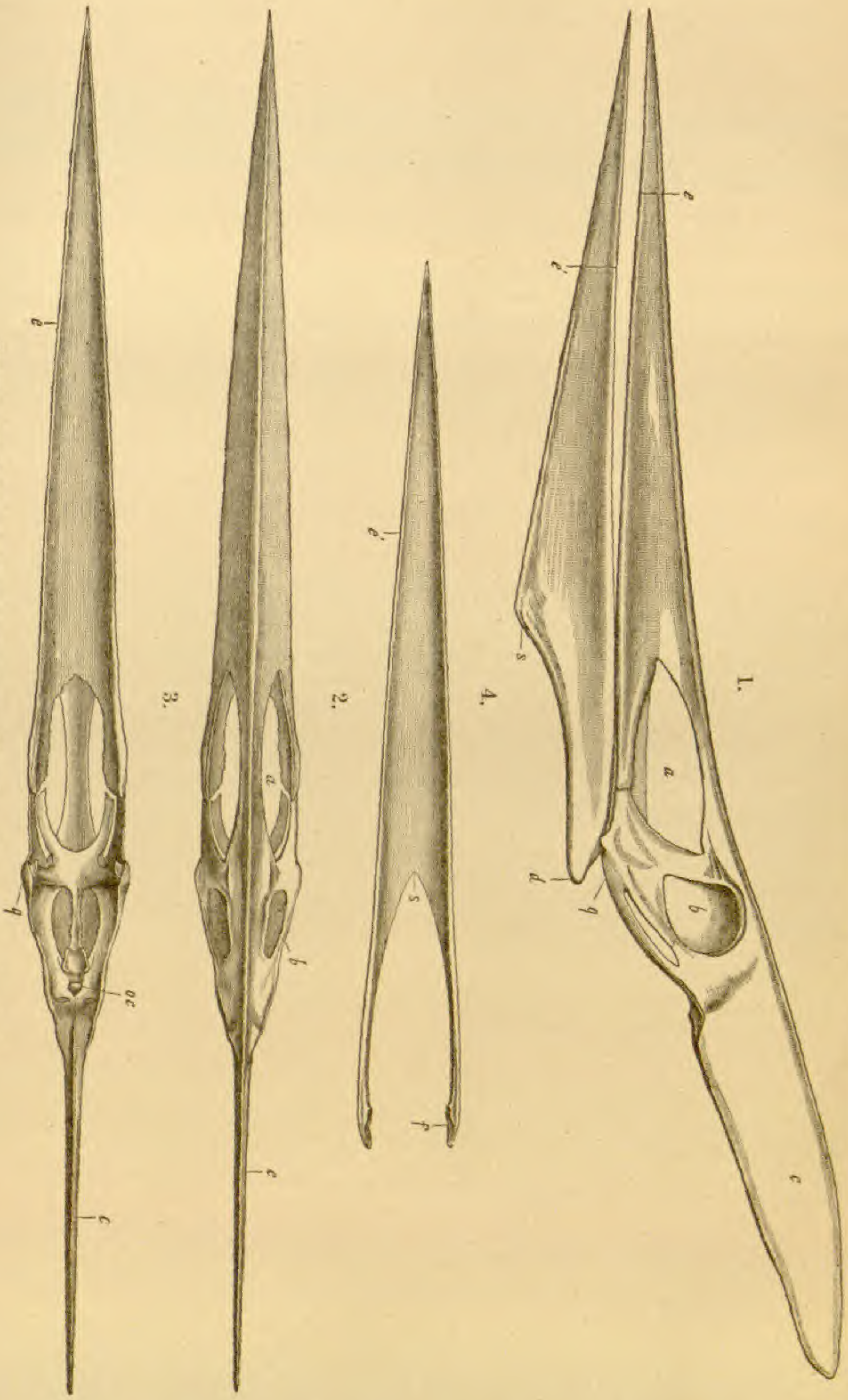
FIGURE 2.—The same skull; top view.

FIGURE 3.—The same skull; bottom view.

FIGURE 4.—Lower jaw of *Pteranodon longiceps*; top view.

a, Antorbital aperture; *b*, orbit; *c*, sagittal crest; *d*, angle of jaw; *e*, lower margin of upper jaw; *e'*, upper margin of lower jaw; *f* articulation of lower jaw; *oc*, occipital condyle; *q*, quadrate bone; *s*, symphysis of lower jaw.

All the figures are one-sixth natural size.



Skull of Pteranodon longiceps, Marsh. One-sixth natural size.

THE

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[THIRD SERIES.]

ART. XLIX.—*The Sufficiency of Terrestrial Rotation for the Deflection of Streams*; by G. K. GILBERT.

[Read to the National Academy of Science, April 15, 1884.]

IT was long ago perceived that rivers flowing to the north or to the south should by the rotation of the earth be thrown severally against their east or west banks. It is even many years since it was shown by Ferrel that these tendencies are but illustrations of a more general law, that all streams in the northern hemisphere are by terrestrial rotation pressed against their right banks, and all in the southern are pressed against their left banks, the degree of pressure being independent of the direction of flow. Yet the question of the sufficiency of the cause for the production of observable modifications in the topography of stream valleys is still an open one. A number of geologists have observed peculiarities of stream valleys which they referred to the operation of the law, while others, including myself, have looked in vain for phenomenal evidence of its efficiency. Nevertheless, it is my present purpose to maintain the sufficiency of the cause.

So far as I am aware, all those who have attempted to consider analytically the mode in which the lateral tendency arising from rotation should modify the channel or valley of a stream have reached the conclusion that no appreciable results can be produced, and for the most part their conclusions legitimately follow their premises. My own different conclusion is based upon an essentially different analysis of the processes involved. In the celebrated discussion in the French Academy of Science, it was computed by Bertrand that a river flowing in N. lat. 45° with a velocity of three meters per second exerts a pressure on its right bank of $\frac{1}{63539}$ of its weight, and he regarded this pressure as too small for consideration. It has been pointed out by Henry Buff that the deflecting force, by combining with gravitation, gives the stream's surface a slight inclination toward the left bank, thereby increasing the depth of water near the right bank, and consequently increasing the velocity of the current at the right. To this increment of velocity he ascribed a certain erosive effect, but regarded it as less than that assignable to wind-waves on the same water-surface. He therefore accorded a more important influence to the prevailing winds than to the rotation of the earth. It has been held by others that the combination of the deflective force with gravitation is equivalent simply to a slight modification—so far as the stream is concerned—of the direction of gravitation; and that, the flood-plain of the stream having been adjusted normal to this modified direction of gravitational attraction, no other geological effects are produced. The last was my own view until I perceived the importance of certain considerations to which I now proceed.

The form of cross-section of a stream flowing in a straight channel depends on the loading and unloading of detritus and is essentially stable. It is evident that the form of the cross-section controls the distribution of velocities of current within its area, and that through the interactions of these velocities its parts are interdependent. Each element of its curve is so adjusted to the adjacent current and to the detrital load of the stream that it can neither be eroded nor receive a deposit, and the stability of the profile depends on the fact that an element not adjusted to the contiguous current and load becomes subject either to erosion or to deposition until an adjustment is reached. The distribution of velocities within the cross-section is symmetric, the swiftest threads of the current being in the center and the slowest adjacent to the banks.

If, now, curvature be introduced in the course of the channel, centrifugal force is developed. This centrifugal force is measured by the square of the velocity, and is therefore much greater for swift central threads of the current than for slow lateral threads. As pointed out by Thomson and others, the central threads, tending more strongly toward the outer bank, displace the slower threads of that bank, and the symmetry of distribution of velocities is thus destroyed. In other words, the centrifugal force developed by curvature exercises a selective influence on velocities, and transfers the *locus* of maximum velocity from the center of the channel toward the outer bank.

The conditions of symmetry in the profile of the cross-section are thus destroyed. The outer bank is eroded; a deposit is accumulated on the inner bank. Moreover there is no compensating tendency to restore an equilibrium, for the erosion of the outer bank increases the sinuosity of the channel instead of rectifying it.

Curvature of course thus causes a stream to shift its channel laterally, and in this manner enlarge its valley. It is the most important condition of lateral corrasion.

As shown by Ferrel, the deflective force due to terrestrial rotation varies directly with the velocity of the stream. It therefore has a selective influence on the velocities within the cross-section of the channel; and it too tends to produce erosion at one side and deposition at the other. For a given amount of deflective force its selective power is only half as great as that of the centrifugal force developed by curvature of course, for centrifugal force varies with the second power of the velocity while the rotational deflective force varies only with the first power. But its selective power is of the same kind and may be quantitatively compared. For the purpose of this comparison I will develop an equation:

Let F=deflective force, per unit of mass, due to rotation.
n=angular velocity of the earth's rotation.
v=velocity of stream.
λ=latitude of the locality.
ρ=radius of a curvature of the stream's course.
f=the centrifugal force, per unit of mass, developed by such curvature.

Then $$f=\frac{v^2}{\rho} \qquad (1)$$

and, from Ferrel,

$$F=2vn \sin \lambda \qquad (2)^*$$

Let v_r=velocity of a rapid-flowing thread of the current,
v_s= " " slow " " " "

Represent by F_r, F_s, f_r and f_s the corresponding deflective forces due to rotation and curvature,

then $$F_r-F_s=(v_r-v_s)\times 2n \sin \lambda \qquad (3)$$

and $$f_r-f_s=\frac{v_r^2-v_s^2}{\rho} \qquad (4)$$

F_r-F_s evidently expresses the selective power due to curvature; f_r-f_s similarly expresses the relative power due to rota-

* This Journal, II, xxxi, 29, equation (5). Ferrel's expression is modified above by the substitution of the sine of the latitude for the cosine of the polar distance.

tion. Where the curvature has a convexity to the right, these two influences conspire, and their resultant is deducible by addition. Where the curvature has a leftward convexity the influences are opposed, and their resultant is deducible by subtraction. [The terminology here and through the remainder of the paper is adjusted to the northern hemisphere exclusively.] If we represent by R the joint selective power on curvatures of right hand convexity and by L the joint selective power on curvatures of left hand convexity, then we deduce by simple combinations and transformations of equations (3) and (4).

$$\frac{R}{L}=\frac{v_r+v_s+2\rho n \sin\lambda}{v_r+v_s-2\rho n \sin\lambda} \quad - \quad - \quad (5)$$

v_r and v_s may be the velocities of any two threads of current moving at different rates, but for purposes of convenience and simplification we now assume that they are symmetrically related to the mean velocity v; and introducing this relation in (5) we obtain

$$\frac{R}{L}=\frac{v+\rho n \sin\lambda}{v-\rho n \sin\lambda} \quad - \quad - \quad (6)$$

This equation expresses the ratio between the selective influences tending to determine the maximum velocity toward the right and left banks respectively of a meandering stream. Since these tendencies result in erosion, the ratio is a function of the tendency of a stream to erode its right bank as compared with its tendency to erode the left.

For the purpose of securing a quantitative result the Mississippi River will be used in illustration. In its lower course the sharpest bends have a radius of curvature, measured to the center of the channel, of about 8,000 feet. These curves, together with all other channel features, are determined by the water at its flood stage. It is therefore proper to consider in this connection the mean flood velocity. That was determined by Humphreys and Abbott to be, at Columbus, Kentucky, 8·4 feet per second. The latitude of the locality is 37°. Giving these values to ρ, v, λ, and substituting for n its numerical value ·000072924, we obtain from (6)

$$\frac{R}{L}=1{\cdot}087$$

The selective tendency toward the right bank is therefore nearly nine per cent greater than toward the left.

With the elements of another stream it is probable that a very different result would be obtained; but this single example suffices to show that while the influence of rotation is small, as compared to that of curvature, it is still of the same order of magnitude, and may reasonably be expected to modify the results of the more powerful agent. In the present state of hydraulic science it is impossible to define the quantitative relation between the tendency of swift threads of current toward a bank and the consequent erosion; but whatever that relation may be, I conceive that rotation is competent to produce appreciable results wherever those due to curvature are great.

It will be observed that the efficiency of rotation thus advocated is only in connection with, and as an adjunct to, lateral wear by means of curvature. There are two general cases, including a large share of all streams, to which the conclusion does not apply. (1.) A stream which rapidly corrades the bottom of its channel does not notably corrade its banks; and in such case the effect of rotation should not be discoverable. (2.) A stream engaged in the deposition of detritus, as on a delta or an alluvial fan, shifts its channel from side to side by a process entirely distinct from the one just described. It builds up its bed until it is higher than the adjacent plain, and then transfers its current bodily to a different course. Rotation has its share of influence in determining the direction of this transfer, and it thereby induces the stream to build its alluvial plain higher on the right than on the left; but, the difference of level having been established, the stream has thereafter no more tendency to one side than the other. Deflective effects of rotation are therefore not to be sought in regions of alluvial deposition.

It may be remarked also that the tendency of a stream toward one bank or the other by reason of curvature and rotation is often overpowered by an opposite tendency due to obstructions. These include resisting members of the eroded terrane and alluvial dams deposited at one bank or the other by tributaries.

A general curvature in the course of the valley through which the stream flows has the same tendency, though in a less degree, as does the curvature of a short bend, and this tendency must in many instances nullify or conceal the results of rotation.

Visible examples of the work of rotation are therefore to be sought especially in streams which, with courses in the main direct, are slowly deepening their valleys by the excavation of homogeneous material. The best locality of which I have any knowledge is one to which attention was called by Mr. Elias Lewis in this Journal for February, 1877, and which has recently been visited at my request by Mr. I. C. Russell. The south side of Long Island is a plain of remarkable evenness, descending with gentle inclination from the morainic ridge of the interior to the Atlantic ocean. It is crossed by a great number of small streams which have excavated shallow valleys in the homogeneous modified drift of the plain. Each of these little valleys is limited on the west or right side by a bluff from ten to twenty feet high, while its gentle slope on the left side merges imperceptibly with the general plain. The stream in each case follows closely the bluff at the right. There seems to be no room for reasonable doubt that these peculiar features are, as believed by Mr. Lewis, the result of terrestrial rotation. As the streams carve their valleys deeper, they are induced by rotation to excavate their right banks more than their left, gradually shifting their positions to the right and maintaining stream cliffs on that side only.

ART. L.—*Examination of Mr. Alfred R. Wallace's Modification of the Physical Theory of Secular Changes of Climate;* by JAMES CROLL, LL.D., F.R.S.

[Continued from page 93.]

PART II.—*Geological and Paleontological Facts in relation to Mr. Wallace's Modification of the Theory.*

MR. WALLACE'S chief, and indeed only real modification of my theory, is to the effect, as I have pointed out, that the alternate phases of precession causing the winter of each hemisphere to be in aphelion and perihelion each 10,500 years would produce a complete change of climate only when a country was partially snow-clad. According to his view, when the greater part of Northwestern Europe was almost wholly buried under snow and ice, those glacial conditions must have continued, and perhaps have even become intensified, when the winter solstice moved round to perihelion, instead of being replaced, as I have maintained, by an almost perpetual spring. In short, Mr. Wallace's conclusion is that, during the Glacial Epoch proper, a warm and equable Interglacial Period could not have occurred.

In the preceding part of this paper I have endeavored to show that physical principles do not warrant such a conclusion. I shall now proceed to consider what the direct testimony of Geology and Paleontology is on the subject; and I believe we shall find that the facts of Geology and Paleontology are as much opposed to the conclusion as are the principles of Physics.

On this point I may quote the evidence of a geologist who, more than any other, has devoted special attention to all points relating to Glacial and Interglacial periods. Prof. J. Geikie, after devoting upwards of 500 pages of his 'Prehistoric Europe' to the consideration and accumulation of facts from all parts of this country and the continent relating to Glacial and Interglacial periods, gives the following as the result of his investigations:—

"We note," he says, "as we advance from Pliocene times, how the climatic conditions of the colder epochs of the Glacial Period increase in severity until they culminate with the appearance of that great northern *mer de glace* which overwhelmed all Northern Europe, and reached as far south as the 50th parallel of latitude in Saxony. Thereafter the glacial epochs decline in importance until in the Postglacial Period they cease to return. The genial climate of Interglacial ages probably *also attained a maximum* toward the *middle* of the Pleistocene Period, and afterwards became less genial at successive stages, the temperate and equable conditions of early Postglacial times being probably the latest manifestation of the Interglacial phase." ('Prehistoric Europe,' p. 561.)

I shall now quote the same author's description of an Interglacial Period as demonstrated by its flora and fauna. The reader must, however, observe that by Pleistocene Period, Professor Geikie means the so-called Glacial Period with its alternations of severe arctic climate and mild and genial conditions. See p. 544, 'Prehistoric Europe.'

"An examination," he says, "of Pleistocene organic remains leads us to conclude that strongly contrasted climatic conditions alternated during the Period. At one time an extremely equable and genial climate prevailed, allowing animals, which are now relegated to widely-separated zones, to live throughout the year in one and the same latitude. Hippopotamuses, elephants and rhinoceroses, Irish deer, horses, oxen and bisons then ranged from the borders of the Mediterranean as far north at least as Middle England and Northern Germany. In like manner, plants which no longer occur together—some being banished to hilly regions, while others are restricted to low grounds, and yet others have retreated to the extreme south of the Continent or to warmer regions beyond the limits of Europe —lived side by side. The fig-tree, the judas-tree, and the Canary laurel flourished in Northern France along with the sycamore, the hazel, and the willow. And we encounter in the Pleistocene deposits of various countries in Europe the same remarkable commingling of northern and southern forms—of forms that demand a humid climate and are capable of enduring considerable cold, together with species which, while seeking moist conditions, yet could not survive the cold of our present winters. The testimony of the mammals and plants is confirmed by that of the land and freshwater mollusca—all the evidence thus conspiring to demonstrate that the climate of

Pleistocene Europe was, for some time at all events, remarkably equable and somewhat humid. The summers may not indeed have been warmer than they are now; the winters, however, were certainly much more genial." ('Prehistoric Europe,' p. 540.)

This, be it observed, is a description of a condition of things which existed during an interglacial period belonging, not to the close, but to the very climax of the Glacial Epoch. For immediately preceding and succeeding this Period almost the whole of Northern Europe was enveloped in one continuous sheet of ice. "But if," continues Professor J. Geikie, "the evidence of such a climate having formerly obtained be very weighty, not less convincing are the proofs, supplied by the Pleistocene deposits, of extreme conditions. Think what must have been the state of middle and Northern Europe when Paleolithic man hunted the reindeer in Southern France, and when the arctic willow and its congeners grew at low levels in Central Europe. Reflect upon the fact that in the very same latitude in France, where at one time the Canary laurel and the fig-tree flourished, the pine, the spruce, and northern and high-alpine mosses at another time found a congenial habitat. Bear in view, also, that the land and freshwater mollusks testify in like manner to the same strongly contrasted climate. Besides those that tell of more equable and genial conditions than the present, there are species now restricted to the higher Alps and northern latitudes that formerly abounded in middle Europe, and their shells occur commingled in the same deposits with the remains of lemmings, marmots, reindeer, and other northern and mountain-loving animals." (p. 541.)

But more convincing still is another range of facts, some of which have been adduced by Mr. Wallace himself. In a section on alternations of warm and cold periods during the Glacial Epoch ('Island Life,' p. 114), he says:—

"The evidence that such was the case" (alternate warm and cold periods) "is very remarkable. The 'Till,' as we have seen, could only have been formed when the country was entirely buried under a large ice-sheet of enormous thickness, and when it must therefore have been, in all the parts so covered, almost entirely destitute of animal and vegetable life. But in several places in Scotland fine layers of sand and gravel, with beds of peaty matter, have been found resting on 'till' and again covered by 'till.' Sometimes these intercalated beds are very thin, but in other cases they are twenty or thirty feet thick, and in them have been found remains of the extinct ox, the Irish elk, the horse, reindeer and mammoth. Here we have evidence of two distinct periods of intense cold, and an intervening milder period sufficiently prolonged for the country to become covered with vegetation and stocked with animal life."

Let us now see to what all this leads. It has been proved beyond the possibility of a doubt that, at the time the till was being formed which *overlies* the Scottish interglacial beds, the whole of Scotland, Scandinavia, the bed of the North Sea, and a great part of the north of England was covered with one continuous sheet of ice upwards of 2000 feet in thickness. This sheet overwhelmed the Hebrides, the Orkney and Shetland islands, extended into Russia, filled the basin of the Baltic, overflowed Denmark and Holstein, and advanced into North Germany as far at least as Berlin. It has also been demonstrated that, at the time the Lower Till was being formed which *underlies* these interglacial beds, northwestern Europe was under a still more severe state of glaciation. The ice-sheet at this time advanced farther south into England, and extended into North Germany as far as Saxony. It is perfectly obvious that this sheet must have destroyed all plant and animal life in Scotland; and before the country could have become covered with vegetation and stocked with those interglacial animals, to which Mr. Wallace refers, the ice must have disappeared and the climate become mild.

Equally conclusive are the facts adduced by Mr. Wallace in reference to the interglacial beds of England. "In the east of England, Mr. Skertchly," he says, "enumerates four distinct bowlder clays with intervening deposits of gravels and sands. Mr. Searles V. Wood, Jr., classes the most recent (Hessle) bowlder-clay as 'post-glacial,' but he admits an intervening warmer period, characterized by southern forms of mollusca and insects, after which glacial conditions again prevailed with northern types of mollusca. Elsewhere Mr. Wood says: 'Looking at the presence of such fluviatile mollusca as *Cyrena fluminalis* and *Unio littoralis* and of such mammalia as the hippopotamus and other great pachyderms, and of such a littoral Lusitanian fauna as that of the Selsea bed, where it is mixed up with the remains of some of those pachyderms, as well as of some other features, it has seemed to me that the climate of the earlier part of the Post-glacial Period in England was possibly even warmer than our present climate; and that it was succeeded by a refrigeration sufficiently severe to cause ice to form all round our coasts, and glaciers to accumulate in the valleys of the mountain districts.'" That these faunæ indicate a warm and equable condition of climate is further evident from Mr. Wallace's remarks: "The fact," he says, "of the hippopotamus having lived at 54° north latitude in England, quite close to the time of the Glacial Epoch, is absolutely inconsistent with a mere gradual amelioration of climate from that time to the present day. The immense quantity of vegetable food which this creature requires, implies a mild and uniform climate with hardly any severe winter; and no theory that has yet been suggested renders this possible except that of alternate cold and warm periods during the Glacial Epoch itself. . . . . . Thus the very existence of the hippopotamus in Yorkshire as well as in the south of England in close association with glacial conditions must be held to be a strong corroborative argument in favor of the reality of an interglacial warm period."

I trust that Mr. Wallace has not been misled by Mr. Wood's unfortunate use of the term "Post-glacial" as applied to the Hessle bowlder-clay. The Hessle bowlder-clay as surely belongs to the Glacial Period proper as does the true Till of Scotland, which covers the lowlands and overlies the interglacial beds of that country. It is the *moraine profonde* of the last *mer de glace* which covered the greater part of northwestern Europe. The Upper Till of Scotland and the Hessle bowlder-clay of England belong to the same period. This has been clearly shown by Professor J. Geikie in his 'Great Ice-Age,' chapter xxx (2d edition), and in 'Prehistoric Europe,' chapter xii, and elsewhere. The Hessle bowlder-clay is, in short, a continuation of the Upper Till of Scotland.

The position of these Hessle beds to which Mr. Wallace refers, like that of the interglacial beds of Scotland, is between two bowlder-clays—the Hessle and the Purple bowlder-clays, both of which indicate a period of extreme glaciation; only the Purple bowlder-clay period was somewhat the more severe of the two. At both periods the greater part of northwestern Europe was buried under ice. We know that during the last great ice-period, which was undoubtedly the period of the Hessle bowlder-clay, the ice-sheet reached in North Germany as far as Berlin; while during the period of the Purple bowlder-clay it advanced to about Saxony.

The observations of Professor Torrell, Dr. A. Penck, Professor Credner, Professor Berendt, Dr. Jentzsch, A. Helland, F. Wohnschaffe, H. Habenicht, and other geologists have shown that there are in North Germany three distinct bowlder-clays—an Upper, Middle, and Lower, with two series of interglacial beds. In these interglacial beds have been found organic remains which evidently indicate a mild and genial condition of climate. The younger interglacial period (the one prior to the last great extension of the ice) in all probability corresponds to the last interglacial period of Scotland, England and Ireland. Interglacial beds belonging to the same period have been found in Switzerland, Italy, Denmark, North America, and other places, all indicating a mild and equable condition of climate.

There is another class of facts, almost entirely overlooked, which prove even more conclusively the warm character of interglacial periods. These facts will, however, be more appropriately discussed when we come to consider the question of warm polar climates.

It would be impossible within the limits of the present paper to give even the briefest outline of the recent discoveries in regard to interglacial periods. But though this were possible it would be wholly unnecessary, as the facts which have already been adduced by Mr. Wallace himself are perfectly sufficient for our present purpose.

If now it be true, as it undoubtedly is, that the Hessle bowlder-clay of England belongs to the same age as the Upper Till of Scotland, and that the last warm interglacial period, when the *Cyrena fluminalis* and *Unio littoralis*, the hippopotamus, the *Elephas antiquus*, and other animals of a southern type lived in England, occurred between two glacial periods so severe as to envelop the greater part of northwestern Europe in a continuous sheet of ice, then this particular interglacial period must have intervened during a high state of eccentricity, and not, as Mr. Wallace assumes, at a period subsequent to the Glacial Epoch proper, when the eccentricity had greatly diminished. This is obvious; for if the last great ice-sheet could have been produced without a high state of eccentricity, then there seems no reason why the one preceding it should not also have been produced without high eccentricity. If so, then all the previous ice-sheets may in like manner have been so produced. For the difference in magnitude between the last and penultimate ice-sheets was not so great as to warrant the supposition of any considerable difference in the amount of eccentricity at the two periods when these ice-sheets were respectively developed. In short, if the last great ice-sheet can be explained without the supposition of a high state of eccentricity, then there does not appear to be any real necessity for any theory of eccentricity in accounting for the Glacial Epoch.

If we adopt the Physical theory of the cause of the Glacial Epoch, we are compelled to maintain that the last two great Ice-periods were the indirect results of a high state of eccentricity, and in this case we can hardly avoid the conclusion that the mild intervening period was due to the same cause. The occurrence of a mild interglacial period between the two ice-periods is directly in opposition to Mr. Wallace's view that during a high state of eccentricity the ice would not disappear but be continued. It is in perfect harmony, however, with that which I advocate; for during high eccentricity a mild and equable condition of climate, when the winters occur in perihelion, is as much a necessary result as a cold and glacial condition when they occur in aphelion.

The facts of Geology thus to me appear so far to be as much opposed to Mr. Wallace's modifications as are the principles of Physics.

Difficulty in detecting the Climatic Character of the earlier Interglacial Periods.—It follows according to theory that, other things being equal, the greater the amount of eccentricity the more equable and mild will the interglacial periods be. It is probable therefore that some of the earlier interglacial periods were milder and more equable than the last. It may be difficult in the present state of our knowledge to prove this conclusion by direct geological and paleontological evidence; but, on the other hand, it is certainly impossible to disprove it by that means. The absence of deposits containing organic remains indicative of a superior mildness of climate having obtained during early interglacial periods cannot certainly be regarded as satisfactory evidence against the conclusion just referred to. When we consider the enormous pressure and destructive power of an ice-sheet some 2000 or 3000 feet in thickness grinding down the face of a country, our surprise is that so much evidence remains of even the last interglacial period That so few relics of the flora and fauna of preceding interglacial periods have been preserved is a conclusion which we might *à priori* anticipate. This fact has been clearly pointed out by Mr. Wallace himself, who says:—"If there have been, not two only, but a series of such alternations of climate, we could not possibly expect to find more than the most slender indications of them, because each succeeding ice-sheet would necessarily grind down or otherwise destroy much of the superficial deposits left by its predecessors, while the torrents that must always have accompanied the melting of these huge masses of ice would wash away even such fragments as might have escaped the ice itself" (p. 118).

When we pass beyond the limits reached by the ice-sheets of the Glacial Epoch we may expect, of course, to find the remains of many of the plants and animals which lived during the earlier interglacial periods. But here, again, we encounter another difficulty; for we have in this case seldom any means of determining the age to which these remains belong. Unless in relation to overlying and underlying bowlder-clays, there seems in many cases no way of knowing to what interglacial period they ought to be assigned; or, in fact, whether they are really interglacial or not. If the remains in question indicated a condition of climate much milder than the present, the probability is that they would be classified as preglacial. I fully agree with Prof. J. Geikie, that many of those plants and animals of a southern type which have been regarded as Preglacial are in reality of Interglacial age.

Objection as to the number of Interglacial Periods.—It has been urged as an objection to the Physical theory of the Glacial Epoch, that according to it there ought to have been more interglacial periods than we have direct evidence of having actually occurred. I am doubtful as to the force of this objection. I do not think that there could have been more than about five well-marked interglacial periods during the entire Glacial Epoch; three probably during the former half of the epoch, and certainly not more than two during the latter half. There would be a large interval between the two maxima of eccentricity of 100,000 and 200,000 years ago, when the alternations of climate would be comparatively moderate in extent. Besides it is not correct to assume, as is generally done, that the interval between two consecutive interglacial periods is only 21,000 years; for the mean rate of motion of the perihelion during the Glacial Epoch was considerably less than has been assumed. It will be seen from the table of the Longitude of the Perihelion, given in 'Climate and Time,' p. 320, that it has taken the perihelion 231,000 years to make one complete revolution.

If, therefore we assume, what of course is not certain, that mean rate of precession during the Glacial Epoch to have been the same as the present, then the rate of precession to that of the perihelion's motion would, in this case, be as 9 to 1. The equinoxial point will take 25,811 years to make one revolution; but as the perihelion moves in the opposite direction, it will reduce the time taken by the point in passing from perihelion round to perihelion to 23,230 years, which will represent the mean interval between two consecutive interglacial periods. But as the motion of the perihelion was very irregular, the length of the interval between the periods would of course differ considerably.

When we consider how difficult it must be to detect in teh drift covering glaciated countries even a relic of early interglacial deposits, and when moreover we remember that it is only within the past few years that geologists have begun to bestow any attention on the subject, it is certainly not surprising that direct geological evidence of so few interglacial periods has as yet been discovered. In England, geologists have, however, already detected evidence of three interglacial periods with four or five ice-periods. In Germany, quite recently, two interglacial periods and three or more ice-periods have been recognized by competent observers. In Denmark there are four bowlder-clays separated by intercalated beds of sand and clay. In severely glaciated Scotland, where traces of former interglacial periods can hardly be expected, there have nevertheless been found in old preglacial buried channels and other sheltered hollows three, four, and in some places five, bowlder-clays, separated from one another by immense beds of sand, gravel and clay. Some of these beds are found to be continuous for long distances. It is true that these intercalated beds have yielded few or no organic remains, but it may well be that further research will yet result in the discovery of more abundant fossils; for frequently the beds in question are too thick and too extensive to allow us to infer their subglacial origin. They do not in such respects resemble the deposits which have been accumulated by aqueous action under ice, but have all the characteristics of deposits which have been laid down in lakes and lacustrine hollows. As some have already yielded organic remains, a more extended scrutiny will probably lead to the discovery of similar fossils in those beds which are at present believed to be unfossiliferous.

Interglacial Periods less strongly marked in Temperate Regions than Glacial.—I quite agree with Mr. Wallace that the interglacial deposits never exhibit any indication of a climate whose warmth corresponded to the severity of the preceding cold. This, however, cannot be urged as an objection, for it is a result which follows as a necessary consequence from theory. It theoretically follows that the cold of the glacial periods will not only exceed in severity the heat of the interglacial, but will also be of longer duration. During the glacial periods extreme cold is the characteristic of the winters, which, owing to the presence of snow and ice, only becomes moderated, although, of course considerably, during the summers. But, on the other hand, during interglacial periods mildness and equability of temperature rather than heat are the characteristics both of summer and winter.

That the cold of the glacial periods must have continued longer than the warmth of the interglacial will, I think, be apparent from the following considerations. As long as a country remains permanently covered with snow and ice, the climate, as has been repeatedly shown, must continue cold, no matter what the direct heat of the sun may be. Astronomically considered the interglacial periods are, of course, of the same length as the glacial,—the mean length of which, during the Glacial Epoch, was about 11,600 years; but the cold of a glacial period would not, as we shall presently see, actually terminate at the end of the period, but would be continued on probably for centuries into the succeeding interglacial period. Suppose that during a glacial period the country is covered with a sheet of ice, which during the continuance of the period had accumulated to the thickness of 2000 or 3000 feet. All this enormous quantity of ice would have to be melted off the ground before the warmth of the interglacial period would commence. So long as a single inch of ice covered the surface of the country, the cold would continue. Ice, as we have seen, by chilling the air induces fresh snow to fall; and of course it is only when the amount of ice annually melted exceeds that being formed from the falling snow, that a diminution in the thickness of the sheet would begin to take place. A real melting of the ice, and consequent decrease in the thickness of the sheet, would probably not commence till the astronomical and physical agencies in operation during the glacial period began to act in an opposite direction. In short, it would be the favorable conditions of the interglacial period that would effectually remove the ice; and it would be then, and only then, that the warmth would begin. While, again, at the close of the period, when the first inch of ice made its appearance on the surface of the country, the interglacial condition of climate would come to an end. The time required to remove the ice does not prevent an interglacial condition of climate; it only somewhat shortens its duration.

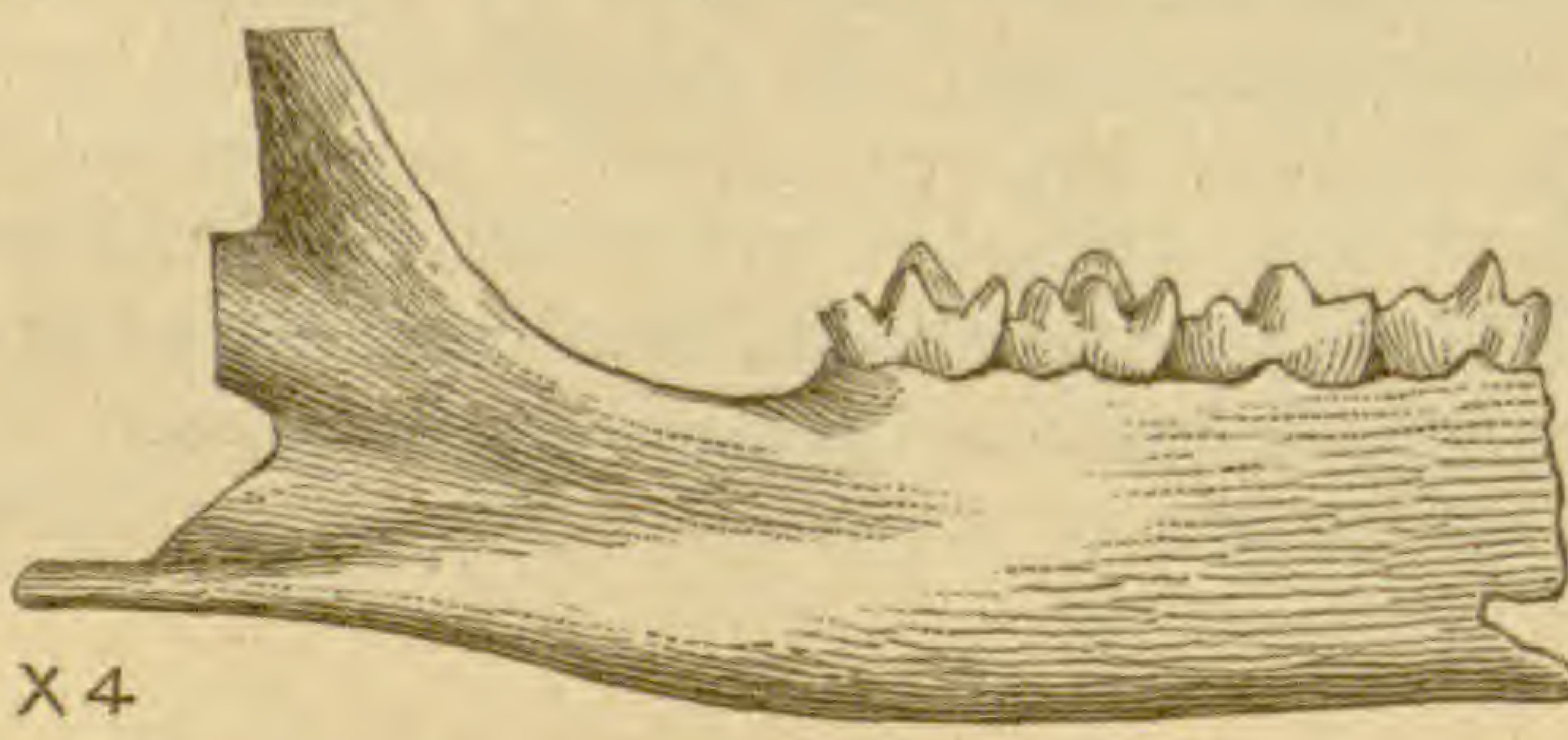
There is another circumstance worthy of notice here. It is this: as the mild and equable character of the climate during interglacial periods resulted to a large extent from the enormous transference of equatorial heat, and its distribution over temperate and polar regions, the difference of climatic conditions between the subtropical and the temperate and polar regions would be less marked than at present; in other words, the temperature would not differ so much with latitude as it does at present. This, as we have seen, is a conclusion which is fully borne out by geological and paleontological facts.

The question as to the probable cause of warm polar climates will next be considered.

ART. LI.—*A new Marsupial from the Miocene of Colorado;* by W. B. SCOTT.

ALTHOUGH there can be no reason to doubt that Marsupial animals of the opossum type existed in North America during Miocene times no remains of them, so far as I am aware, have hitherto been found. The Princeton expedition of 1882 obtained from the Miocene deposits of Chalk Bluffs, Colorado, a portion of a very small lower jaw containing four molar teeth, which on examination proves to have belonged to a small opossum not generically different from *Didelphys virginiana*, but very obviously distinct from that species.

This species may be called *Didelphys pygmæa*, and is defined as follows. Opossum very small, intermediate in size between *D. murina* and *D. elegans* of South America. Lower margin of the jaw nearly straight, and the ramus beneath the molar teeth of nearly uniform depth; coronoid process very weak, condyle marked off on a distinct neck; inflected angle of jaw projecting considerably behind the condyle. Molar teeth constructed on the ordinary opossum type, antero-internal cusps of penultimate molar very small, and heel of last molar consisting of two cusps instead of three, as in *D. virginiana*.



Left ramus mandibuli of *D. pygmæa*, seen from the inner side; 4 times the natural size.

This little animal was doubtless an insectivorous opossum, some three or four inches long, and finds its nearest living representatives in the small insect-eating opossums of South America. It would be interesting to make an extended comparison with some of the latter, but as yet I have had no opportunity to do this. Such opossums probably abounded in the sub-tropical Miocene forests of our western territories, in spite of the fact that they are extremely rare as fossils. This rarity can readily be understood when we remember their minute size and probably arboreal habits. The homogeneous and fine-grained matrix of Chalk Bluffs is well adapted to the preservation of such forms, and it is therefore no matter of surprise that a far larger number of very small mammals should be found there than in the coarser matrix of the White River district in Dakota.

Morphologically this new species is of very small value, as it throws no important light upon questions of descent. But as a contribution to geographical zoology it is of great interest. It demonstrates the fact that the small insectivorous opossums, now characteristic of South America, existed in Miocene times in North America, and is additional evidence that the latter continent is the source from which the former received the greater part of its animal population, just as the great Pale-arctic continent seems to have been the original source of the modern faunas of the Ethiopian and Oriental regions. Thus, the tapir, the llama tribe, many edentates, the peccaries, and in all probability the monkeys and cats, have been traced to their origin in North America. The small opossum just described gives another characteristic feature of the South American fauna; and I may add that a small lizard from Chalk Bluffs, now in the Princeton Museum and as yet undescribed, points in the same direction.

There is thus every reason to believe that future discoveries will supply the missing terms and that it will be seen that the Tertiary fauna of North America was the starting point for the recent fauna of South America, just as migrations from Greece in Pliocene times gave rise to the characteristic mammalian population of modern Africa.

MEASUREMENTS.

Length of molar series	0·007^{m}
" 1st molar	0·0015
" 2d "	0·002
" 3d "	0·002
" 4th "	0·0015
Height of 4th molar	0·002
Depth of ramus beneath 1st molar	0·0035
Depth of ramus beneath 4th molar	0·004

For the accompanying sketch, as well as for the exceedingly delicate and difficult work of preparing and mounting this minute specimen, I am indebted to Curator F. C. Hill.

Princeton, N. J., May 5, 1884.

ART. LII.—*On a method of obtaining autographic records of the free vibrations of a tuning-fork, and on the autographic recording of beats;* by ALFRED G. COMPTON.

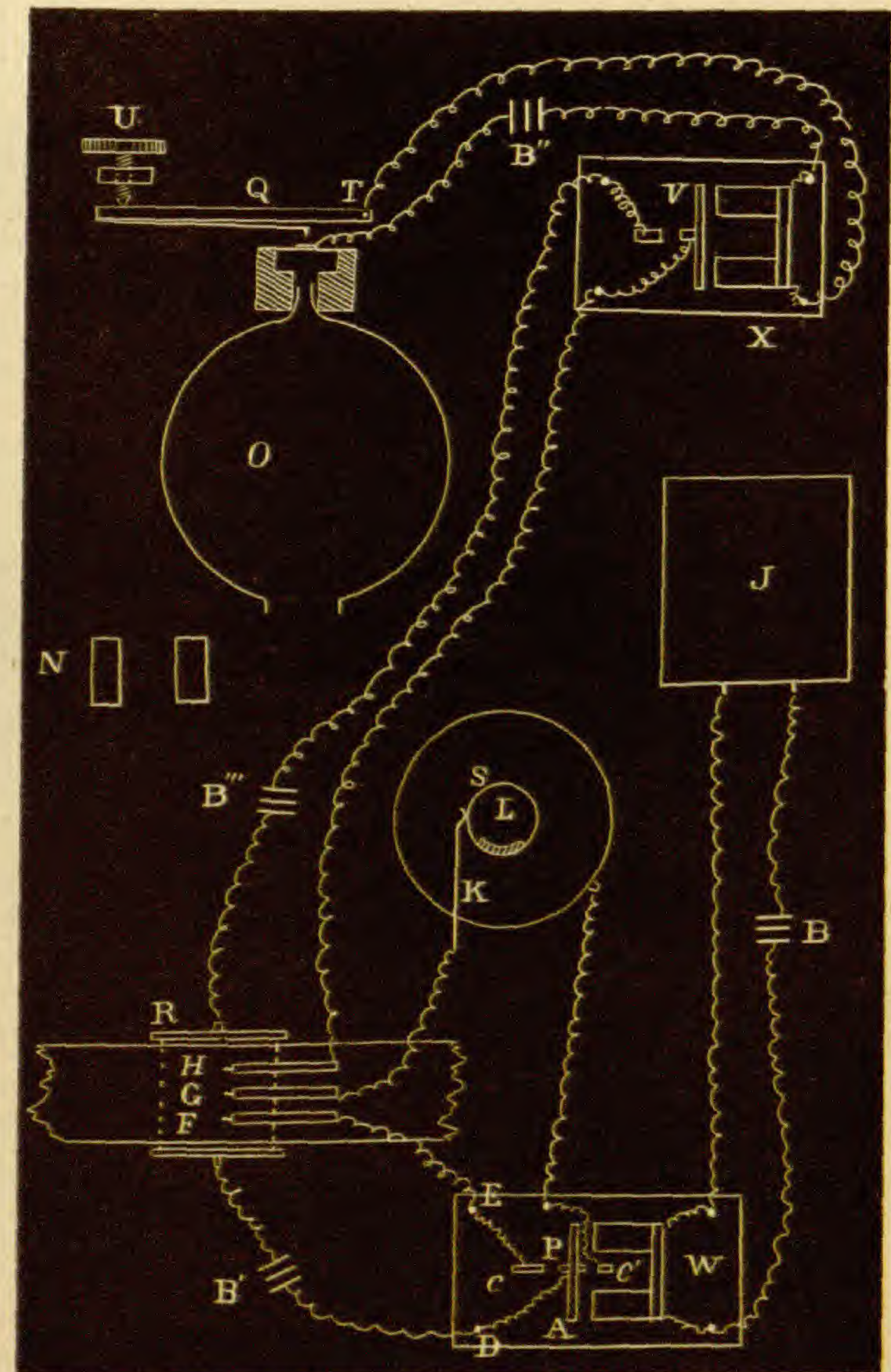
THE exact determination of the rate of vibration of a tuning-fork by means of the siren has heretofore been attended with errors resulting from imperfections of the recording gear, and difficulty of maintaining and counting the beats of the two tones. I have sought to remove these errors by obtaining autographic records of the rate of the siren and of the difference between this rate and that of the fork. The experimenter, while obtaining these records, being freed from the necessity of even counting the beats, no personal element enters into the observation, and the records being permanent, can be studied at leisure. The following is the method of obtaining the autographic records.

A strip of chemically prepared paper, which rests on a metal wheel, being drawn by clock-work under three platinum pens placed in electric circuits, three simultaneous electro-chemical records are received. One of these is a line of dots made at the rate of one a second, by a chronometer placed in the circuit of the same battery with one of the pens. The second is a row of dots made by the closing of the same circuit by a siren once in each revolution, while singing nearly in unison with the fork. The third is a row of dots made by the closing of the circuit of a second battery, once for each beat of the fork and the siren.

It thus results that from the same strip of paper can be counted the number of revolutions made by the siren in any number of seconds (from which the number of impulses produced by the siren results), and the number of beats in the same time,—which is the difference between the number of shocks imparted to the air by the siren and the number imparted by the fork. The record being made without throwing any work upon the fork, the rate of vibration of the unconstrained fork results.

The following description will give an idea of the details of the method.

A break-circuit chronometer J and a relay W are included in the circuit of a battery B of one carbon cell. The armature A is therefore freed from the magnet once a second by the break-circuit mechanism of the chronometer. When the armature is thus freed, a platinum point P closes the circuit of another battery B′, the current of which then passes through the armature A, the platinum contact point *c*, the pen F, the metallic wheel R on which the pen point rests, and so back to the battery. When the circuit of battery B is closed, the relay-armature makes contact at C′. From C′ a wire passes to the framework of a De la Tour's siren S. Attached to the frame of the siren is an insulated support carrying a platinum spring K, which bears against an ebonite drum on the axis of the siren, and touches at each revolution a strip of metal embedded in the drum, and in electrical communication with the axis. From the spring, a wire passes to the platinum pen G.



It follows that, when the armature is in contact with C′, which is about $\frac{99}{100}$ of each second, the current of the battery B′ flows through the post D, the armature A, the contact point C′ and the siren S to the pen G, and so to the battery. A clock-work gives motion to a fillet of paper moistened with a solution of iodide of potassium, drawing it between the pens and the roller R. When the siren is revolving, the current of B′ passes through the pen F at each beat of the chronometer, and through the pen G at each revolution of the siren, unless, at the moment of closing the siren-circuit at S, the same circuit is opened through the absence of the platinum point P from the contact point C′. There are thus two rows of dots, side by side on the paper, which give the number of revolutions of the siren and the time.

The object sought in making the records at the two pens, F and G by the current of the same battery is to secure the suppression of one of the siren dots, whenever it coincides exactly with one of the seconds dots. If this adjustment is perfect, the interval of time between two missing dots in the siren record is a whole number of seconds in which an exact whole number of revolutions of the siren has been made; otherwise the number of revolutions made is a whole number plus a fraction of uncertain value. The method of making this adjustment, and the conditions on which its accuracy depends, will be discussed below.

Between the siren tube and the bellows is placed one of Cavaillé Col's pressure-regulators. With this and a proper adjustment of the weight on the bellows, it is easy to keep the pitch of the siren so constant that it shall give with the tone of a fork any desired number of beats a second, for thirty or forty seconds, with scarcely any perceptible change of rate. To cause these beats to record themselves, the following arrangement is used.

The fork N is mounted before the mouth of a Helmholtz resonator O, which is nearly or exactly in unison with it. To the small opening of the resonator is fitted a cylindrical drum, of which the farther end is closed by a membrane to which is glued a small disk of platinum foil. A lever Q, whose fulcrum is at T, is moved by a fine screw U, so that a platinum point carried by the lever may be made to nearly or quite touch the platinum disk. The platinum disk is connected, by fine wire, with one pole of the battery B″, the current of which flows through the relay X, the lever Q, and the platinum disk, as long as the latter touches the platinum point. Whenever the membrane recedes from the platinum point, the circuit B″ is broken; the armature V then closes the circuit of the battery B‴ and a record is made by the pen H on the paper.

If now the siren and the fork be singing nearly in unison, beats will be heard; the two sets of vibrations being imparted to the membrane, its vibrations are intermittent. The contact between the point and the disk being so adjusted that the circuit B″ is broken once at every beat, the beats record themselves on the fillet as a row of dashes side by side with the other two records.

The contact of a rigid platinum point being found to interfere too much with the motion of the membrane, the point was attached to one end of a light spring about 115^{mm} long, the other end of which is soldered to the lever Q. The spring is made by flattening a piece of copper wire. It lies close to the lever and has very little play, but answers its purpose perfectly.

It may be thought that the relay X might be dispensed with, the battery B″ being made to record directly through the pen H. By the use of the relay, however, the dash made by the pen H at each beat, can be reduced to any convenient length; and besides, the distinct clicks of the relay at the beats, are much easier to observe than the beats themselves, particularly when these are not more frequent than two or three to the second. The variations in the rate of these clicks give clear indications of changes in the rate of the siren, and their cessation shows when the excursions of the membrane are too small to cause a record of the beats.

In the management of the apparatus, it is obviously not necessary that the motion of the fillet of paper should be uniform. Care has to be taken, however, that it shall not at any time be retarded very much, as the siren dots then become too crowded, and cannot be counted. Considerable inequality of the pressure of the pens on the paper will cause the fillet to run off to one side. This is prevented by placing the three pens as near together and as near the middle of the fillet as possible, equalizing the pressure on them, providing the sides of the roller with flanges, and placing guides for the fillet just in front of the roller. Of course the roller and all the contact points must be kept clean.

Care must be taken that the armature A, while very close to the poles of the magnet, shall not touch them, otherwise the residual magnetism will retard its release. I find it most convenient to place the plane of the mouth of the resonator nearly parallel to the plane in which the fork vibrates, as the resonator is then not in the way of the bow. The best effect of the fork in producing beating vibrations of the membrane occurs, however, when the opening of the fork is not exactly in front of that of the resonator, but at a distance to one side, which depends on the distance of the siren. The best position is found by sounding the siren and the fork, and moving the stand carrying the resonator, till the relay X is heard ticking in unison with the beats. As finally placed in the experiments which gave the best results, the center of the siren was 80^{mm} in front of the plane of the mouth of the resonator and 50^{mm} to the right of the center of the mouth, while the center of the fork was 20^{mm} in front of the plane of the mouth, and 50^{mm} to the left of it.

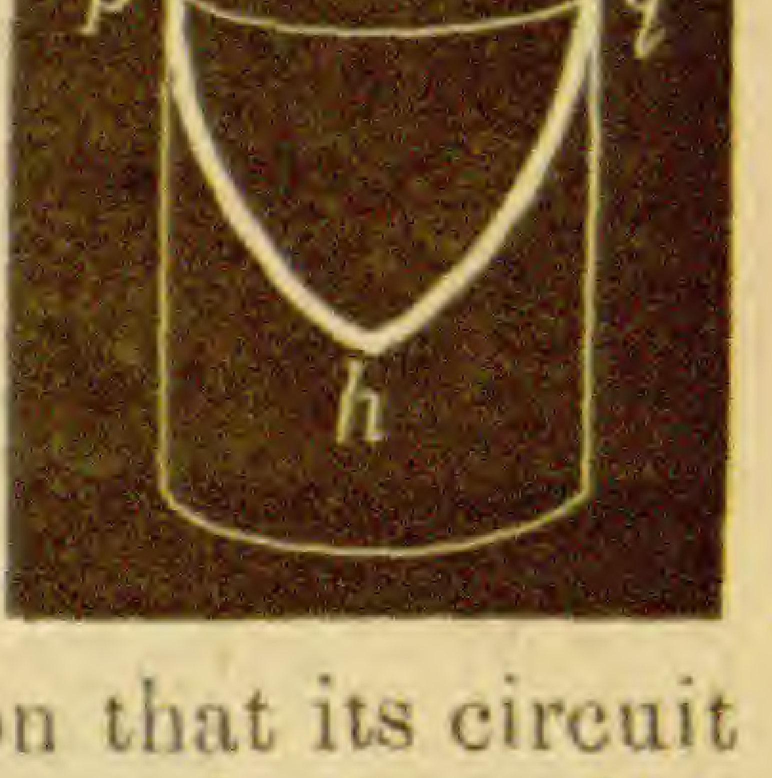
To adjust the contact point of the membrane, the set-screw is turned forward while the siren is sounding, but the fork silent, till the click of the relay X reports the circuit closed. If now the screw is turned gradually back, the relay will begin to rattle or chatter. The best position is that in which the chattering is just about to begin. If the fork be now sounded by a stroke of the bow, the circuit will be broken, showing that the membrane moves *inward towards* the vibrating fork, affording thus an interesting illustration of the well-known law that atmospheric pressure is diminished in the neighborhood of a vibrating body. As the tone of the fork dies out, the membrane gradually returns, continuing its vibrations, and while returning, it will at every beat close the circuit and produce a dash on the paper. If the fork be too near the mouth of the resonator, the strokes of the beating relay will not begin till some time after the stroke of the bow, when the vibrations of the fork have nearly died out; if it is too far away, they will begin immediately, but will not last long. The dashes will sometimes be seen to consist of a row of dots, showing that the circuit has been broken several times, not merely by the maximum inward vibration of the membrane, but by several preceding and following it. But generally, these dots flow together, and only appear as a dash. In the accompanying specimen records, the dashes have a length equal to that of about three siren-revolutions or thirty vibrations.

For membranes, I have used thin sheet rubber, paper, gold-beater's skin, thick vulcanized rubber (about 2^{mm}), and leather. The best results have been obtained with white kid such as is used in the making of organ bellows. The membrane with which the best records have been obtained is of this material, is 28^{mm} in diameter, and carries a platinum disk about 4^{mm} square and $0{\cdot}1^{mm}$ thick. The connecting wire (No. 28), is carried across the membrane to the edge, where it is securely fastened to the support. If left loose, it produces by its accidental vibrations, a constant chattering of the recording relay. To steady the membrane a little, I have sometimes found it advantageous to give it a slight tension and outward convexity by means of a thread wound round a small wrest-pin.

The exactness of the coincidence between seconds and siren revolutions indicated by the missing siren dots in the record, depends on the following considerations.

If we denote the duration of an excursion of the armature of the relay W by a, and the duration of the siren contact at S by b, we shall have if $a > b$, $a - b =$ the excess of the duration of the break in the siren-circuit at A over the duration of the siren contact at S. If the whole siren contact is coincident with any portion of the break a, the siren-record will be elided; this elision will happen, therefore, if the beginning of the break precedes or follows the beginning of the contact by the amount $a-b$; and the fact of the elision of a record will indicate that the second and siren records coincide to within $\pm(a-b)$. The possible error therefore in the counting of the number of siren revolutions in the interval between two coincidences amounts to $2(a-b)$, and is 0 when $a=b$. If, however, the chemical record does not begin till a time t' after the contact is closed and continues for a time t'' after it is broken, then making $t=t' \backsim t''$, what may be called the "effective" or "chemical" contact will have the duration $b \pm t$, and the error may amount to $2(a-b \pm t)$. The quantity t may be due to either the delay in the starting or the stopping of the chemical action after the circuit has been made or broken, or to the dragging of the color under the point of the pen when the paper is too wet. The former appears from experiments to be inappreciable, the latter becomes large and uncertain if the paper is too wet, but is apparently insignificant when care is taken to have the paper only just wet enough to let the current pass. If $a<b$, the siren-record will never be completely elided, but it may be shortened at either end or cut into two. It may be thus so much shortened as to appear to be elided, and so occasion an apparent coincidence when there is none in reality. This is therefore an additional reason for making b at least equal to a.

For the purpose of easily bringing about the equality of a and b the siren contact was arranged as follows. The strip of metal embedded in the ebonite drum L on the axis of the siren was of the form shown at *phq*, and the platinum spring which rested on the drum was movable up and down the drum by a set-screw. After adjusting the magnet and the spring of the relay W, so as to give the shortest possible excursion of the armature A, the duration of the siren contact was made equal to that of the excursion by moving the spring to the proper position. In effecting this equalization, the duration of the siren-cotnact was measured by drawing the paper very rapidly under the pen, while the siren was rotating, and measuring the length of the dashes and the distance between the middle points of two consecutive dashes. The ratio of the first to the second, gives the duration of the contact in terms of the duration of a revolution, which latter is known. The duration of the armature excursion is found



by stopping the siren, setting it in such position that its circuit is closed, drawing a paper rapidly under the pen, and measuring the ratio of the short gaps in the now nearly continuous record, to the interval between the centers of two gaps, which latter is one second. In this way, after several adjustments, the duration of the armature-excursion and that of the siren were made very nearly equal and each equal to about 0·009 second.

With this adjustment, the "frequency" of the fork as found by counting the number N of revolutions of the siren and the number n of beats in a number N′ of seconds, would be, if the siren was higher than the fork and if the number of holes in the siren was 10, $\frac{10N-n}{N'}$; and this determination would be exact, if the two coincidences were exact. As the error in the coincidences is $\pm(a-b\pm t)$ the possible error in the frequency of the fork would be, neglecting t, $2\left(\frac{a-b}{N'}\right)$; so that when a and b were nearly equal and N′, as was frequently the case, was as great as ten or twelve seconds, the method would seem to promise a high degree of precision.

The following table shows the results obtained with one of Koenig's vowel-sound forks (marked OU):

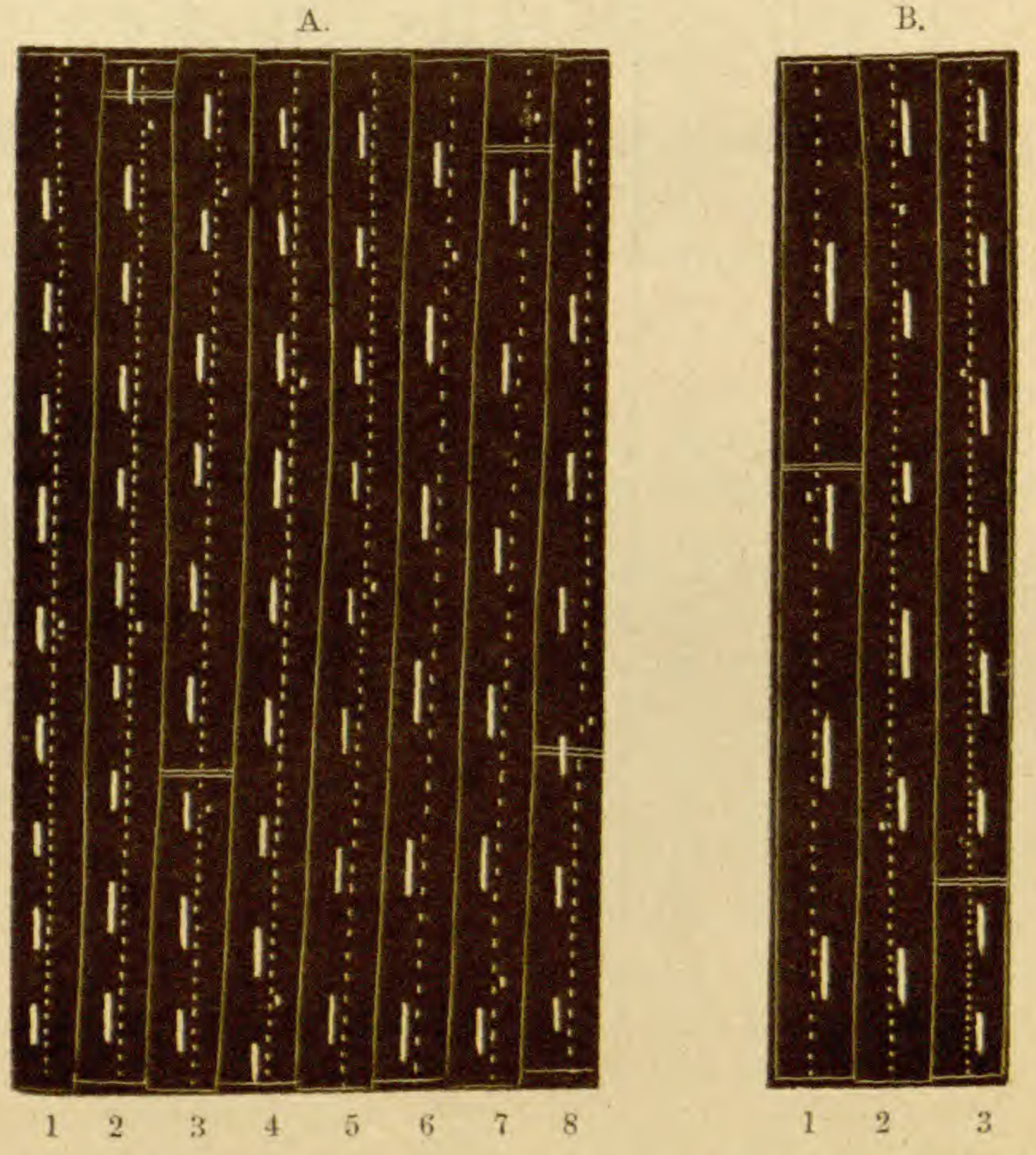
Exp.		Vibrations of siren.	No. of beats.	Vibrations of fork.	Time, seconds.	Vibrations per second.
1.	Oct. 8	1730	25	1705	5	341·0
2	" 8	3100	30	3070	9	341·1
3.	" 10	1040	16	1024	3	341·33
4.	" 11	3100	31·6	3068·4	9	340·93
5.	" 11	2770	43	2727	8	340·9
6.	" 11	1390	25	1365	4	341·25
7.	" 11	2060	15	2045	6	340·83
8.	" 11	4470	41·5	4428·5	13	340·66
9.	" 11	1040	16·7	1023·3	3	341·1
10.	" 12	2071	26·6	2044·4	6	340·73
11.	" 12	2400	11·5	2388·7	7	341·2
12.	" 12	3099	29·6	3069·4	9	341·04
						4092·07
				Mean,		341·01

The temperature during the experiments varied from 68° to 73° F. and the rate of beating from 1½ to 6 beats a second.

Nine selected experiments on October 20, 27 and 30, being experiments in which the coincidences were the most perfect and the records the clearest, gave the following results:

Exp.	Vibrations of siren.	Beats.	Vibrations of fork.	Time, seconds.	Vibrations per second.
1	3780	29·25	3750·75	11	340·98
2	1730	25·6	1704·4	5	340·88
3	3460	51·6	2408·4	10	340·84
4	2410	23·5	2386·5	7	340·93
5	1030	7·25	1022·75	3	340·92
6	1030	6·5	1023·5	3	341·17
7	4130	38·45	4091·55	12	340·96
8	2750	22·28	2727·72	8	340·96
9	5540	84·48	5455·52	16	340·97
T=73° F.			Mean,		340·96

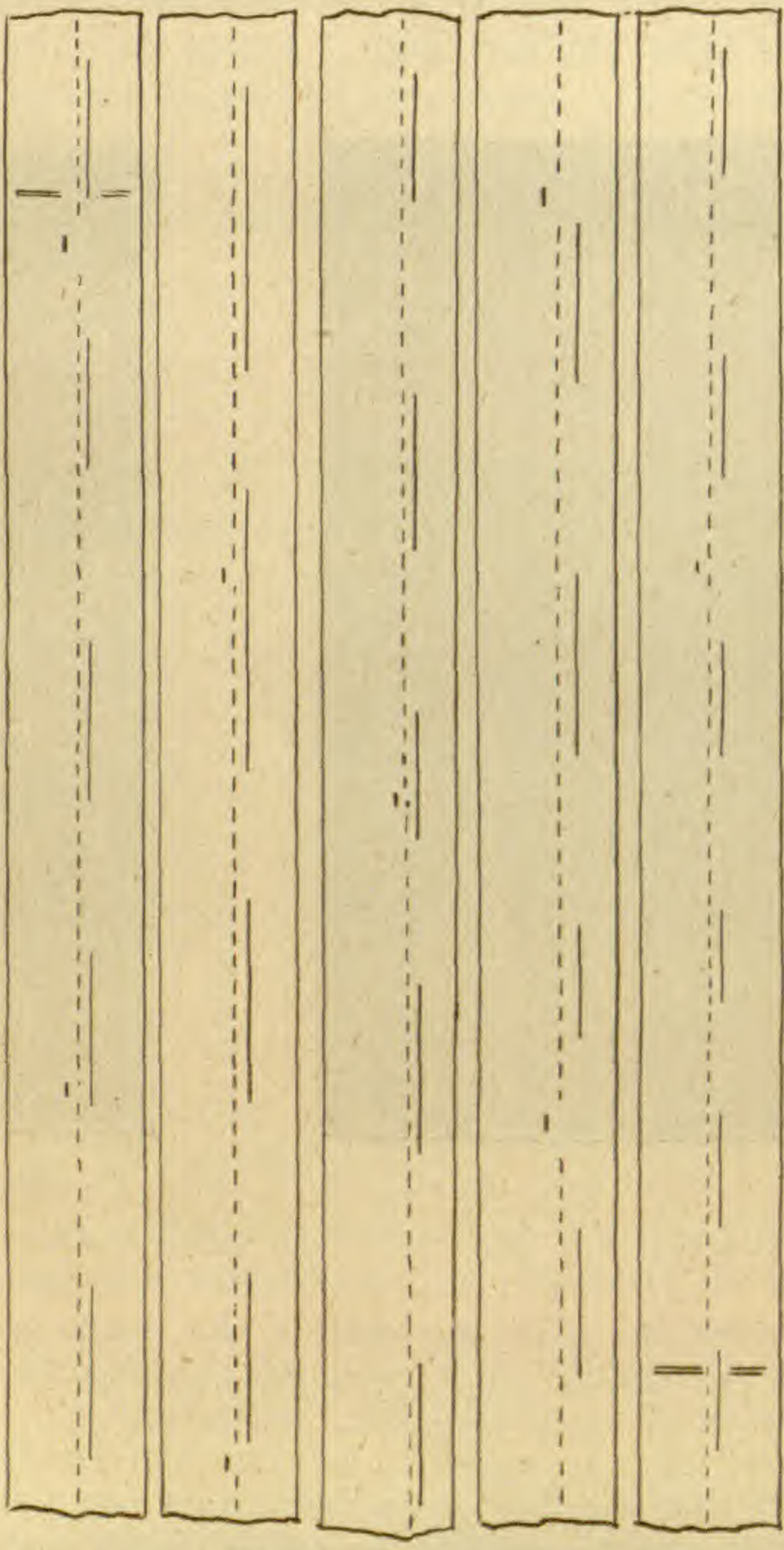
The specimen records illustrate the character of the autograph. The record A is that of the experiments 2 and 3 of the second series. The dots in the middle row represent the siren revolution, the heavy dashes on one side of them the beats, and the light dots on the other side the seconds. It will be observed that the first two seconds of the record were useless for want of a coincidence. The first coincidence occurs at the mark ‖, a second one similarly marked occurs three seconds later, a third five seconds after the first, and a fourth at the end of ten



seconds. Experiment No. 2 of the table gives the results recorded in the interval between the third and eighth seconds, and experiment No. 3 is the result of the whole ten seconds. The "marginal remark" on the original record is "coincidences not quite perfect, but errors similar and equal."

The record B is a rejected observation of October 20. It will be seen that the first second's dot does not quite coincide with the siren record, though the nearest siren dash is partly effaced. If this were taken as a coincidence, the result would be $\frac{1384-14}{4}=341{\cdot}5$ showing how much the accuracy of the method depends upon the exactness of the coincidence. It might be estimated that the first fraction of a revolution in this record is 0·8 in which case the result would be $\frac{1378-14}{4}=341$; but it is preferred to reject the result, particularly as the time, four seconds, is short.

C.



The records A and B having been rendered somewhat indistinct in the photographic reduction, the record C is added, and is reproduced without reduction or reversal. It shows the exact coincidences at the first, fourth, sixth, seventh and ninth seconds, and the imperfect coincidences at the second, third and fifth. The rate of the fork as determined from it is

$$\frac{2750-22 \cdot 8}{8} = 340 \cdot 97$$

The above results are submitted as the first obtained by the proposed method. I believe that, with certain improvements in some of the mechanical details, a considerably higher degree of accuracy may be attained, and the method be made as exact as the optical methods, with the additional advantage of permanence.

ART. LIII.—*Notes on the Volcanic Rocks of the Great Basin;* by ARNOLD HAGUE and JOSEPH P. IDDINGS, of the U. S. Geological Survey.

BETWEEN the abrupt eastern wall of the Sierra Nevada and the western base of the Wahsatch Range lies the broad expanse of country, over 400 miles in width, known as the Great Basin.

It offers such sharply defined topographical and geological characteristics in such striking contrasts to the adjoining areas that it forms on the grandest scale one of the most marked physical features of the Cordillera. As the region in general presents such great uniformity of geological structure, and has everywhere been subjected to much the same physical conditions it has been called by both King and Powell the geological province of the Great Basin.

Across the broadest portion of this interior basin the Geological Exploration of the 40th parallel examined a belt of country nearly 100 miles wide, and the geologists attached to the expedition brought in large collections of volcanic rocks and gathered many data as to their mode of occurrence and geological relations, the results of which will be found in the published reports and maps of the exploration. In volume vi of these publications Professor Zirkel* presented the results of his investigation and determination of the crystalline rocks based upon an examination under the microscope of many hundred thin sections.

One result of this work has been to give a great impetus to the study of microscopic petrography both in this country and in England. Since the publication of Zirkel's work microscopic petrography has made rapid strides, new methods have been introduced and many errors pointed out. Perhaps the

* Microscopical Petrography, Washington. 1876.

most important advance made lies in the direction of more accurate methods for determining the species of feldspars.

Investigations in recent years have shown that many feldspars formerly regarded as sanidin really belong to one or more species of triclinic forms. This is noticeably the case with the rocks of Hungary and the volcanic islands of the Mediterranean, like Santorin. In consequence many lavas formerly determined as trachytes are now more properly referred to andesites. Again, since Zirkel's work a large number of new thin sections have been prepared from the rocks not heretofore examined in the collection of the Fortieth Parallel Exploration and considerable new material has been gathered from the many mining districts scattered throughout the Great Basin. The Washoe and Eureka districts, the two most important mining regions in Nevada, localities rich in the variety of their volcanic extrusions, have been studied with care and the results greatly increase our knowledge of the volcanic phenomena of the region.

For these reasons the writers of the present article have for some time been engaged in reviewing the Tertiary and Post-Tertiary igneous rocks of the Great Basin and hope before many months to submit their report for publication to the Director of the United States Geological Survey.

Zirkel classified the volcanic rocks of the region under the following heads: propylite, andesite, augite-andesite, dacite, trachyte, rhyolite and basalt, a classification adopted by the geologists of the Fortieth Parallel Exploration, they only differing from him in certain specific determinations.

Propylite.—Recently Mr. George F. Becker* in his work on the Washoe District made a thorough investigation of the so-called propylite and as a result denied the independence of the rock-species. His method of work and conclusions are given so fully that it is unnecessary to enter upon the subject here, except to say that we quite agree with him, so far as the non-existence of propylite as a distinct rock-species in the Great Basin is concerned.

Trachyte.—It will be readily admitted that in a classification of volcanic rocks based primarily upon the prevailing feldspar present it is a most serious error if the feldspars are wrongly determined. This is just the error that Zirkel was constantly committing in the work above quoted, and throughout his report he describes the feldspars in certain rocks as sanidin, when careful observations show in the light of the present day that they belong to one or more species of triclinic forms.

We find after long and searching investigation of the rocks from the Great Basin, so far at least as they have come under

* Geology of the Comstock Lode, Washington, 1882.

our observation, that there are none which can be classed as trachytes,—using the term, of course, in the strict sense in which it is now employed by most petrographers and probably by all who make use of the microscope in the determination of crystalline rocks. A trachyte is that variety of volcanic rock in which the predominating feldspar is orthoclase, but which is so low in silica as to be free from secretions of quartz if fully crystallized. This definition agrees with that of both Zirkel* and Rosenbusch,† "a Tertiary or Post-Tertiary quartzless orthoclase rock."

Now none of the rocks described as trachytes by Zirkel from the Great Basin contain any appreciable sanidin. They are all plagioclase rocks. Of the feldspars in the thin sections studied by Zirkel, nearly all show more or less striation. There occur many, however, in which the lamellæ do not traverse the entire crystal, reaching only a quarter or one half the way, and others in which only a single narrow stripe can be detected. It was formerly considered that any feldspar which did not show lines of striation was orthoclase, and so strongly had this idea intrenched itself in the mind, that those feldspars whose thin sections showed twinned lamellæ only at one end were thought possibly to be orthoclase containing lamellæ of a triclinic feldspar, as suggested by Zirkel.‡

The application of optical tests to the feldspars of these so-called trachytes and questionable rocks of the Great Basin leaves no doubt as to their true nature. Simple Carlsbad twins when cut so as to give symmetrical extinction angles or good cleavage, prove to be quite basic plagioclase; indeed a scarcity or even a total absence of polysynthetic lamellæ is rather characteristic of the smaller sized porphyritic feldspars, the striations of the larger ones being usually so well developed as to be noticed in the hand specimen upon careful search with a pocket lens.

Chemistry fully confirms these optical determinations. This is well shown in the analytical work of the late Dr. George W. Hawes upon the "trachyte" of Mt. Rose, Washoe, Nevada, the results of which are published in detail in Mr. Becker's § recent report.

Similiar results have been obtained by us from the "trachyte" of the Wahsatch Range, from characteristic rock of Eureka, Nevada, and from the volcanoes of the Pacific Coast.‖

In these cases the feldspars were isolated by the Thoulet

* F. Zirkel, Mikroskopische Beschaffenheit, 1873, p. 290. F. Zirkel, Exploration of the Fortieth Parallel, vol. vi, 1876, p. 6.

† H. Rosenbusch, Mikroskopische Physiographie, 1877, vol. ii, p. 179.

‡ Mikroskopische Beschaffenheit, p. 134.

§ Geology of the Comstock Lode, p. 67.

‖ Notes on the Volcanoes of California, Oregon and Washington Territory, this Jour., Sept., 1883.

solution of the double iodide of mercury and potassium and were found upon analysis to be andesine or oligoclase. Again, in examining the feldspars in these so-called trachytes application was made of Dr. Szabó's method of determining feldspar in rocks by means of the color imparted to the flame of a Bunsen burner with most satisfactory results, the feldspars giving the reactions for andesine and oligoclase, and confirming the optical and chemical determinations.

The normal trachytes of Zirkel mainly resolve themselves into hornblende-mica-andesites; the augite-trachytes into hypersthene-augite-andesite, and most of those that remain should be classed as dacites, while a few fine-grained earthy rocks more properly belong to rhyolites.

Among the localities in the Great Basin which are frequently mentioned as affording fine exposures of trachyte is the Snake River Cañon, but the specimens which we have examined from near Shoshone Falls are clearly plagioclase rocks, although they possess many of the superficial aspects which formerly were regarded as characteristic of trachytes, or orthoclase rocks. In all probability the great sheets of acidic lava that underlie the basalts of the Snake Plains are andesitic.

Investigation having demonstrated the non-existence of propylite and trachyte in the Great Basin we classify all the volcanic rocks of the region under the following types, arranging them for the purposes of the present paper according to their basicity rather than according to their geological relations: basalt, pyroxene-andesite, hornblende andesite, hornblende-mica-andesite, dacite and rhyolite. Within the limits of the present article it is only designed to point out some of the more important mineralogical and structural features, leaving all questions of their mode of occurrence, order of succession and chemical relations till the final report.

Basalt.—These rocks may be divided into two general types: (*a*) the porphyritic, consisting of a glassy and microlitic or microcrystalline groundmass, bearing relatively large crystals of olivine, feldspar, and occasionally augite, a structure showing close relations to that of many andesites; (*b*) the granular (granular in the sense used by Rosenbusch,*) an aggregate of quite uniform grains composed of well-developed plagioclase and olivine crystals with ill-defined patches of augite and magnetite, and frequently with considerable glass base.

The porphyritic variety is the type most frequently observed in the collection of the Fortieth Parallel Exploration and is probably by far the most abundant in the Great Basin. It is well described by Zirkel in his report. It is not, however, always holocrystalline, often carrying considerable glass base.

* Neues Jahrbuch für Mineralogie, etc., 1882, Band 2.

In this variety of basalt there is great variation not only in the relation of groundmass to porphyritic crystals but also in the size of individual crystals. No sanidins could be detected. In some basalts the larger secretions are confined to olivine, in others to small feldspars, with olivine in minute grains, while augite only occurs occasionally among the larger crystals, and only in exceptional cases are all three minerals found associated together as porphyritic secretions.

Other varieties show less and less olivine, and with the gradual increase of silica and the coming in of more and more hypersthene, rocks occur intermediate between normal olivine basalts and those with the typical andesitic composition and structure. The granular variety of basalt occurs far less frequently than the porphyritic, but is well shown in the structure of the rock which forms the top of the lava plain at Shoshone Falls, and there is reason to believe is well developed on the great table-land of the Snake Plains.

Pyroxene-andesite.—For the purposes of the present paper this provisional designation may be used to include both hypersthene-andesite and hypersthene-augite-andesite, two varieties of andesitic rocks not always easily distinguished. Whether there are any extrusions in the Great Basin which should be classed as augite-andesite is a matter of some doubt, and presents a question which can only be answered by the investigation of similar rocks in various quarters of the globe, and by lithologists coming to some conclusion as to where the line should be drawn. It is quite certain that characteristic augite-andesites have not been observed in this region. There are no augite plagioclase rocks free from olivine found here which are not characterized by either hypersthene or hornblende. Under the head of augite-andesite, Zirkel has described a number of typical hypersthene-andesites. They are porphyritic rocks having a groundmass for the most part glassy with the "felt-like" structure formed of innumerable feldspar and pryoxene microlites and magnetite grains, through which are scattered microscopical crystals of plagioclase, hypersthene and augite. Occasionally the rock occurs holocrystalline.

Until recently hypersthene has only in very exceptional cases been recognized as an ingredient in andesitic rocks, and not till Mr. Whitman Cross* published his description of the rock from Buffalo Peaks, Colorado, was the variety hypersthene-andesite generally admitted by lithologists.† Since his publication the present writers‡ have shown not only the wide-spread occurrence of this rock for several hundred miles along

* Bulletin of the U. S. Geological Survey, No. 1, 1883.

† Niedzwiedzki described a hypersthene-andesite from St. Egidi in South-Steiermark in 1872. Tschermak's Mineralogische Mittheilungen, 1872, iv, p. 253.

‡ This Journal, Sept., 1883.

the line of Pacific Coast volcanoes, but that all the pyroxene-andesites examined by them from along this belt may be referred to hypersthene-andesite.

Over the wide area of the Great Basin hypersthene is found in nearly all varieties of volcanic rocks. Its microscopic characters are very constant and quite similar to those given for this mineral in the andesites of the volcanoes of California, Oregon and Washington Territory. It is of a light brown color in thin sections and with few exceptions strongly pleochroic, being green parallel to the *c* axis and yellowish-brown at right angles to it. The strong pleochroism, generally gray or yellow color between crossed nicols and the constant parallelism of its extinction with the direction of the *c* axis distinguish it from the accompanying augite. The hypersthene varies somewhat in the strength of its pleochroism, which, as shown by analysis, probably corresponds to a variation in its chemical composition. Its determination rests upon a microscopic study of the thin sections, together with optical investigations upon isolated crystals showing their orthorhombic character by always extinguishing light parallel to the vertical axis and presenting interference figures with their bisectrices normal to the pinacoidal planes. Chemical analysis upon carefully selected material abundantly confirms optical tests.

Attempts to separate hypersthene from hornblende and augite in a fine-grained rock by means of a solution of cadmium-boro-tungstate proved only partially successful. The mixed grains were easily divided into two parts, one containing all the hornblende and a little pyroxene, and the other made up of a mixture of hypersthene and augite. By repeated treatment with a solution of specific gravity 3·39, the latter residue was divided into two parts, one consisting almost wholly of hypersthene with a small amount of augite, and the other largely composed of augite but still carrying a trace of hypersthene. A careful examination under the microscope of the purest hypersthene product indicated that considerably less than one-tenth belonged to augite. An analysis by Mr. S. L. Penfield, of the Sheffield Scientific School, is given in column I. Assuming now that the relation existing between the hypersthene and augite is in the proportion of nine to one and calculating a possible composition for the two minerals, it is evident that the orthorhombic mineral carries more lime and alumina and less magnesia and iron than the hypersthene found in the pumice of Mount Shasta.* In columns II and III are given a calculated theoretical composition of the hypersthene and augite based upon Mr. Penfield's analysis of the mixture of the two minerals.

* This Journal, Sept., 1883.

	I Mixture.	II Hypersthene.	III Augite.
SiO_2	51·16	51·39	49·02
Al_2O_3	3·50	3·26	5·64
TiO_2	·73	·73	·73
FeO	15·46	16·45	6·45
MnO	·56	·56	·56
MgO	19·22	19·75	14·37
CaO	8·84	7·31	22·60
Ignition	·42	·42	·42
	99·89	99·87	99·79

Wherever the two minerals occur together, the hypersthene is seen to be of earlier crystallization than the augite, and, at the same time it undergoes decomposition much more readily, in this respect resembling olivine. When decomposition sets in a fibration starts from the surface and cracks in the crystals, and advances parallel to the vertical axis. Fibrous hornblende of light green color, or colorless in thin sections with low angle of extinction, is the ordinary alteration product, a change which is similar to the formation of uralite from augite, the minerals resulting from the two processes being indistinguishable from one another under the microscope. Hypersthene occurs in all the volcanic rocks of the Great Basin except typical olivine basalts and the most acidic rhyolites. It forms an essential ingredient in many of the hornblende-andesites, occurs sparingly in dacite and has been detected in some varieties of rhyolite, presenting almost as wide a range as augite.

Hypersthene occurs as an essential ingredient in the rocks from Washoe described as augite-andesite by Mr. George F. Becker in his recent work on the Comstock Lode.

Indeed it may be said that there is no pyroxene-andesite in the collection from this district in which hypersthene does not equal and in most cases surpass the augite in amount. It presents all stages of alteration from the fresh to the thoroughly decomposed mineral. In many thin sections the augite is perfectly fresh, accompanied by hypersthene wholly altered. It is this mingling of both hypersthene and augite in the rock which explains the otherwise strange occurrence of both fresh and wholly decomposed pyroxene in the same thin section mentioned by Mr. Becker, who in his examination of the augite-andesite failed to recognize the hypersthene. He frequently makes use of such expressions as "A portion of the augites are fresh, the remainder converted into chlorite,"* and "Some of the augites are almost unattacked and show thor-

* Geology of the Comstock Lode, p. 128.

oughly characteristic cleavages, extinctions, etc. Others are partially converted to chlorite, and yet others are wholly replaced by the uniaxial dichroitic green mineral." In the light of the present investigation it is now perfectly evident that the decomposed mineral is mainly referable to hypersthene.

The relationship already pointed out by us as existing between olivine and hypersthene in the rocks of the Pacific Coast volcanoes* holds equally good for the Great Basin, the olivine increasing and replacing the hypersthene as the rock becomes more and more basic.

Hornblende-andesite.—This rock forms a well characterized type of the volcanic rocks of the Great Basin, standing as an intermediate variety between the acidic and basic lavas, in general being more acidic than the pyroxene-andesites. Many of the rocks classed by Zirkel as simply andesites we would regard as pyroxene-andesite carrying a small amount of hornblende scattered through a groundmass of pyroxene and plagioclase, the hornblendes being too few in number to characterize the rock. Hypersthene and augite occur as the accessory minerals in the more basic varieties of hornblende-andesite, showing transitions into pyroxene-andesite, while, on the other hand, mica gradually comes in as the rock becomes more and more acidic.

Hornblende-mica-andesite.—Under this head may be classed a large number of andesitic extrusions scattered throughout the Great Basin from the Sierras to the Wahsatch in which mica occurs as a characteristic and essential ingredient. Indeed a large proportion of the rocks formerly regarded as trachytes properly fall under this division. In these rocks the feldspars have a decidedly vitreous appearance, while the texture of groundmass possesses a rough porous character presenting what is known as the "trachytic habit," but, as already shown, the entire absence of orthoclase among the porphyritic crystals prevents their being considered in any other light than as andesites. While, as already stated, sanidin is regarded by most lithologists as the prevailing feldspar found in trachytes, it should be remembered that von Richthofen recognized an "oligoclase-trachyte" in which sanidin was not even an essential ingredient; this rock agreeing with the hornblende-mica-andesites of the Great Basin.†

Dacite.—Following the development of the mica, quartz secretions begin to appear as the rock passes more and more into acidic varieties, and with the appearance of quartz, hornblende and pyroxene rapidly diminish. This gives a well-defined rock composed mainly of plagioclase, quartz and mica,

* This Journal, Sept., 1883.

† Natural System of Volcanic Rocks, San Francisco, 1867, p. 36.

with a varying amount of sanidin as an accessory ingredient. In the extent of its extrusions dacite is of less importance than either andesite or rhyolite, yet its occurrences are far more widespread than has been supposed, as many rocks heretofore regarded as acidic trachyte and rhyolite have upon investigation proved to be characterized by plagioclase instead of orthoclase. This is especially the case with many rocks of the Fortieth Parallel Exploration formerly classed as hyaline, pumiceous and glassy forms of rhyolite, but whose feldspars as shown by the microscope are unquestionably triclinic.

Rhyolite.—Notwithstanding the absence of trachyte, orthoclase rocks are by far the most abundant of all the acidic rocks of the Great Basin. Rhyolite extrusions occupy very large areas forming broad plateaus, high mountain peaks and innumerable minor outbreaks. In most localities between the Sierras and the Wahsatch, wherever volcanic activity has played an important part, rhyolite in one form or another has reached the surface. Although plagioclase crystals are well developed in varying proportions in a large number of rhyolites, orthoclase is in all cases the prevailing and characteristic feldspar. The rhyolites have been so well discussed and mapped in the reports of the Fortieth Parallel Exploration and their microscopical characters described in such great detail by Zirkel that very little need be said within the limits of this paper except to give their subdivision and to point out some of their relations to other rocks.

All the rhyolites of the Great Basin may be classified under one or the other of the following heads:

Nevadite,
Liparite,
Lithoidal Rhyolite,
Hyaline Rhyolite.

This sub-division agrees with that proposed by von Richthofen with the exception that he included both the lithoidal and hyaline varieties under one head. As many of the lithoidal rocks present a characteristic physical habit, as well as a thoroughly crystalline groundmass, it seems proper to separate them from the distinctly glassy forms, although varieties frequently occur which pass by insensible gradations from one to the other.

Nevadite.—This rock is characterized by an abundance of porphyritic crystals imbedded in a relatively small amount of groundmass. It bears a strong superficial resemblance to granite, produced, as von Richthofen says, "by the similarity of color, which is of light shades of gray and red, and by some affinity in mineral composition." This resemblance, however, does not hold in a strict lithological sense, as the nevadites possess a porphyritic and not a granitic structure, the rock varying from a holocrystalline groundmass to one rich in glass and from a dense to a porous texture. Von Richthofen's use of the expression "nevadite or granitic rhyolite," has, it seems to us, misled lithologists to infer that he referred to the internal structural habit of nevadite, and that he regarded its structure as similar to granite. Professor Zirkel slightly modifies von Richthofen's definition of nevadite* and in his chapter on rhyolites says, "The scope of this section will be confined to a description of the proper felsitic or porphyritic rhyolites, for the almost granitic rhyolites (nevadites) are wanting in the examined territories."† From that time the signification of the term nevadite has gradually changed until it has come to designate a Tertiary volcanic rock having the "rein körnig" or granular structure of granite.‡ Now such a rock has never, as yet, been recognized in Nevada and its existence anywhere is at least highly problematical. Moreover it is evident that von Richthofen comprehended the glassy nature of the rocks called by him "nevadite" as he says, speaking of the larger crystals, that, "they are enclosed in a paste which is probably a partially microcrystalline, and partially amorphic aggregation of the same ingredients."

Liparite.—This rock in distinction from nevadite is characterized by a small number of porphyritic crystals imbedded in a relatively large amount of groundmass but like nevadite may occur in a holocrystalline condition as well as in a glassy one. Both nevadite and liparite possess the porphyritic structure, but both varieties are so characteristic of Nevada, with such distinct lithological features and rarely if ever occur together that it seems desirable to retain at least for the Great Basin the classification as first suggested by von Richthofen.§

Between rhyolite and dacite, as might be supposed, there exist many rocks upon which opinions might justly differ as to which class they should properly be referred. Such instances are, however, no more frequent than the transitions between basalt and hypersthene-andesite, between hornblende- and pyroxene-andesite, or any two closely allied species. Indeed, where the conditions for the developement of sanidin seem favorable it usually comes in strong force; the change from plagioclase to orthoclase being in many cases quite marked.

* Microscopical Petrography, p. 8. † Ibid, p. 8.

‡ H. Rosenbusch, Neues Jahrbuch für Mineralogie, 1882, vol. ii.

§ It seemed necessary to enter somewhat fully into an explanation as to the position of nevadite, partly because its exact relations to other volcanic lavas has, in our opinion, been misunderstood, and partly because in the paper on the "Volcanoes of California, Oregon, and Washington Territory" we pointed out that the rock from Lassens Peak mentioned by von Richthofen as a typical nevadite, was not an orthoclase rock, consequently not to be classed with the nevadites of the Great Basin which form such characteristic extrusions in the state of Nevada.

Again the distinction between dacite and rhyolite is somewhat sharply drawn by a large development of biotite in the dacites, whereas as soon as the sanidin makes its appearance as the predominant feldspar mica loses its prominence, and in most rhyolites of the Basin, although there exist a few marked exceptions, mica plays a very subordinate part.

It might seem natural to suppose that where the basic rocks are largely characterized by anorthite and labradorite, the intermediate rocks by andesine and oligoclase, and the acidic varieties by orthoclase, that the trachytes would be represented by at least some minor extrusions. Investigation, however, shows that the typical trachyte known to occur in other parts of the world has never been brought in from this region. Over this wide area with its great variety of volcanic rocks sanidin only makes its appearance after quartz has come in as an essential constituent among the porphyritic crystals. It may be laid down as a general law for the Great Basin that there is among the volcanic lavas no quartzless variety of orthoclase rocks.

In geological reports descriptive of volcanic areas we frequently meet with the statement that the rocks are made up of "andesites and trachytes" or "trachytes and rhyolites." It seems to us that in future such expressions should be more carefully considered, it having been shown that at least in the Great Basin such an association of lavas is unknown.

Our work leads us to believe that trachytes occupy a far more restricted position among volcanic rocks than has heretofore generally been supposed. The independence of rhyolite and trachyte from a geological point of view seems quite clear, for in regions of widespread volcanic activity it is far more frequently associated with andesitic than with trachytic eruptions.

ART. LIV.—*Transition from the Copper-bearing Series to the Potsdam;* by L. C. WOOSTER.

DURING the summer of 1883, some facts throwing light upon the relationship existing between these formations along the St. Croix River, Wisconsin, fell under my observation, and, though not new in kind,* they may be of interest to those who are endeavoring to find in the East a correlative of the Wisconsin Potsdam.

In northwestern Wisconsin the Potsdam sandstone has a total thickness, from the Laurentian granite below to the Lower Magnesian limestone above, of about one thousand feet. There are two horizons in which fossiliferous remains are especially

* See vols. i, and iii, Wisconsin Geological Reports.

abundant, viz: (1) the middle of the formation, and (2) the middle of the upper third.

At Osceola Mills, about four miles from the southernmost outcrop of the Copper-bearing or Keweenawan Series, the second of these two horizons is found at an elevation of about 100 feet above the level of St. Croix River, and presents a somewhat peculiar though characteristic fauna. Some of these layers are exceedingly porous and friable, and yet they contain casts of *Holopea Sweeti* and a Bellerophon in great abundance. Were it not for the Potsdam trilobites and brachiopods in these same layers, one might well imagine that he was gazing upon a *Trenton* sandstone. But, a few feet below these layers all evidence of life ceases and one looks in vain for a fossil down to the water's edge. While closely examining these lower layers at Osceola, I was greatly interested in the discovery of several pebbles in the sandstone evidently derived from the Keweenawan series at the northward. The sandstone here became variable in color and hardness, being on the whole darker and in certain places exceedingly compact, or as Capt. Knapp expressed it, baked. But no fusion or evidence of heat from steam-holes was present.

The government force engaged in building dams on the St. Croix under the supervision of Capt. Knapp had, the previous winter, dug into a most curious deposit on the Minnesota side of the river, about four miles north of Osceola and near the outlying outcrops of Copper-bearing rock. Under the guidance of Capt. Knapp, the locality was visited late one afternoon, and the "most curious deposit" was found to consist of "trap" conglomerate. The conglomerate composed a ridge which stretched to the westward from the river bank to the bordering ledge of sandstone one-fourth of a mile back. The river end of the ridge is about fifty feet in height and one hundred feet in breadth at its base. The component bowlders, bowlderets and pebbles of the conglomerate varied in size from those at the base of the exposure thirty inches in diameter to the finely comminuted material at the top where the rock might with propriety be called sandstone. All the bowlders were highly altered, so that Capt. Knapp could see little resemblance between them and the hard, resistant and apparently unchanging "trap" bowlders and ledges with which he was familiar. But after much search a bowlder was found near the base of the exposure with an *unchanged* center of "trap." The matrix of this conglomerate consisted of the same material as the imbedded bowlders. Here and there in all parts of the exposure this matrix contained fragments of linguloid shells, apparently *Lingulepis pinniformis*. Many cavities in the matrix and in the bowlders were lined with quartz crystals. Not the slightest evidence of heat was discovered, all the alterations being evidently the work of infiltrating waters continued through countless ages.

Conclusions: 1. The material of this conglomerate, all being more or less rounded, and the shells, being without exception fragmental, must have been subjected to violent wave action along cliffs of Copper-bearing rock at this exposed point of the ancient (not to say Archæan) island. 2. There was some evidence to show that this fifty feet in depth of conglomerate not only graduates into sandstone above, but also on each side. Hence the ridge may mark the mouth of a primordial mountain torrent. 3. The age of the deposit seen must be late Potsdam since it graduates into sandstone of that age.

4. This conglomerate is not exceptional, since the Potsdam is conglomeritic along its shore margin in Wisconsin, and on the St. Lawrence River in New York (as seen by the writer). This conglomerate is well shown in the vicinity of Laurentian granite at Chippewa Falls and Eau Claire, Wisconsin, and near Oak Point eighteen miles above Ogdensburg, New York. Hence the Keweenawan or Copper-bearing rocks were subjected to the same erosive and denuding agency, whatever that may have been, which broke off and transported to the sea-shore portions of Laurentian and Huronian ledges. In Wisconsin, only the lower layers of the Potsdam may, at the present time, be seen in contact with the Laurentian and Huronian rocks, except around the islands of quartzite and quartz-porphyry in southeastern Wisconsin. Here the conglomerate is uniformly present and presents phenomena analogous to that just described on the St. Croix above Osceola. 5. The Keweenawan series is older than, unconformable with, and has supplied much of the material for, the Potsdam sandstone.

These conglomerates bordering the Laurentian, Huronian and Keweenawan areas must have supplied a large part of the bowlders of the drift deposits of the Northern States.

ART. LV.—*On the Expression of Electrical Resistance in Terms of a Velocity*; by FRANCIS E. NIPHER.*

IF a spherical shell of radius r be charged with Q units of electricity, the density of electrification being ρ, the force dF over any element ds of its surface will be $2\pi\rho^2 ds$. This force is directed radially outward, and is due to the action of the electrification Q on the quantity ρds upon the element.

If the radius r be diminished to r', the energy of the electrification will increase if Q remains constant, this increase

* From Trans. Acad. Science of St. Louis. Read March 17th, 1884.

in energy being due to work done on the sphere by some external source, causing the sphere to collapse. If the element ds sweeps through a distance dr, the stored energy will be

$$dE = dF\,dr \tag{1}$$

in which both dF and dr are essentially negative.

Substituting in (1) the above value of dF and remembering

that $$\rho = \frac{Q}{4\pi r^2}$$

and $$ds = r^2 d\omega,$$

where $d\omega$ is the solid angle subtended by the element ds, we

have $$dE = \frac{Q^2}{8\pi}\frac{dr}{r^2}\,d\omega,$$

or $$E' - E = \frac{Q^2}{8\pi}\iint\frac{dr}{r^2}\,d\omega,$$

where one integration is carried over the surface of the sphere, and the other is carried inward between the limits r and r'. Performing the integrations, we have

$$E' - E = \frac{Q^2}{2}\left(\frac{1}{r'} - \frac{1}{r}\right) \tag{2}$$

But $\frac{1}{2}\frac{Q^2}{r'}$ is the energy of a sphere of radius r', charged with Q units of electricity, and hence the potential of the sphere on itself between the limits r and r' is equal to the difference in its initial and final energy.

If the sphere were connected with the ground by a wire of resistance (R), the radius (r) might be changed in such a manner as to preserve the potential (V) constant. In this case a current of constant intensity would flow through the wire, and as $V = \frac{Q}{r}$ it is clear that r must change at a uniform rate, or

$$\frac{r - r'}{v} = t' - t \tag{3}$$

where $t' - t$ is the duration of the operation. Further,

$$V = \frac{Q}{r} = \frac{4\pi r^2 \rho}{r} = 4\pi r\rho$$

and $$\rho = \frac{V}{4\pi r};$$

hence $$dE = dF\,dr = 2\pi\,\rho^2\,ds\,dr = \frac{V^2}{8\pi}dr\,d\omega,$$

or $$E-E' = \frac{V^2}{8\pi}\iint dr\, d\omega = \frac{V^2}{2}(r-r') \tag{4}$$

This is the stored energy during the operation. But the energy of the electrification at first was $\frac{1}{2}rV^2$, and at the end is $\frac{1}{2}r'V^2$, so that there has nevertheless been a diminution of energy

of $$E-E' = \frac{V^2}{2}(r-r') \tag{5}$$

It appears that, under conditions of our experiment, the sphere has less energy at the close of the experiment than at the beginning by a quantity $\frac{V^2}{2}(r-r')$, while the equal energy represented by the potential of the electrification on itself was added. The total energy lost by the shell was, therefore,

$$E = V^2(r-r') \tag{6}$$

The current in the wire was, by Ohm's law,

$$C = \frac{dQ}{dt} = \frac{V}{R};$$

hence $$Q-Q' = \frac{V}{R}(t'-t),$$

and hence the energy of the current during the operation was

$$E = \frac{V^2}{R}(t'-t),$$

or by (3), $$E = \frac{V^2}{R}\frac{r-r'}{v} \tag{7}$$

The expressions (6) and (7) must be equal to each other, and

hence $$Rv = 1, \quad \text{or} \quad R = \frac{1}{v},$$

where v is the constant velocity of each point in the surface of the shell during the operation. This problem is well known, and a solution of it is given in Mascart and Joubert's treatise. The above solution is new to the writer, and embraces some features of interest.

ART. LVI.—*Lateral Astronomical Refraction;* by J. M. SCHAEBERLE.

IN astronomical investigations where an extreme limit of precision is sought, systematic errors are frequently recognized, which, for want of any other apparent cause, are usually attributed either to irregular variations in the constants used (as for instance, a change in the clock rate, a variable coefficient of flexure), or to a change in the personal equation of the observer. The object of this paper is to point out one more source of error by which astronomical observations are always more or less affected, and to show how, in a simple manner, the error can, in general, be eliminated.

In the theory of astronomical refraction as given by Laplace, Bessel and others, each investigator assumes that the refraction always takes place in a vertical plane, and all refraction tables in use at the present time are constructed on this hypothesis, which therefore assumes that all layers of atmosphere of the same density, over any given locality, are parallel to the horizon. That such an assumption is frequently the cause of errors, by no means insensible, which can, at most observatories, be removed by computation, will now be shown.

Let us suppose that two observers at points A and B, on the same level and separated by the short distance D, observe at the same instant, equal temperatures, the barometric pressures however being p_1 and p_2. Now in order that the pressures over the two stations shall be the same, the observer at B must ascend through the distance Δh corresponding to a decrease in the pressure p_2 equal to p_2-p_1. A line drawn from A to the elevated station will then be the line of equal pressure, and the inclination of this line to the horizon will equal $\tan^{-1}\frac{\Delta h}{D}$ which, since this angle will always be small, can be placed equal to $\frac{\Delta h}{D}$.

As the differences between the refractions computed for inclined and for horizontal strata will always be very small, an error in the assumed law of refraction will have little or no effect on these differences; terms of the second order becoming sensible only at great zenith distances. The familiar expression

$$r=a \tan z$$

giving nearly the observed mean refractions, and nearly corresponding to the refractions that would be produced by a homogeneous atmosphere 5·12 miles high, having an index of refraction $m=1·00028$, can for the present purpose be assumed to represent the observed mean refractions.

Let $\frac{\Delta h}{D}$ be the inclination of the plane of equal density to the horizon, and let ψ be the angle which a vertical plane, perpendicular to the line of intersection of the inclined and horizontal planes, makes with the meridian, reckoned from the south point toward the west through 360°; the angle ψ always being in that quadrant in which the prêssure is greatest.

Now a ray of light from a star lying in the plane whose azimuth is ψ, and making with the normal to the horizontal plane the angle ζ, will make the angle $\zeta+\frac{\Delta h}{D}$ with a normal to the inclined plane. For a homogeneous atmosphere the refractions for the first and second cases would then be given by the equations

$$\sin z=\frac{m}{\sin\zeta} \quad \text{and} \quad \sin z'=\frac{m}{\sin\left(\zeta+\frac{\Delta h}{D}\right)}$$

$$r=\zeta-z \qquad\qquad r'=\zeta+\frac{\Delta h}{D}-z'$$

or

$$r=a\tan z \qquad\qquad r'=a\tan\left(z-\frac{\Delta h}{D}\right) \text{ very nearly.}$$

The error in the computed refraction due to the inclination of the strata will therefore be

$$\Delta r=a\left(\tan z-\tan\left(z-\frac{\Delta h}{D}\right)\right)$$

which, if we neglect terms of the second order, can be written

$$\Delta r=a\frac{\Delta h}{D}\sec^2 z.$$

The refraction Δr will moreover be wholly in zenith distance, and all rays, lying in the vertical plane whose azimuth is Ψ, will be refracted in a vertical plane. If Ψ'' denotes the angle which any other vertical plane makes with the meridian, all rays of light in this plane will, after refraction, lie in a plane which is inclined to the horizon by the angle

$$90°-a\frac{\Delta h}{D}\sin(\Psi-\Psi'')$$

The vertical and lateral components of refraction due to the inclination will then be respectively

$$a\frac{\Delta h}{D}\sec^2 z\cos(\Psi'-\Psi'') \quad \text{and} \quad a\frac{\Delta h}{D}\cos z\sin(\Psi-\Psi'').$$

The second expression giving, for the zenith distance z, the angular distance of a star from the vertical circle in which it actually lies, while the first expression gives the displacement in zenith distance.

As the corrections resulting from the introduction of the term $\frac{\Delta h}{D}$ would only be applied to observations made with the best instruments, we need but deduce the formulæ, and tables for the corrections to meridian observations. In other words the corrections to the observed times of meridian transit, and to the reduced zenith distances. Let Δa and Δz denote these corrections, then we evidently have, since $\Psi''=0$

$$\Delta \alpha = \frac{a}{15}\ \frac{\Delta h}{D} \cos z \sin \Psi \sec \delta$$

$$\Delta z = a\frac{\Delta h}{D} \sec^2 z \cos \Psi.$$

Thus far we have assumed the temperature to be constant; as however this is not the case, the above values will be largely in error unless similar terms allowing for the change in temperature are included in the expressions for Δa and Δz.

According to Bessel the coefficient of expansion of atmospheric air is $e=0{\cdot}002$ (nearly) for each degree Fahrenheit. Now, if at two stations, on the same level (separated by the distance D), p_1 and p_2 are the simultaneous pressures when the corresponding temperatures are τ_1 and τ_2, the refraction at the second station expressed in terms of the refraction at the first station will be given by the equation*

$$r_2 = r_1\left(\frac{1}{1+\varepsilon(\tau_2-\tau_1)}\ \frac{p_2}{p_1}\right).$$

For, the values of r_1 and r_2, for temperatures and pressures different from the assumed normal values, will be in error by practically the same amount, and as we have only to deal with the differences in the refractions at the two stations, the results obtained will not, in general, be sensibly in error. The last equation, if we neglect small quantities, can be put into the following form:

$$r_2 - r_1 = a\left(\varepsilon(\tau_1-\tau_2) + \frac{p_2-p_1}{p_0}\right) \tan z.$$

p_0 being the assumed normal height of the barometric column, which in Bessel's refrection tables is taken at 29·6 inch, while his value of a is 57″·75 for $z=0$, varying (at first slowly) to 55″·75 for $z=80°$. By equating the barometric and thermometric terms we find $p_2-p_1=-0{\cdot}059$ inch $(\tau_2-\tau_1)$. An increase of 10° in the temperature therefore produces nearly the same change in the refraction, as does a decrease of 0·59 inch in the pressure.

* See Chauvenet's Spherical and Practical Astronomy, vol. i, p. 160.

Now the term r_2-r_1 being due to the difference in the density of the atmosphere at the two stations, the layers of the same density will not be parallel to the horizon. The equivalent inclination of the layers of equal pressure, for a uniform temperature, will depend upon the term $\frac{p_2-p_1}{p_0}=\Delta h$, while the inclination of the layers of equal density, for a uniform pressure, will depend upon the term $\varepsilon(\tau_1-\tau_2)=\Delta h'$. These layers will not necessarily be inclined in the same direction.

The tri-daily weather maps of the U. S. Signal Service, will generally furnish all the necessary data for finding the amount and direction of inclination for points in the United States.

Let D denote the length of the shortest line that can be drawn, on the map (through the point of observation) connecting two isobars, one being on each side of the station, and let Ψ denote the angle which this line makes with the meridian, reckoned from the south point toward the west through 360°. Let the similar data for two isotherms be D′ and Ψ'; the angles being in the quadrants of greater pressure and temperature respectively. The component inclinations in the prime vertical and meridian planes will then be respectively,

$$\frac{\Delta h}{\mathrm{D}}\sin\Psi,\quad \frac{\Delta h'}{\mathrm{D}'}\sin\Psi',\quad \text{and}\quad \frac{\Delta h}{\mathrm{D}}\cos\Psi,\quad \frac{\Delta h'}{\mathrm{D}'}\cos\Psi'.$$

Hence the complete expressions for $\Delta\alpha$ and Δz will become

$$\Delta\alpha=\frac{a}{15}\left(\frac{\Delta h}{\mathrm{D}}\sin\Psi+\frac{\Delta h'}{\mathrm{D}'}\sin(180°+\Psi')\right)\cos z\sec\delta$$

$$\Delta z=a\left(\frac{\Delta h}{\mathrm{D}}\cos\Psi+\frac{\Delta h'}{\mathrm{D}'}\cos(180°+\Psi')\right)\sec^2 z.$$

If D and D′ are expressed in miles, Δh and $\Delta h'$ must also be expressed in the same unit. As the adjacent lines on the maps differ by 0·10 inch for the isobars, and by 10° F. for the isotherms, we have*

$$\Delta h=\frac{0{\cdot}10}{29{\cdot}6}\,5{\cdot}12 \qquad \Delta h'=\frac{0{\cdot}59}{29{\cdot}6}\,5{\cdot}12.$$

Now let b denote the inclination of the axis of rotation of a meridian instrument, then if for b we substitute

$$b+a\left(\frac{\Delta h}{\mathrm{D}}\sin\Psi+\frac{\Delta h'}{\mathrm{D}'}\sin(180°+\Psi')\right)$$

and use this value in the reduction of the observations, the corrections to the times of transit, for meridian refraction in right ascension, will be wholly allowed for.

* If still greater accuracy is desired, the mean of the two given pressures should be used in place of 29·6.

In order to show the facility with which these corrections are applied, as well as to give a general idea of the magnitude of the corrections, the following tables are given:

I.

D' miles.	$a\frac{\Delta h'}{D'}$.	$a\frac{\Delta h}{D}$.	D miles.
10	0''·59	0''·10	10
20	·30	0·05	20
30	·20	·03	30
40	·15	·03	40
50	·12	·02	50
60	·10	·02	60
70	·08	·01	70
80	·07	·01	80
90	·07	·01	90
100	0·06	·01	100

II.

Ψ	sin.	
0°	0·00	90
10	·17	80
20	·34	70
30	·50	60
40	·64	50
50	·77	40
60	·87	30
70	·94	20
80	·98	10
90	1·00	0
	cos	Ψ

III.—*Corrections to the reduced zenith distances.*

$\Psi = 0 \qquad a\frac{\Delta h'}{D'}\sec^2 z.$

D'	z 0°	10°	20°	30°	40°	50°	60°	70°	80°
10	0''·59	0''·61	0''·67	0''·79	1''·00	1''·42	2''·35	4''·99	18''·87
20	·30	·30	·33	·39	·50	·71	1·17	2·50	9·43
30	·20	·20	·22	·26	·33	·47	·78	1·66	6·29
40	·15	·15	·17	·20	·25	·36	·59	1·25	4·72
50	·12	·12	·13	·16	·10	·28	·47	1·00	3·77
60	·10	·10	·11	·13	·17	·24	·39	·83	3·14
70	·08	·09	·10	·11	·14	·20	·34	·71	2·69
80	·07	·08	·08	·10	·13	·18	·29	·62	2·38
90	·07	·07	·07	·09	·11	·16	·26	·56	2·10
100	·06	·06	·07	·08	·10	·14	·25	·50	1·89

$\Psi = 0 \qquad a\frac{\Delta h}{D}\sec^2 z.$

D	z 0°	10°	20°	30°	40°	50°	60°	70°	80°
10	0''·10	0''·10	0''·11	0''·13	0''·17	0''·24	0''·40	0''·85	3·20
20	·05	·05	·06	·07	·08	·12	·20	·42	1·60
30	·03	·03	·04	·04	·06	.08	·13	·28	1·07
40	·02	·02	·03	·03	·04	·06	·10	·21	·80
50	·02	·02	·02	·03	·03	·05	·08	·17	·64
60	·02	·02	·02	·02	·03	·04	·07	·14	·53
70	·01	·01	·02	·02	·02	·03	·06	·12	·46
80	·01	·01	·01	·02	·02	·03	·05	·11	·40
90	·01	·01	·01	·01	·02	·03	·04	·09	·37
100	·01	·01	·01	·01	·02	·02	·04	·08	·32

To obtain the correction to be applied to the level constant b, of the instrument, we have but to multiply the values $a\frac{\Delta h'}{D'}$ and $a\frac{\Delta h}{D}$ taken from table I, with the arguments D′ and D, by the *sines* of the angles $180°+\Psi'$ and Ψ respectively, and take the algebraic sum of the products. Similarly the quantities in table III are to be multiplied by the *cosines* of the angles $180°+\Psi'$ and Ψ respectively. For stars north of the zenith Δz must have the opposite sign from that given by the equation.

An inspection of the weather maps of the Signal Service, as published by the War Department, will show that the distance between two adjacent isobars or isotherms is frequently less than thirty miles, and at times not more than one-half of this distance. As the times of observations will not in general correspond with the times for which the maps are constructed, the values of D, Ψ and D', Ψ', can when necessary, be interpolated for the middle time of the observations and assumed to remain constant for the series. A glance at the map will at once indicate whether the corrections will be sensible or not. At an isolated station, if the hourly thermometric and barometric changes are noted, the observer can still deduce the corrections, provided he has any means for finding the veloctiy and direction of motion of the thermometric and barometric waves.

The most reliable data would of course be obtained from simultaneous observations made (while the astronomical work is going on), at three or more nearly equidistant stations on the same level and lying within a radius of fifty miles. One of these stations would be at the observatory itself.

Where the aim of an observatory is to determine *absolute* positions, an arrangement of this kind, if not indispensable, is at least most desirable.

Ann Arbor, Mich., March 18, 1884.

POSTSCRIPT.—The formulæ for finding the magnitude and direction of inclination of the strata from observations made at three stations, can be reduced to very simple forms. Let h_0 denote the height of a layer of given density at the point of observation, and let h_1 and h_2 be the heights of the layer at the stations whose azimuths are A_1 and A_2, the distances being D_1 and D_2. Let

$$\frac{h_1-h_0}{D_1}=i_1 \quad \text{and} \quad \frac{h_2-h_0}{D_2}=i_2,$$

($h_1-h_0=\Delta h$, etc. being found according to the method already given). If $\frac{\Delta h}{D}=i$ denotes the inclination of the strata to the horizon, we have, with all desirable accuracy, the equations

$$i\cos(A_1-\Psi)=i_1 \qquad i\cos(A_2-\Psi)=i_2.$$

As A_1 and A_2 are constants, let us put $\frac{A_2+A_1}{2}=A_0$ and $\frac{A_2-A_1}{2}=A'_0$; the above equations then become

$$i \cos (A_0 - \Psi) = \frac{i_2 + i_1}{2 \cos A'_0}$$

$$i \sin (A_0 - \Psi) = \frac{i_2 - i_1}{2 \sin A'_0}$$

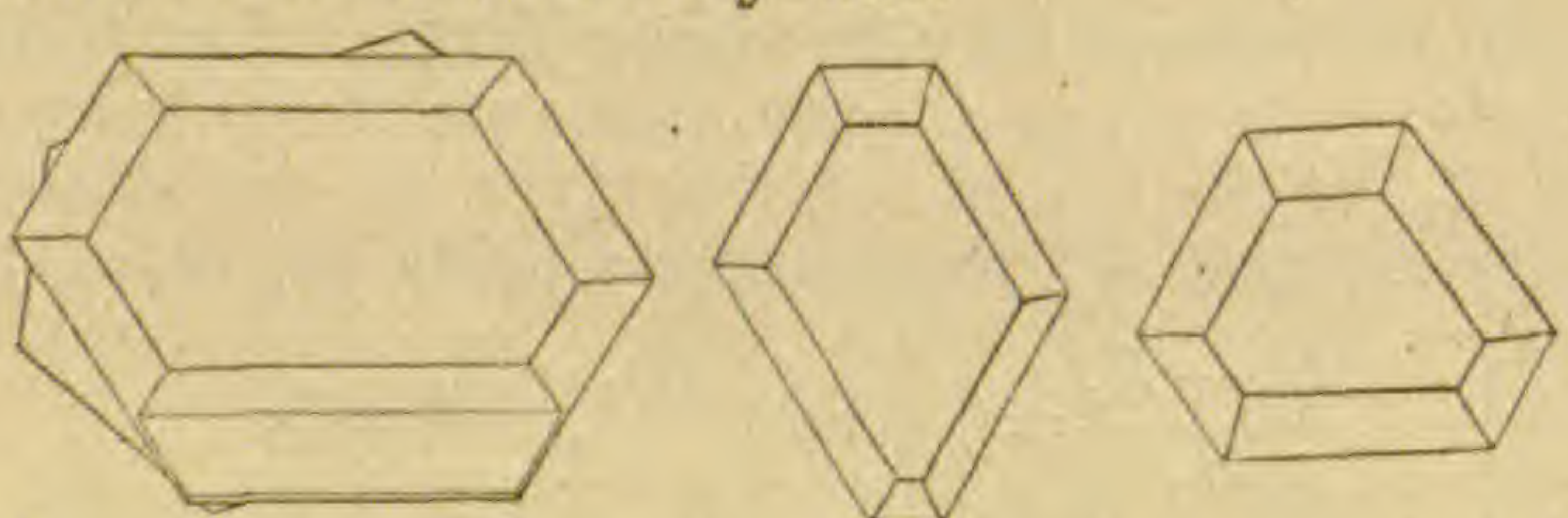
from which i and Ψ are easily found. The most favorable values of A_1 and A_2, give $A_2 - A_1 = \pm 90°$. The angle Ψ' should (in order to use the formulæ already given for $\Delta\alpha$ and Δz) be taken in the quadrant of greatest temperature; then in order that i may always be considered positive we substitute, as before, the value $180° + \Psi'$ in the equations for $\Delta\alpha$ and Δz. The argument D can be found by means of table I from the expression $ai = a\,\frac{\Delta h}{D}$.

Ann Arbor, April 12, 1884.

ART. LVII.—*Kaolinite, from Red Mountain, Colorado;* by RICHARD C. HILLS.

AT a recent meeting of the Colorado Scientific Society, Mr. Whitman Cross called attention to an interesting variety of kaolinite found by the writer in the National Belle mine at Red Mountain, Ouray County, Colorado.

The appearance of the mineral in question is that of a mass of small glistening white scales visible to the naked eye. Under the microscope these scales are resolved into remarkably perfect transparent crystals, all of which differ from those hitherto described under the head of kaolinite in the development of well-defined pyramidal planes, to the exclusion, in most instances, of those in the prismatic zone. The general form is shown in the annexed diagram, which is a camerâ lucida drawing of three of the observed crystals.



The mineral occurs in considerable quantities, associated with galena and its oxidation products, in the huge vuggs, or chambers lined with ore, found irregularly distributed through an immense mass of quartz, the latter being enclosed in a highly kaolinized rock of eruptive origin.

ART. LVIII.—*The influence of Convection on Glaciation;* by GEO. F. BECKER.

THE suggestion made by Captain Dutton,* that the increase of precipitation due to a higher sea-level temperature might conceivably be confined to regions below the isotherm of 0° C., is one of such extreme simplicity that I can scarcely believe it to have escaped the physicists and geologists who have written on glaciation. Some months since I ventured to contribute a few pages† to the discussion, which were not written, however, until I had carefully considered the possibility which my colleague has since brought forward. I arrived at the conclusion that though conceivable, it was inapplicable to terrestrial conditions; but before giving the reasons for this conclusion I beg leave to restate the problem as I understand it.

This can be done in two ways, of which the first and most usual is: Given a definite locality, the mean temperature of which is now compatible with the existence of glaciers, will an increase of temperature at sea-level tend within certain limits to increase the accumulation of ice upon it? In this form the question is one of great complexity, for it involves a knowledge of all the climatic changes which would accompany a change of sea-level temperature. A portion only of these are known with any sort of approximation, and the gaps must be filled with assumptions which every opponent is at liberty to deny.

The second method of stating the problem is as follows: If two periods of different sea-level temperature and correspondingly different permanent snow-lines are compared, which will show the greater accumulation of ice above its own snow-line under similar topographical conditions? This question, which is that to which I attempted to give an answer in my former paper, appears comparatively simple, for it does not compel any definite assumption as to the relation between elevation and temperature.

As I understand Captain Dutton, he would reply to this latter question that the accumulation in each period would be the same, the whole excess of moisture of the warmer period falling as rain below the snow-line. His statement might have been made somewhat more broadly, for the same argument shows that upon his suppositions the precipitation above any isotherm is independent of the temperature at sea-level. If, for example, the characteristic temperature at sea-level in the cooler period were 10° and in the warmer period 20°, then the entire excess of moisture evaporated during the warmer period would

* This Journal, vol. xxvii, p. 1. † This Journal, vol. xxvii, p. 167.

be precipitated below the isothermal line or surface characterized during the same period by a temperature of 10°. His suppositions are two: that the atmosphere is saturated (unless special exception is made, which is not the case in his concluding remarks), and, as the results of a calculation that the difference in the velocity of the wind in the two periods is insignificant. Granting for the sake of argument the insignificance of the difference in the velocity of the wind,* it is certain that, if the supposed complete saturation of the atmosphere would produce no essential alteration in the problem, Captain Dutton's result is immediate and inevitable; but as complete saturation represents an extreme case, it seems desirable to examine its bearing on the results.

No one of course would think of denying that the mean saturation of the whole atmosphere is never complete nor even the mean saturation of the portion of it which is in immediate contact with the sea. All know, on the contrary, that descending currents of relatively dry air constantly mingle with the moist air at the sea-level, more or less reducing its vapor contents. A similar process goes on at every level, and all must, I think, admit not only that complete saturation of any entire stratum of the atmosphere has never been observed, but that such a phenomenon cannot have taken place at least during later geological epochs. At every level above the surface of the earth the rise of air bodies, and sometimes other causes, tend to chill the air below its dew-point, while at the same time the continual admixture of drier air from higher regions tends to dilute the vapor and to keep it in the gaseous form. Precipitation therefore must be, as it certainly is, a local phenomenon induced by circumstances which favor the chilling of the air while (absolutely or relatively) retarding the intermixture of dry air with the moist. Were it not for the constant return to the surface of desiccated currents, evaporation must evidently altogether cease. On the other hand so long as precipitation takes place, air must be more or less completely desiccated and the process of distillation must continue.

More or less completely saturated air from the surface mingled with dry air from above forms a mixture, the dew point of which is considerably below the temperature of sea-level, and such a mixture may of course rise to the isothermal surface corresponding to its own dew point without precipitation. The process of admixture however is in general continuous, taking place at all levels, and it cannot be asserted of any particular molecule of vapor that it may not reach the confines of the atmosphere unprecipitated.

* It appears to me improbable that the additional energy which a warmer climate would impart to the air currents would be distributed simply among existing currents.

If a comparison is made between a warmer and cooler period, the conditions otherwise being equal, it will not be denied by any one that the lower strata of the warmer atmosphere contain a greater absolute amount of moisture than the lower strata of the cooler atmosphere, but on Captain Dutton's suppositions this excess is confined entirely to the lower strata. Suppose this condition of things to exist at a given instant. Then if the descending dry currents come into play and the tendency of the warm, moist surface air to rise is taken into consideration, it appears that a portion of this excess will be carried upward by convection and be added to the moisture of higher strata as explained in the preceding paragraphs. And though a part of this additional moisture might and probably would be precipitated at various levels, I cannot avoid the conclusion that, by the continuous admixture of dry air, a part of the excess would be carried on indefinitely, or, in other words, that the absolute humidity at every isothermal surface, or the relative humidity of the whole atmosphere, would be greater during the warmer period than during the colder one. There would indeed be a very slight, as it seems to me insignificant, counteracting tendency. The humidity of the lower strata of the air could not be increased by descending currents, because a rise of temperature and an increased capacity for moisture would attend their compression in sinking,* but rain drops from upper levels fall through warmer air than that in which they form, and there must be a minute evaporation during their passage. It seems, however, hardly possible to maintain that this addition to the moisture of the atmosphere near the surface is comparable with the contrary tendency which has been enlarged upon.

It appears quite certain therefore, that the absolute humidity at what I have called the glacial isotherm (where the tendency to the accumulation of névé is a maximum, not far from 0° C.) or, what is exactly the same thing, the mean relative humidity of the air over the glacial zone, during a warmer period, will be greater than over the corresponding but not identical glacial zone during a cooler one. Precipitation at the glacial isotherm may most naturally be supposed to be simply proportional to the mean relative humidity. It is indeed conceivable that though the mean saturation during the warmer period at this isotherm would be greater, complete saturation might be more seldom attained; but I know of nothing tending to prove such a relation. On the other hand, as I showed in my former paper, the empirical inference from observations on the diminution of temperature with altitude along mountain slopes is, that the higher the sea-level temperature the more rapid would be the decrease of temperature at the glacial isotherm, a relation

* It is of course supposed here that the sea-level temperature remains constant.

which would tend to increase precipitation at this line independently of the relative humidity; so that if the relation between relative humidity and precipitation is not simple and direct, it is probable that precipitation at the glacial isotherm increases more rapidly rather than less rapidly than the relative humidity.

I must conclude therefore, as I did before, that "the rate of decrease of temperature and the mean saturation will probably be greater in the warmer period . . . near the glacial isotherm," and indeed on the same grounds, for I prepared a passage for my former paper presenting in a more condensed form precisely the arguments here offered, but omitted it as being manifest without special mention.

The argument here presented does not include all the important factors involved in the relations of temperature to glaciation, some of the others being sketched in my previous paper. That here offered, however, may serve to show the essential part which convection plays in the distribution of precipitation.

San Francisco, Office U. S. Geological Survey, Feb., 1884.

ART. LIX.—*A New Dinicthys from the Portage Group of Western New York;* by EUGENE N. S. RINGUEBERG.

TAKING advantage of one of the pleasant days of January to make a short trip, down among the black carbonaceous shales of the Portage Group, to a fine exposure extending along the lake shore at Sturgeon Point, a projection of land about twenty miles below Buffalo, principally for the purpose of obtaining some of the Calamites found there, I was so fortunate as to obtain, besides a quantity of undetermined fish scales, the fossil here described.

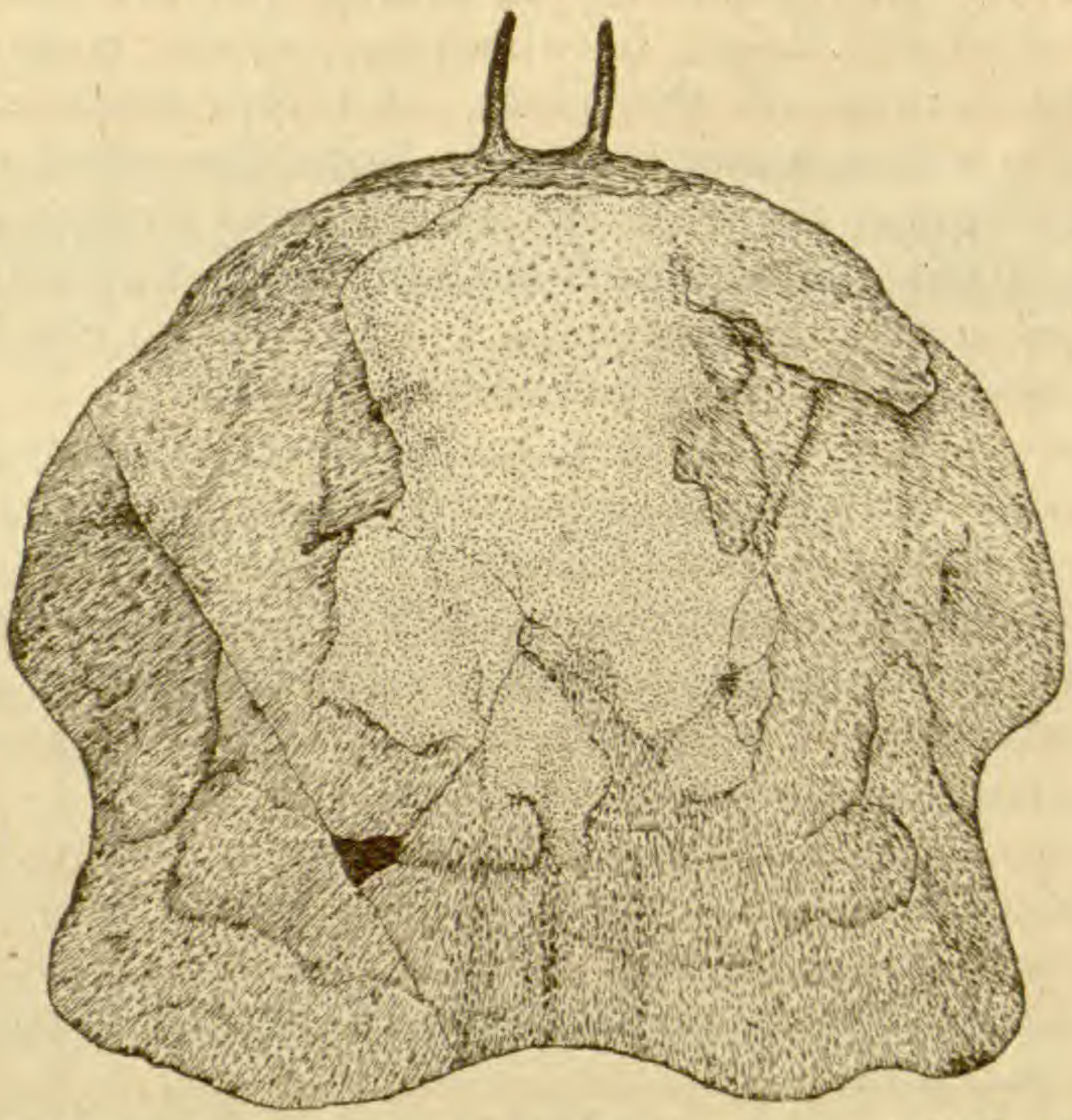
Immense placoderms of the genus *Dinicthys* have been known for quite a number of years past from the Huron shales of Ohio; but none till now have been recognized from its equivalent in this State.

The specimen found consists of a dorsal shield belonging to a *Dinicthys* which exhibits such distinctive specific variations from the two Ohio species, *D. Hertzeri* and *D. Terrelli* Newb., both in size (which is only one-fifth of that of the largest of this species), and in form, as to require a specific description.

Dinicthys minor (n. sp.)

Dorso-median shield. Surface having a fine grained rugose appearance. Plate gently arched anteriorly and gradually sloped toward the flattened posterior margin which is but slightly arched.

1.



Dinicthys minor. Dorso-median shield, dorsal surface, one-half natural size.

2.

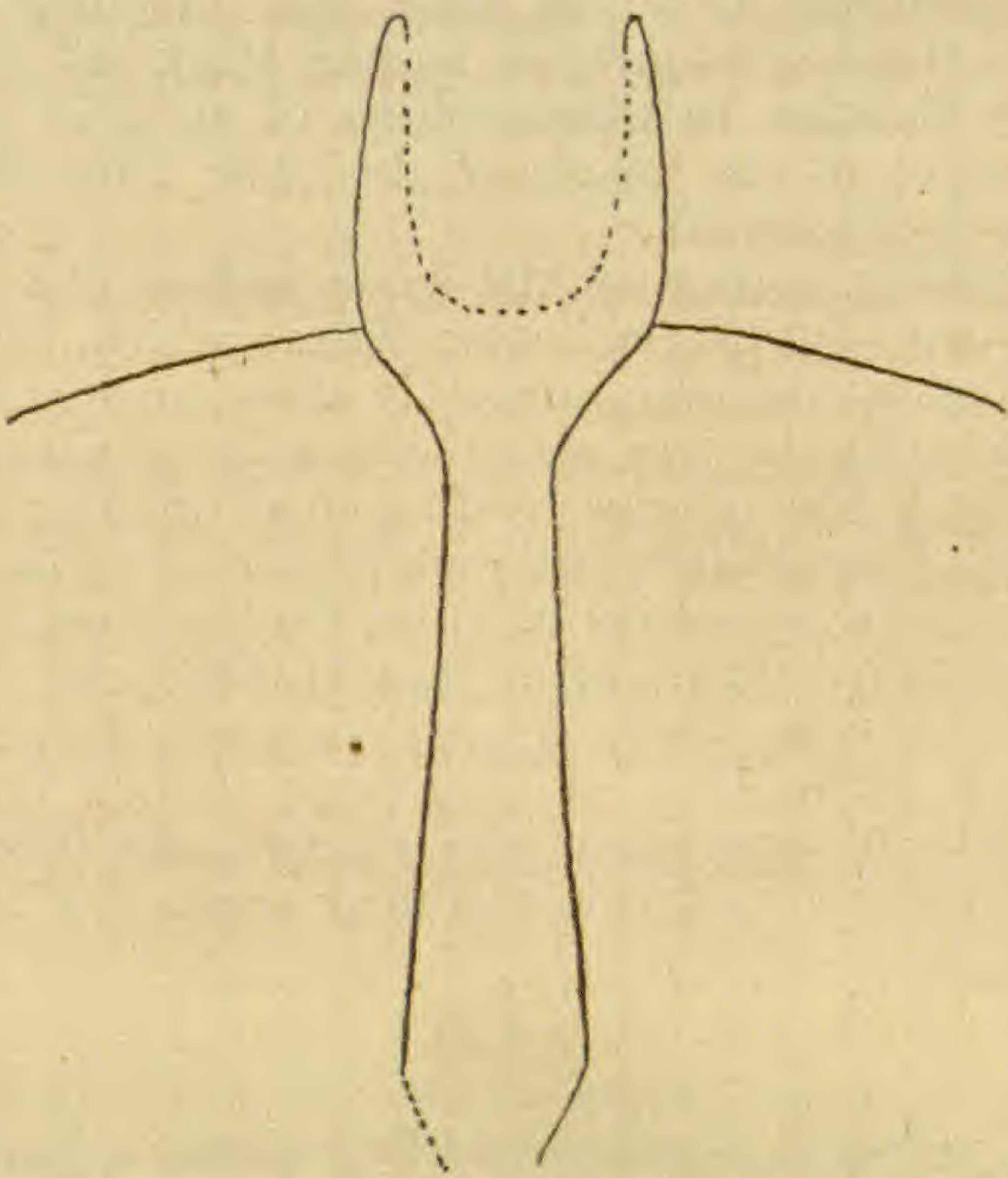


Diagram of anterior inferior surface, natural size, showing all that is exposed to view of the inferior median crest or spine, the specimen being embedded in a slab of shale.

Anterior margin describing an almost perfect semicircle of five and one-half inches in diameter, which comprises the anterior five ninths of the plate, and represents its widest extension; a slight sinus half way from the crest on either side. The highest point of the shield is on a ridge situated a little back from the anterior median margin and extends at right angles across the upper part, from which elevation the surface is beveled off toward the outer margin.

Posterior portion rather squarish, strongly sinuate; the two lateral sinuses sharply cut out nearest the forward part, where they end with a well defined angle at their junction with the anterior semicircular portion; posteriorly, curving around the sub-obtuse latero-anterior angles into the lateral posterior sinuses. Posterior margin with a wide shallow median sinus, and two smaller lateral ones.

The latero-posterior angles are placed on a line with the central portion of the median sinus, and the shield is one-half inch narrower here than at the median transverse diameter. A slight median longitudinal depression along the central portion of the lateral third.

Under side concave; divided into two lateral fossæ by a strong longitudinal spine or crest projecting anteriorly beyond the margin of the shield, where it bifurcates. It projects one-half inch downward from the plate near the anterior border where it is about one-fourth of an inch thick and from which it gradually enlarges to three-eighths of an inch at a point about one-third of the length of the plate from the border, when it rapidly tapers off.

The projecting portion of the spine widens out and bifurcates into two thin perpendicular plates; which, after passing somewhat beyond the margin rapidly slope downward and forward, terminating in two sharp points on a plane with the lower border of the inferior crest, one-half inch apart, with a projection of five-eighths of an inch beyond the plate.

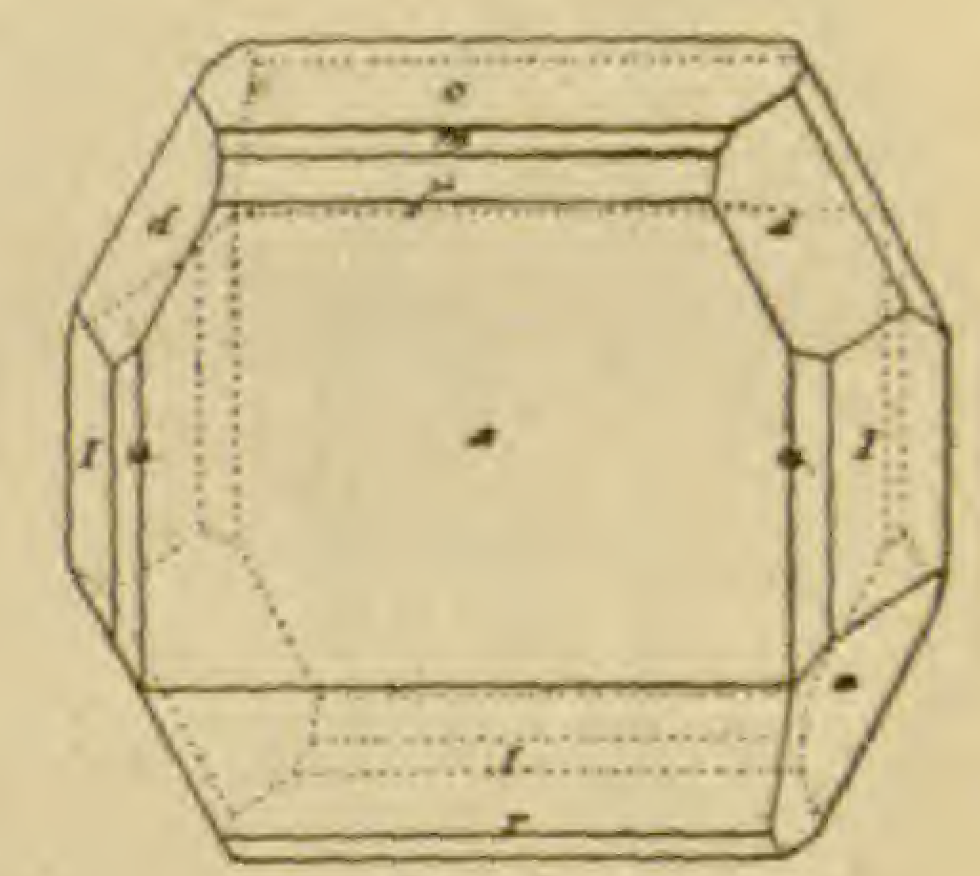
Length of plate, exclusive of spine, four and one-half inches. Median portion one-eighth of an inch in thickness. The right lateral sinus in the specimen figured is slightly deeper than the left. It must have been of large size, though but a pigmy compared with its congeners of the adjacent seas, some of which were from two to three feet across their armor-clad backs.

ART. LX.—*Mineralogical Notes*; by EDWARD S. DANA.

1. ALLANITE.

SOMEWHAT more than a year since, Professor James Hall placed in the hands of the writer a crystal of allanite for crystallographic description. This crystal was obtained from the magnetite ore bed at Moriah, Essex County, New York. This locality has in time past afforded specimens of the same mineral and sometimes of very considerable size, but the crystal in question is remarkable for this locality and the species, both in respect to size and perfection of form. The crystal is tabular in form, through the predomination of the orthopinacoid, and is in general rectangular in outline. It measures about $3\frac{3}{4}$ by $4\frac{1}{2}$ inches; the planes are smooth, their intersection lines mostly sharply defined and the entire crystal is nearly perfect and symmetrical except where the surface is penetrated by magnetite. The habit of the crystal is shown in the adjoining figure,* which is one-fourth of the natural size. The occurring planes are as follows:

i-i	(100, *a*)	−1-*i*	(101, *μ*)
O	(001, *c*)	+1-*i*	($\bar{1}$01, *r*)
I	(110, *I*)	+2-*i*	($\bar{2}$01, *l*)
i-2	(210, *u*)	1-*i*	(011, *o*)
−½-*i*	(102, *m*)	−1	(111, *d*)
		+1	($\bar{1}$11, *n*)



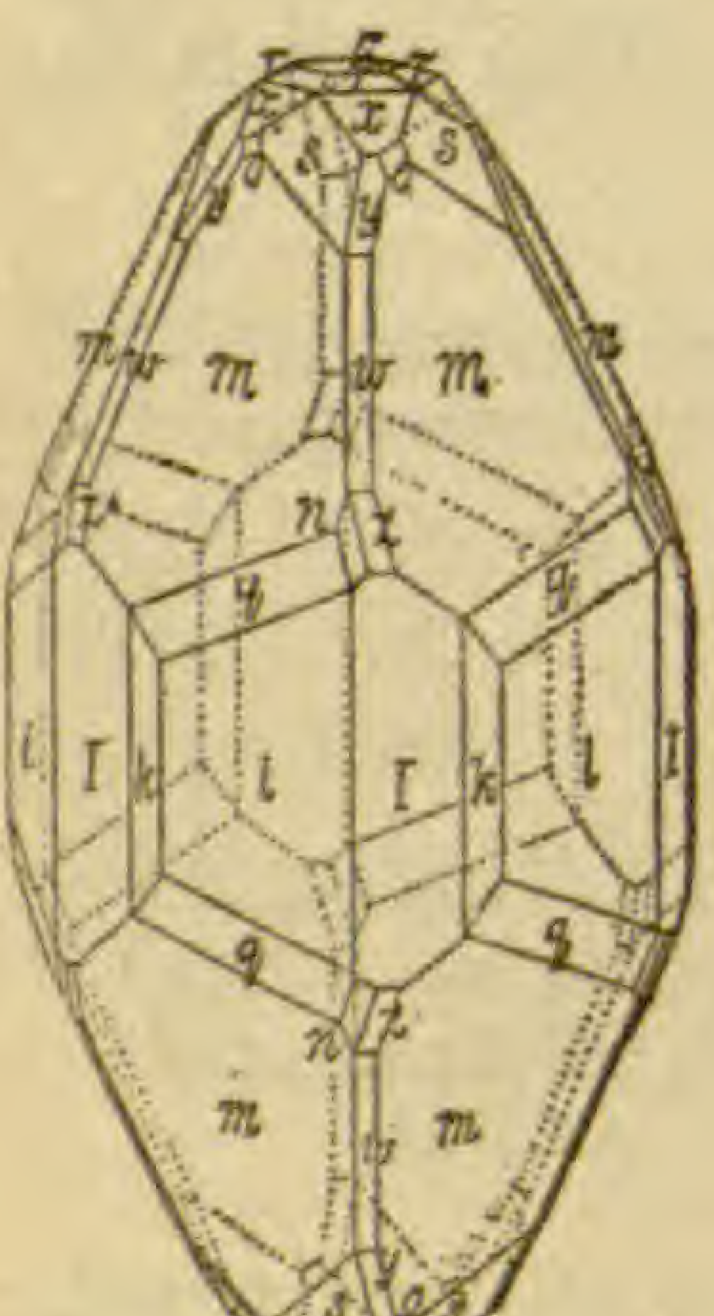
Allanite.

The position here adopted is that of Kokscharof (Min. Russl., iii, 344), and the letters are the same as his except those of the pinacoids and the unit prism: *a*=*T*, *c*=*M* and *I*=*z*. For comparison it should be stated that in the figures on p. 286, Dana's System, 5th edition, 1-*i* is the orthopinacoid, and *i-i* the basal pinacoid of Kokscharof (*a* and *c* respectively of the above figure); the position taken in Dana's System is that of Mohs. The angles on this crystal could be measured only with the contact goniometer, and hence they are not sufficiently accurate to give a basis of comparison with those obtained in more favorable circumstances; they are consequently not quoted here; in general it may be said that they agreed satisfactorily with those generally accepted for the species.

* This figure was inserted, by mistake of the printer, in a paper by the present writer on Stibnite in the number of the Journal for September, 1883 (III, xxvi, p. 217).

2. Apatite.

Several years ago the writer, through the kindness of Mr. Samuel R. Carter of Paris, Me., was able to examine a crystal of apatite of so unusual form as to deserve a special notice. The examination was completed at that time but the results are now for the first time published. The crystal was from the tourmaline locality at Paris, Me., and when received was partly coated by a film of cookeite which, however, readily scaled off, leaving the planes beneath uninjured. The crystal was small, about one-fourth of an inch in length, and had a deep blue color. The form of the crystal is given in the adjacent figure; it is remarkable both for its complexity and also because the pyramidal termination is essentially formed by a pyramid of the third order. The occurrence of these hemihedral forms on apatite is common, but they are usually subordinate, being only modifications of the predominating simple form. The pyramidal angle in this case $(21\bar{3}1 \wedge 3\bar{2}\bar{1}1)$ is 51° 37′. The planes here present are:



O	$(0001, c)$	$\frac{7}{3}$	$(70\bar{7}3, w)$*
I	$(10\bar{1}0, I)$	3	$(30\bar{3}1, z)$
i-2	$(11\bar{2}0, i)$	2-2	$(11\bar{2}1, s)$
$+\frac{1}{2}(i\text{-}\frac{5}{4})$	$(\pi 41\bar{5}0, k)$	$+(2\text{-}\frac{4}{3})$	$(\pi 31\bar{4}2, o)$
$\frac{1}{2}$	$(10\bar{1}2, r)$	$+(3\text{-}\frac{3}{2})$	$(\pi 21\bar{3}1, m)$
1	$(10\bar{1}1, x)$	$+(7\text{-}\frac{7}{4})$	$(\pi 43\bar{7}1, q)$*
2	$(20\bar{2}1, y)$	$-(4\text{-}\frac{4}{3})$	$(\pi 13\bar{4}1, n)$

Of these planes, the two marked by an asterisk are new to the species, namely $\frac{7}{3}$ (w), which was determined by the fact of its being in the zone I to O, and also in the zone between m and m $(21\bar{3}1$ and $3\bar{2}\bar{1}1)$. The form 7-$\frac{7}{4}$ (q) was determined in part by the zone i-2, 3-$\frac{3}{2}$, etc. $(11\bar{2}0, 21\bar{3}1)$, and also by the measured angle on i-2 = 11° to 12°. The planes q were uniformly rough and allowed of only approximate measurements. The calculated angles for both these forms (taking $\dot{c}=0{\cdot}734603$ as given by Kokscharof) are:

$O \wedge \frac{7}{3}$,	$0001 \wedge 70\bar{7}3$	=	63° 12′
$I \wedge \frac{7}{3}$,	$10\bar{1}0 \wedge 70\bar{7}3$	=	26 48
$O \wedge 7\text{-}\frac{7}{4}$,	$0001 \wedge 43\bar{7}1$	=	79 2
$I \wedge 7\text{-}\frac{7}{4}$,	$10\bar{1}0 \wedge 43\bar{7}1$	=	27 25
$i\text{-}2 \wedge 7\text{-}\frac{7}{4}$,	$11\bar{2}0 \wedge 43\bar{7}1$	=	11 56

3. TYSONITE.

Mr. S. T. Tyson recently showed to the writer a large specimen of the rare species tysonite from Colorado, described by Allen and Comstock and proved by them to be a fluoride of the cerium metals (this Journal, III, xix, 390, 1880). This specimen is much the largest which has yet been found, having a weight of no less than two and a half pounds. It was very homogeneous and only on one side showed a partial alteration to bastnäsite; it exhibited very distinctly the characteristic basal cleavage of the species. At one point the summits of a few crystals were observed, and through the kindness of Mr. Tyson the writer has been able to obtain some data to complete the description of the species. The original crystals showed only the basal plane and the prisms of the first and second order (*I*, and *i*-2). The crystals now in hand, or rather crystalline fragments, showed in addition the planes 1, 2, and 2-2. It was furthermore observed on them that the mineral has a distinct cleavage parallel to the unit prism *I*. The observed planes for the species are then:

O	(0001, *c*)	1	($10\bar{1}1$, *p*)
I	($10\bar{1}0$)	2	($20\bar{2}1$, *q*)
i-2	($11\bar{2}0$, *i*)	2-2	($11\bar{2}1$, *s*)

On two crystals the angle between *O* and 1 admitted of accurate measurement; the result was

$$O \wedge 1,\quad 0001 \wedge 1011 \;=\; 38^\circ 25' \text{ and } 38^\circ 24\tfrac{1}{2}'$$

Of these the former is accepted as the fundamental angle, as the planes affording it were best suited to give accurate results. The length of the vertical axis is then

$$c = 0{\cdot}68681;$$

and the more important angles calculated from it are:

			Calculated.	Measured.
$O \wedge 1$,	$0001 \wedge 10\bar{1}1$	=	38° 25′*	38° 25′ and 38° 24½′
$\wedge 2$,	$\wedge 20\bar{2}1$	=	57 46	57 42
$\wedge$ 2-2,	$\wedge 11\bar{2}1$	=	53 57	53 42 approx.
$I \wedge 1$,	$10\bar{1}0 \wedge 10\bar{1}1$	=	51 35	
$\wedge$ 1 (ov. 2-2),	$10\bar{1}0 \wedge 01\bar{1}1$	=	71 54	
$\wedge 2$,	$\wedge 20\bar{2}1$	=	32 14	
$\wedge$ 2-2,	$\wedge 11\bar{2}1$	=	45 34	
i-2 $\wedge$ 2-2,	$11\bar{2}0 \wedge 11\bar{2}1$	=	36 3	
1 $\wedge$ 2-2,	$10\bar{1}1 \wedge 11\bar{2}1$	=	26 20	26 50 approx.
1 $\wedge$ 1 (pyr.),	$10\bar{1}1 \wedge 01\bar{1}1$	=	36 12	
1 $\wedge$ 1 (basal),	$10\bar{1}1 \wedge 10\bar{1}\bar{1}$	=	103 10	

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *New Determinations of Atomic Weights.*—The results which have recently been reached with the rarer earths by successive fractional precipitations or decompositions, showing that elements whose oxides are closely allied in properties may yet have widely different atomic weights, have led Marignac to submit some of the more common oxides to a similar course of fractional precipitations in order to detect any progressive variation in the atomic weight. In the case of bismuth, a solution of the nitrate was fractionally precipitated by water, the basic nitrate converted into the oxide by ignition and this reduced by hydrogen to the metal. Six experiments gave 208·62, 208·92, 208·58, 208·82, 208·08, 208·56; the mean being 208·60. A second set of experiments was made by converting a known weight of the oxides obtained by fractioning into sulphates and weighing. Six determinations gave 208·06, 207·94, 208·13, 208·33, 208·11 and 208·36; or 208·16 as the mean. To prepare the manganese oxide the nitrate was partially precipitated by oxalic acid, the filtrate evaporated to expel excess of nitric acid, diluted and again precipitated with oxalic acid as before. Seven separate fractions as oxalates were thus obtained, of which 1, 3, 5 and 7 were converted into oxide by roasting, and this reduced to manganous oxide by hydrogen at a high temperature. By converting a known weight of this oxide into sulphate, the atomic weight of manganese was found to be 55·12, 55·03, 55·07, 55·06; or 55·07 as a mean. For the determination of the atomic weight of zinc, five successive products were obtained by partial decompositions of the nitrate by heat. The oxide was at first converted into sulphate, in order to determine by the increase of its mass, the atomic weight. But the results were not satisfactory. It was then converted into the double chloride of potassium and zinc, and the chlorine determined in a weighed portion by titrition. The values found were 65·26, 65·22, 65·37, 65·31 and 65·28; or 65·29 as a mean. Three subsequent determinations made upon specially purified crystals gave 65·28, 65·39 and 65·32; or 65·33 as a mean. For the determination of the atomic weight of magnesium two sets of experiments were made. In the first, magnesium nitrate was fractionally calcined, giving five successive products of oxide; the sulphate was thus calcined giving three specimens of oxide; and the carbonate thus treated gave two specimens. These samples of oxides were all converted into sulphates and weighed, giving 24·40, 24·37, 24·37, 24·39, 24·40, 24·37, 24·36, 24·37, 24·38, 24·38; or 24·38 as a mean. In the second set, fractionally crystallized specimens of sulphate were calcined, giving six specimens of oxide; the sulphate fractionally precipitated by alcohol was calcined, also giving six specimens;

and a last fraction of the sulphate was calcined, which had crystallized from an acid solution. The values obtained were 24·38, 24·35, 24·39, 24·37, 24·35, 24·37, 24·41, 24·37, 24·37, 24·37, 24·36, 24·38, and 24·37; excluding the seventh as erroneous from the presence of a trace of calcium, the mean of the above values is 24·37 for magnesium.—*Ann. Chem. Phys.*, VI, i, 289, March, 1884.

G. F. B.

2. *On a new reaction of Ethyl Carbamate.*—The substance $C_{11}H_{19}NO_2$, obtained by Haller by the action of cyanogen on sodium-borneol, was observed to split up under the action of alcoholic potash into potassium cyanate, water and borneol. The body $C_{11}H_{21}NO_2$, obtained by ARTH by acting similarly on menthol splits in the same way. As these bodies have the composition and properties of carbamic ethers, the latter chemist undertook an examination to ascertain whether this behavior was characteristic of the class of urethanes. On submitting ethyl carbamate to the action of boiling alcoholic potash in a flask with an upward condenser for half an hour, the liquid contained abundant hard brilliant crystals of potassium cyanate. The mother liquor evaporated with ammonium sulphate readily gave urea. Hence the above reaction is general.—*Bull. Soc. Chim.*, II, xli, 334, April, 1884. G. F. B.

3. *On the synthesis of a Glucoside of Tartaric acid.*—GUYARD has succeeded in effecting the synthesis of a glucoside of tartaric acid, by projecting the anhydrous tartaric acid of Fremy into melted glucose until the mixture becomes pasty and less fusible. An abundant evolution of aqueous vapor is observed and the resulting product is white, soluble readily in water, and unaltered by prolonged ebullition. The presence in it of neither glucose nor tartaric acid can be detected. If boiled for a few minutes with a dilute acid, glucose and tartaric acid result.—*Bull. Soc. Chim.*, II, xli, 291, March, 1884. G. F. B.

4. *On the Physical Isomerism of Camphol-urethanes.*—The substance obtained by HALLER by the action of cyanogen on right-sodium-camphol, and which has been shown by Arth above to be a camphol-urethane, rotates the polarized beam to the right and crystallizes in hemihedral crystals. Haller has now prepared this urethane from left-camphol obtained from the borneol of Ngaï. Its aqueous solution on cooling deposited crystals of left-camphol-urethane in fine needles melting at 126°–127°. The solution rotates the polarized beam to the left $\alpha D = -29·90°$. The crystals while hemihedral like those of right-camphol-urethane, are so in an inverse sense. In the right-handed variety certain planes exist only on one side of the crystal while they are absent on the other. In the left-handed variety these planes are present but in an opposite sense, being on the left side instead of the right. These two camphol-urethanes present in their crystals the same kind of physical isomerism relatively to each other that Pasteur observed in the right and left ammonium-sodium tartrates. The borneol carbonate formed simultaneously with the urethane is

the same whether the camphol be right or left, having the constant fusing point of 226°–227°. By the action of alcoholic potash it splits into camphol and potassium carbonate.—*Bull. Soc. Chim.*, II, xli, 327, April, 1884. G. F. B.

5. *On a relation between the Capillary constant of a Liquid at the boiling-point, and its Chemical composition.*—SCHIFF has succeeded in obtaining a relation between the capillary constant of certain liquids and their chemical composition, by determining this constant at the boiling point. For this purpose a U-tube was employed, the two sides of different diameters, hung in the vapor of the liquid with which it was filled. From the difference of level in the two legs, the capillary constant was readily calculated. Beside this value, which the author represents by a^2, he uses $\frac{1}{2}a^2s$ to represent the weight of the raised liquid for unit length of the contact line, where s is the specific gravity of the liquid. If $m =$ the molecular weight, $\frac{m}{s} = v$, the molecular volume, and $\frac{\frac{1}{2}a^2s}{m} = \frac{\frac{1}{2}a^2}{\frac{m}{s}} = \frac{a^2}{2v} = \text{N}$, the relative number of molecules raised per unit length of the contact line between the liquid and the wall of the solid. Since the value of N is small, the author multiplies it by 1000. The results of the measurements are given for 60 organic liquids, water being first measured. For this liquid, a^2 was found to be 15·090 at 8·9°. Hexane gives a^2=4·514, $\frac{1}{2}a^2s$=1·386, and N = 16·1 at the boiling point, 68·1°. For ethylbenzene the values are, a^2=4·495, $\frac{1}{2}a^2s$=1·710, and N=16·2 at 135·9°. Ethyl alcohol, a^2=4·782, $\frac{1}{2}a^2s$=1·765 and N=38·4 at 78°, etc. Comparing now together chemically analogous bodies, the values of a^2 and of N are closely similar. Thus isobutyl-alcohol, ethyl formate and ether, bodies which have different boiling points though the same molecular weights, 73·84, have the following values of a^2: 4·416, 4·528, 4·521. And the isomers methyl butyrate, propyl acetate and ethyl propionate give for N the values 15·9, 15·6 and 15·6. Moreover, it appears that among the isomers of the fatty series those with the highest boiling points show the greatest capillary elevation, the greater number of raised molecules, while the converse holds with the aromatic series. If, now, those substances be compared which give practically the same value for N, as for example 16, we have hexane C_6H_{14} giving for N 16·1, the xylenes and ethylbenzene C_8H_{10}, giving 16·0, 15·9, 15·8 and 16·2, and compound ethers of the formula $C_5H_{10}O_2$, giving 15·8, 15·6, 15·6, 15·9 and 15·7. Now C_6H_{14} has C_2 less and H_4 more than C_8H_{10}. Hence, relatively to the constant N, C_2=H_4. So C_8H_{10} has C_3 more and O_2 less than $C_5H_{10}O_2$; and therefore C_3=O_2. Other groups give the same results. From the above it follows that C=H_2 and O=H_3. From dimethyl-acetal and chloroform it appears that Cl=H_7. These values enable us to substitute a certain number of hydrogen atoms for

the chlorine, carbon and oxygen atoms in any molecule and thus to formulate a substance which, if it could exist in the free state would have the same capillary constant as the original body. Hence, two substances having the same value for N, may by means of these equivalents be represented by the same number of hydrogen atoms. Thus $CH_4O = H_9$, the value of N being 59·8; $C_4H_8O_2 = H_{22}$, N being 20·4; $C_8H_{16}O_2 = H_{38}$, N being 8·7; and so on. If a curve be drawn with these hydrogen values as ordinates and the corresponding values of N as abscissas, then obviously, having given any substance containing C, O, H or Cl, its formula may, by using the above equivalences, be translated into its hydrogen equivalent and then from the curve, its capillary constant be obtained. In other words, from the molecular formula of a substance, its capillary constant at the boiling point may be calculated. Since $N = \frac{1}{2}a^2 \div v$, the value of either a or v (the molecular volume) may be calculated if the other is known. The calculated and observed values of N as given in the paper are very close. With regard to the equation of the curve, which is concave toward the axis of abscissas, the author finds it to be $y = \frac{1}{x} \cdot e^{6\cdot48292b - 0\cdot0167628x}$, the equation of a logarithmic curve. A complete table of the liquids tested, their formulas and values of a^2, $\frac{1}{2}a^2s$, and N, concludes the paper.—*Liebig's Annalen*, ccxxiii, 47, March, 1884. G. F. B.

6. *On the Discovery of the Periodic Law and on Relations among the Atomic weights;* by JOHN A. R. NEWLANDS, F.I.C., etc. 34 pp. 12mo. London, 1884 (E. & F. N. Spon).—This little volume contains a reprint of several articles by the author, in which he developed the idea of the Periodic Law in the arrangement of the chemical elements. He thus shows the extent to which he anticipated Mendelejeff in the latter's subsequent development of the same subject. The book is valuable chiefly as a contribution to the history of this important subject.

7. *Absorption Spectra of Water.*—The Society of Physics and Natural History of Geneva has appointed a committee to study the color and the transparency of the water of Lake Geneva. This committee is composed of Plantamour, Soret, Luc, de la Rive, C. de Candolle, Ed. Sarasin, Herm. Lal, L. Pictet, A. Killiet and C. Soret. Two of the committee, MM. Soret and Sarasin, have studied the absorption spectra of the water taken from different localities. The water was contained in four tubes of glass 1·10 meters in length, and 0·05 meters in diameter. One of these tubes did not produce a sensible absorption in the solar spectrum. But with two tubes, that is with a length of a little over two meters, an obscure band appeared in the orange. This band was very feeble and narrow. It was a little less refrangible than the D line and corresponded very nearly with the wave length 600. With three tubes the band is more marked and the absorption increases to the red extremity of the spectrum. With four tubes or a total thickness of nearly 4·50 meters, the band

grows darker, but still remains of a not pronounced gray tint. The water was taken from various localities—from the conduits near the city of Geneva—from the Arve. Distilled water was also used, and water freed from gases in solution and from silica. It seems difficult therefore to attribute the absorption band to impurities in the liquid and it is probably due to a selective absorption of water. Various experiments showed that it was not due to the apparatus employed. That this band has not been perceived by M. Secchi, M. Vogel and other physicists who have studied the absorptive effects of water, is probably due to the conditions under which their observations were made. The red and orange were perhaps too much enfeebled, either by the great length of water traversed by the light or by the employment of a too feeble source of light. Through four meters and even eight meters of water the author could not detect the band between E and *b* which Vogel found in the light in the grotto of Capri. This appears to indicate that this band is due to substances in solution in the water.—*Comptes Rendus*, March 10, 1884, pp. 624–626. J. T.

8. *Magnetic effect of Electrical Convection.*—Rowland's experiment upon the magnetic effect of electrical convection has been called in question by Dr. Lecher of Vienna. Dr. Lecher modified Rowland's experiment by placing the rotating disc in a vertical plane, its axis being horizontal. The magnet needle was placed parallel to the plane of the disc and in the axis of its rotation, relatively as the coil and needle of a Gaugain galvanometer. Discs of brass and *papier maché* covered with graphite were employed and were charged to potentials of about 5000 volts. No deflection was observed with a rotation of 200 revolutions per second.—*Nature*, April 10, 1884. J. T.

9. *Hall's phenomenon.*—M. Leduc has investigated, by means of a capillary electrometer, the phenomenon discovered by Mr. Hall and finds that if the strength of the magnetic field does not exceed a certain value that the deviation of the equipotential line and the line of force at the points where they meet can be represented by the formula $D=kM(1-at)$, k being the deviation produced at the temperature 0 at a point where the magnetic intensity is 1 and a is a constant. For bismuth a is very small; for silver it varies from 0·008 to 0·009. This deviation can be considered as due to a heterotrophy which the metal assumes in the magnetic field and is analogous to that which light undergoes in falling normally upon a doubly refracting substance. The phenomenon is very feeble in an alloy of bismuth and lead of equal weight which is very malleable. It is zero in lead according to Dr. Hall. The crystalline state of bismuth appears therefore to play a greater part in the production of the phenomenon than the nature of the metal itself, as also happens in the case of diamagnetism.—*Comptes Rendus*, March 17, 1884, pp. 673–675.

Mr. Shelford Bidwell, Philosophical Magazine, April, 1884, has tatempted to show that Hall's phenomenon is due to a strain, and

Peltier effect in the thin strip of metal interposed between the poles of an electro magnet, and publishes a table in which he finds great agreement between the direction of the Hall effect and the thermo-electric effect of strain in different metals. Mr. Hall has replied in Science, March 28, 1884, and shows that if the strain is proportional to the magnetic force, as Mr. Bidwell supposes, the Hall effect should be proportional not to the current, as actually is the case, but to the cube of the current.

Professor S. P. Thompson and Mr. C. C. Starling have also varied Dr. Hall's experiment by using a very large sheet of tin foil, so that the wires and connections should be entirely outside the magnetic field, and have also employed pointed electro-magnets. In this case the Hall phenomenon is not produced. An alteration in the equipotential lines due to change of resistance is noticed. Strips of gold and tin show a decrease. Strips of iron show a slight increase of resistance when subjected to a strong magnetic field.—*Physical Society, London. Nature,* April 10, 1884, p. 558. J. T.

10. *A Text Book of the Principles of Physics;* by ALFRED DANIELL, M.A., Lecturer on Physics in the School of Medicine, Edinburgh. 653 pp. 8vo. London, 1884 (Macmillan & Co.).—Teachers of Physical Science will welcome a text-book, which unlike most of the works on general Physics now in use, aims to develop the principles of the Science rather than to give a mere summary of physical phenomena. According to the modern methods of instruction a student is expected to have as wide an opportunity as possible to do practical work in the laboratory, and thus there is much less necessity, than was formerly the case, for the long descriptions of instruments and methods of experiment with which the older books are loaded down. The author treats the introductory parts of the subject with almost too great fullness, that is, the subjects of kinematics and kinetics, the different forms of matter, and so on, leaving only half the space for the development of heat, sound, radiant energy, electricity and magnetism. These latter subjects, consequently, are treated in many points too meagerly to be symmetrical with the earlier part of the work. The author uses throughout the absolute units on the c. g. s. system, but has rejected the usual convention by which the use of a long line of ciphers is avoided.

11. *Absolute Measurements in Electricity and Magnetism;* by ANDREW GRAY, M.A., etc. 207 pp. 12mo. London, 1884 (Macmillan & Co.).—The universal adoption by electricians of the series of electrical units, based upon the absolute system, which was recommended by the Paris Congress of 1881, has served to put electrical measurements upon a basis of precision, which was impossible as long as the old methods were adhered to. This little volume of Mr. Gray starts with the explanation of the relations of these units, and goes on to develop the principles involved in absolute measurements, and the practical methods and instruments employed in them. The subject is one of great importance

at the present time, especially in view of the wide interest felt in the practical applications of electricity, and the excellence of this treatise cannot fail to be appreciated by all who use it.

12. *Heat;* by P. G. TAIT, M.A., etc. 368 pp. 8vo. London, 1884 (Macmillan & Co.).—The well-known name of the author is a sufficient guarantee of the high character of this treatise, and those who take it up expecting to find an exceptionally clear and lucid exposition of the principles of this department of Physics will not be disappointed. The author states that the work is intended especially for students who have not a scientific career before them, but whose aim is to gain an accurate knowledge of the important facts and theories of modern physical science. For this class of students the work is admirably adapted in its clearness and simplicity of style, fullness of word illustration and logical development of the fundamental principles. It is, however, calculated to be of value to more advanced students, and those whose design is more strictly scientific, for there is a freshness in the method of treatment which makes it valuable and suggestive to all.

II. GEOLOGY AND NATURAL HISTORY.

1. *Genera of Fossil Cephalopods;* by Professor A. HYATT, (Proc. Boston Soc. Nat. Hist., xxii, April, 1883).—Professor Hyatt gives in this memoir the last results of his extended study of the Nautiloid, Ammonoid and other groups of Cephalopods. Of these results not the least important are his interesting deductions as to the genesis of the group, based on comparisons of the successive forms of the whorls in individual shells, and with the successive forms in geological time. He appears thus to prove the direct derivation of the Nautilus family and of the Goniatites from a kind having the shell a simple straight cone—the form of an Orthoceras—the *young* form in Goniatites as well as in Nautilus being of this kind. The remaining Ammonoids "skip" this simplest form, and those of Cyrtoceras and Gyroceras, in their development, but still bear evidence, in his view, that they are "descendants of the close-coiled Nautilinidæ." He states that "the generic terms *Cyrtoceras*, *Gyroceras* and *Nautilus* are really only descriptive terms for the different stages in the development of an individual, and for the different stages in the development or evolution of the series of adult forms in time;" that "each of these genera, as now used, includes representatives of all the different genetic series of Tetrabranchs;" that the earliest forms "agree in general aspect, owing to the proximity of the septa, but they do not agree in structure or in their embryos." The general conclusion is extended to the Belemnoid and Sepioid groups, but with less satisfactory proof.

Facts of the above-mentioned kind led Mr. Hyatt, several years since, to announce the "law of acceleration in development" as an explanation of quickened or abrupt steps under the theory of evolution, which he now prefers to designate the law of "concentration of development." He speaks of the sudden appearance of distinct types in Paleozoic and later time as an "acknowledged" fact; of distinct types as far most numerously evolved in Paleozoic type than later; of the field of variation as decidedly narrower in the Mesozoic than in the Paleozoic; observes that the separation of the grander groups under the general type took place rapidly in the Paleozoic; and states as deduced principles that "types are evolved more quickly and exhibit greater structural differences between genetic groups of the same stock while still near the point of origin than they do subsequently;" that important characteristics disappeared with the progress of a type, often abruptly, in accordance with the law of concentration of development and of increase in concentration with the progress of the group.

Mr. Hyatt makes no reference to the vastly greater length of Paleozoic than Mesozoic time—probably not less than five times longer, if not ten—which fact bears on the value of such deductions.

The uncoiled forms which occur in the later part of Mesozoic time are recognized as degraded or retrogressive forms, the embryonic forms in all these uncoiled kinds being coiled; and the return to the earlier Paleozoic forms is made part of the proof as to the derivation of the group from those early species.

In connection, he makes the following reasonable statement:

"Slaves of the embryological lamp consider that they must associate all forms which have similar embryos, and dissociate in classification all forms having different embryos. As a matter of experience the surest guides of affinity are the adult gradations of forms. These show that the Nautiloidea and Ammonoidea, with comparatively distinct embryos, are nevertheless more closely related than the Belemnoidea and Ammonoidea which have precisely similar embryos, and that Sepioidea and Belemnoidea, which have very distinct embryos, must also be closely affiliated."

The principle "acceleration in" or "concentration of development," which has been put forward also by Professor Cope, is an expression in a general form of the idea that there were abrupt steps in the line of progress and to some extent an explanation of it. But we have yet to learn the wherefore as to such abrupt steps.

2. *The Geological History of Serpentines, including Studies of Pre-Cambrian Rocks;* by T. Sterry Hunt. Trans. Roy. Soc. Canada, i, section 4. 1883. Montreal.—Dr. Hunt, reviewing a subject he has treated in former papers, presents here some of the facts connected with the serpentines of North America, and other facts from those of Europe, and his deductions: (1) that serpentine is never a true eruptive rock, and (2) is of aqueous origin. The former conclusion is well sustained; the latter might have been discussed with much greater thoroughness; for the best facts on the subject are overlooked. No sufficient use is made of the

many examples of the derivation of serpentine by alteration from pyroxene, hornblende, enstatite, chlorite, and nothing adequate to the importance of the subject as to its derivation from chrysolite and chondrodite. Under the head of "Serpentines in North America," the author might have cited many more facts than he has done from North Carolina, where the origin of serpentine is illustrated on a grand scale and with details that are exceedingly instructive. Other facts might have been given from the Tilly Foster Iron Mine, at Brewster, New York, where the change of chondrodite (a magnesia silicate containing fluorine) to serpentine is exemplified with wonderful fullness; where white dolomite sprinkled with grains of chondrodite has in some parts the grains partly and in others wholly altered to serpentine; where crystallized chlorite, enstatite and other minerals have participated in the change and show all shades of gradation in it; and where brucite (magnesia hydrate), fluorite (calcium fluoride), and magnetite in fine crystallizations occur as results of the changes that went forward as a consequence of the chemical conditions; where a nearly white serpentine often occurs clouded in spots with black, due to microscopic grains of magnetite, derived apparently from the excluded iron of the chondrodite, these and other similar facts suggesting a possible source for the magnetite of other serpentines. The author describes the New Rochelle serpentine after a visit to the region, but he omits to mention that tremolite, or a white to pale green hornblende occurs abundantly in all stages of gradation in composition between these minerals in the unaltered state and serpentine, and that enstatite or a closely-related mineral is another of the half-altered to wholly serpentinized species. For right conclusions with regard to the origin of serpentine and its relations to the associated rocks there must be a thorough study and consideration of this class of facts, which is here neglected almost *in toto*, although abundantly represented in Europe as well as America.

3. *The Taconic question in Geology;* by T. STERRY HUNT. Part I. Transactions of the Royal Society of Canada. Volume i, section 4, 1883, Montreal.—The deficiencies and one-sidedness of the historical review in this "Part I" are so great that the views cannot be properly considered before the appearance of the closing "part." The subject has been the topic of former publications by the author.

4. *Results of an Examination of Syrian Molluscan Fossils, chiefly from the Range of Mt. Lebanon;* by CHARLES E. HAMLIN. 68 pp. 4to, with 6 plates. Volume x, No. 3 of the Mem. Mus. Comp. Zool. Cambridge, Harvard College. Cambridge, April, 1884.—After speaking of the publications on the fossils of Palestine by Conrad (Dead Sea Exploring Expedition under Lieut. Lynch), L. Lartet, in 1869–1872, and Professor Oscar Fraas in 1867, 1877 and 1878, Mr. Hamlin observes:

"The most important consequence of the labors of Lartet and Fraas is the change of view which they have brought about with respect to the age of the stratified rocks of Palestine and the Lebanon region. It is now an established fact, that the great Cretaceous system which, stretching in northern Africa through Morocco and thence eastward to Egypt, and southward into the Sahara and the Libyan desert, crosses over into the peninsula of Sinai, spreads also over the greater part of Palestine and the ranges of Lebanon and anti-Lebanon, and probaby prevails east of the Jordan and the Dead Sea, in Gilead, Moab, and Idumæa. The earlier explorers seem to have been misled by the strong external resemblance of the light-colored limestones which they observed in Palestine to the rocks of the White Jura of Europe, and therefore regarded them as Jurassic."

The species described and well-figured in Mr. Hamlin's paper are Cretaceous, and probably later than the Cenomanian stage. As to the Tertiary formation, he states, from Fraas and Lartet, that the Eocene occurs in Syria south of Tarabulus (Tripoli); but that, according to Fraas, it is impossible to draw the limit between the Cretaceous and the Eocene, since it is found that Nummulites pass down into the Cretaceous.

5. *Recherches sur les Terrains Anciens des Asturies de la Galice* (*Spain*), par CHARLES BARROIS. 630 pp. 4to, Lille, 1882. —This volume is the report of an extended and careful study of the Paleozoic and underlying rocks of this part of Spain, of its rocks, its stratigraphy and its paleontology, and of the phenomena that have modified the Paleozoic strata since their formation. It is illustrated by an atlas in quarto containing sections, views, and many plates of fossils. The author states that the Primordial or Cambrian group passes gradually into underlying crystalline schists without unconformability or any abrupt lithological change. The Primordial includes argillytes and fine-grained mica schists (which are sometimes staurolitic, chloritic and occasionally contain tourmaline) together with quartzyte or sandstone, and limestone.

The upturning of the series of beds in the Cantabrian Mountains is attributed to lateral pressure, and occurred, as he shows, at or toward the close of the Carboniferous, acting in the direction of the parallels of latitude.

The Mesozoic beds overlie the upturned edges of the Carboniferous, and the strata are conformable to the top of the Eocene, a fact indicating that the next great epoch of disturbance after that closing Paleozoic time in Cantabria occurred after the Eocene and was identical with that which determined the relief of the Pyrenees (p. 604). The pressure was nearly in the direction of the meridians from north to south. The features of the region are chiefly due to the results of this post-Eocene disturbance, for it not only caused the elevation of the Mesozoic beds, but also modified sensibly the relief of the Paleozoic masses, and produced the great difference of level between the coal beds of the Asturias, which are worked even below the sea-level at Arnao, and those of the Cantabrian chain in which they have a height of 2000 meters. The author draws attention to the fact of the transverse directions in the great uplifts of the two mountain-making disturbances.

Mr. Barrois detected coccoliths in the Devonian rocks and concluded that these microscopic convex or plano-convex disks are of inorganic origin and not organic (p. 46). The Paleontological part of the volume contains many observations of wide interest, but there is not space here for a review of them.

6. *Catalogue of the Fossil Sponges in the Geological Department of the British Museum (Natural History), with Descriptions of new and little-known species*, by GEORGE J. HINDE, Ph.D., F.G.S. 248 pp. 4to, with 38 lithographic plates.—The remarkable fullness of the British Museum in its collection of fossil sponges has enabled the learned author of this volume to make a general review of the subject and contribute largely in species and facts to this branch of paleontology. The genera represented by species in the museum are 141 in number; of these 120 are of Siliceous sponges, and the rest of Calcareous; 32 species are from the Paleozoic, 16 from the Triassic, 96 from the Jurassic, 245 from the Cretaceous and 3 from the Tertiary. The many plates are well filled with excellent figures. The text closes with a full bibliography.

7. *Origin of the Italian Serpentine;* by B. LOTTI (Boll. R. Com. Geol. Ital., 1883, p. 11, 12).—The author of this paper reviews the facts connected with the subject, and the opinions of authors, and concludes that the "Pre-silurian Serpentine," which on Elba is interstratified with crystalline calcareous schists, and is in thin alternating beds at other localities, has proceeded from the transformation of pyroxenic, hornblendic, dioritic, etc., schists, which were originally of sedimentary origin; while the Eocene serpentines have been produced by the alteration of the eruptive rocks, diabase and dioryte, or of euphotide, which he is inclined also to place in this class of rocks.

8. *Phosphatic deposits in the Cretaceous of Alabama.* — A letter to the editors from Professor Eugene A. Smith, State Geologist of Alabama, reports the discovery of important deposits of phosphatic nodules and green-sand beds at Hamburg in Perry County, at the base of the Rotten limestone. The Rotten limestone is represented only by its lowermost beds. Below it, occur (1) green-sand beds, 1 to 4 or 5 feet thick; (2) about 6 feet of sandy calcareous beds containing hard phosphatic nodules which vary in diameter from that of a pea to an inch or more, associated with various fossils, species of Nautilus, Ammonites, Baculites, and other well known species, the shells to a considerable extent phosphatic, vertebræ and other bones, large pavement teeth of Cestracionts; (3) one foot to 18 inches of light-colored sandy marl, averaging 10 per cent in its phosphoric acid; (4) whitish calcareous and micaceous sands, holding small oyster-shells, with some phosphate, and, below a level of 20 to 30 feet, compact bluish sands in which there is considerable green sand. The

letter states the probability that these phosphatic beds are continued beneath the Rotten limestone across the State of Alabama, through Eutaw and other places to Farmington in Mississippi. Green sands from Eutaw have been found on analysis to contain 8 per cent of phosphoric acid.

9. *Allgemeine und chemische Geologie* von JUSTUS ROTH, Zweiter Band, erste Abtheilung: allgemeines und ältere Eruptivgesteine. pp. 1 to 210, 8vo. Berlin, 1883 (Wilhelm Hertz).—This first part of the second volume of Roth's very valuable work is devoted to a preliminary discussion of rock-structure, and further, to a description of plutonic and older eruptive rocks.

10. *Third Annual Report of the State Mineralogist of California*, for the year ending June 1, 1883. 111 pp. 8vo. Sacramento, 1883.—Part 1 contains the Report of the State mineralogist, Mr. Henry G. Hanks, as to the condition of the California State Mining Bureau. Part 2 contains a very full report on the borax deposits of California and Nevada, in which Mr. Hanks has brought together a large amount of useful and valuable information bearing upon all the topics concerned in the borax industry of especial practical value to Californians and to others interested in the production of borax. This report contains, in addition to the matter compiled from many sources, the results of personal observation by the author as well as a considerable amount of laboratory work; a map is given showing the principal localities in the two States mentioned.

11. *Brief Notices of some recently described Minerals.*—COLEMANITE is a hydrous borate of calcium, probably identical with priceite. It occurs in monoclinic crystals, with a prismatic angle of 108½°, also massive. The cleavage is clinodiagonal, perfect, affording thin smooth laminæ. Hardness 3·5 (amorphous), 4·25 (crystals); specific gravity 2·428. Luster vitreous to adamantine. Transparent to subtranslucent. An analysis yielded

B_2O_3	CaO	H_2O	
[50·98]	27·18	21·84	= 100

Small amounts of soda were found, even in the clearest crystals, which was regarded as due to mechanical admixture, and the suggestion is made that the mineral may have been formed from ulexite. Colemanite was found in Southern California, and named after Wm. T. Coleman of San Francisco; described by J. T. Evans in the Bulletin of the California Academy of Sciences, Feb., 1884.

BRÖGGERITE.—This name (after the Norwegian mineralogist, W. C. Brögger) has been given by C. W. Blomstrand to a uranium mineral near cleveite, both of which are allied to uraninite. The specimen examined is from the neighborhood of Moss, Norway; it formed part of an octahedral crystal having an iron-black color, with hardness 5 to 6, and specific gravity 8·73. An analysis afforded

UO_3	UO_2	PbO	ThO_2	Cerium, earths.	Yttrium earths.	FeO	CaO	SiO_2	H_2O	
38·82	41·25	8·41	5·64	0·35	2·42	1·26	0·30	0·81	0·83	= 110·12

For this the author writes the formnla UO_2, RO, UO_3 or more exactly $6URO_6U + U_3(O_6U)_2$, in which the R includes the thorium, cerium and yttrium earths and lead. The author gives an extended discussion of the constitution of the related uranium minerals.—*Geol. För. Förh. Stockholm*, vii, 59, 1884.

ALLAKTITE.—A mineral described by A. Sjögren as occurring in small tabular monoclinic crystals, flattened parallel to the orthopinacoid; according to H. Sjögren it is near in form to members of the vivianite group. Hardness 4–5, specific gravity 3·83–3·85. Color yellow to green. Strongly pleochroic (whence the name). An analysis afforded

As_2O_5	MnO	FeO, MgO, CaO	H_2O	
28·57	61·92	1·15	9·01	= 100·65

For this formula $7MnO, As_2O_5, 4H_2O$ is given. It occurs with other manganese minerals at the Moss mines in Nordmark, Sweden.—*Geol. För. Förh. Stockholm*, vii, 109, 1884.

SALMITE.—A manganesian variety of chloritoid from Vielsalm, Belgium, described by Eug. Prost (Geol. Soc. Belg.) It occurs in irregular masses with coarse saccharoidal structure and grayish color. Hardness 5 to 6, specific gravity 3·38 of material containing a little quartz. An analysis afforded

Si_2O	Al_2O_3	Fe_2O_3	FeO	MnO	CoO	MgO	CaO	H_2O	Quartz.
19·14	33·66	3·38	13·05	7.14	0·04	1·79	0·30	6·32	15·06=99·88

12. *Clematides Megalanthes, Les Clématites a Grand Fleurs: Description et Iconographie des Espèces cultivées dans l' Arboretum de Segrez;* par ALPHONSE LAVALLÉE. Paris, 1884. (Baillière.)—A sumptuous volume, in imperial 4to, of 84 pages and 24 plates, from drawings by Bergeron, in the form and style of the Arboretum Segrezianum of the same enterprising and liberal-minded author. It is well for science when an individual has the capacity and the public spirit to carry on such an undertaking as the Arboretum of Segrez and the publications which illustrate both its treasures and the botanical acumen of its founder.

The first section of this work is occupied with the investigation and iconography of the Japanese species of *Clematis*, such as *C. patens*, *C. florida*, etc., which have of late years become so attractive in cultivation, and which especially deserve the name of great-flowered Clematis. But the scientific interest to us centers in the North American species, and in some cultivated species of doubtful origin, which may have American blood.

M. Lavallée figures and describes as distinct species, *C. cylindrica* Sims, Bot. Mag., and *C. crispa*, L. Very probably this is a correct view, although we had put the two together. The latter we have had in cultivation, the former we know only in dried specimens; and they seemed to pass into each other. We commend these species to the attention of our botanists of the middle and southern Atlantic States, and ask for living plants and good dried specimens in flower and fruit. The *C. distorta* which Lavallée figures, from a cultivated plant of unknown origin, seems to us to represent something between the two above-mentioned species or forms, more or less modified by long cultivation. Of the two old figures which he refers to it, that from Bot. Mag. t. 1892, we should say belongs to his *C. crispa*, and that from Bot. Rep. t. 71, to *C. cylindrica*. As to *C. eriostemon* of Decaisne, the *C. Hendersoni* of the gardens, we cannot think that this is at all of American origin, and we hold to our former guess that it is a hybrid of *C. Viticella* and *C. integrifolia*.

C. Viorna and *C. reticulata* are well figured, the latter in a form with under-sized flowers. *C. Pitcheri* is well figured in one of the larger-flowered forms; and the new *C. Sargenti*, if we are not much mistaken, is only a smaller-flowered form of the same species.

C. Texensis Buckley is the name preferred to *C. coccinea* of Engelmann, on the ground that the former is the earlier published. We think quite otherwise, though there is room for question. Buckley's name was published in 1863. But he had before him the second part of *Plantæ Wrightianæ*, published in 1852, in which the present writer, although he called the plant *C. Viorna* var. *coccinea*, yet published Engelmann's name "*C. coccinea* n. sp., Engelm. MSS.," and added the essential characters which distinguish the species. It is clear to us that this characteristic name (under which the plant is cultivated and has been more than once figured,) was truly published in 1852, and therefore should be retained.

In reprinting the notes upon the American large-flowered species of *Clematis*, contributed by the present writer to the Botanical Magazine in the year 1881, at the foot of page 70, a portion of the penultimate sentence under *C. reticulata* has been accidentally dropped in transcription and the last sentence joined to the preceding one, so as quite to spoil the sense.

An appendix gives a brief review of the tubular-flowered species, lately in controversy, in which M. Lavallée corrects the determinations of the lamented Decaisne in some respects.

A. G.

13. *Porto Rico plants.*—A botanical exploration of this island is undertaken by P. Sintenis under the direction of Dr. T. Urban, of Schœneberg, near Berlin, who wishes to receive the names of subscribers, at 30 marks ($7.50) per hundred specimens, payable on delivery. The mountains of Porto Rico ought to yield a good harvest. A. G.

14. *Erythrææ Exsiccatæ quas distribuit* V. B. WITTROCK, Director Musei Botanici Stockholmiensis, Fasc. I, 1884.—This is the beginning of a complete autotype illustration of a genus which, though not large, abounds in critical species and forms; and the North American species doubtless need similar investigation and illustration. Dr. Wittrock informs us that, if he can secure specimens from this country, in sufficient abundance, he will include them in the beautiful work which he has now begun. For the indigenous species we must appeal to botanists of our western

regions, from Arkansas and Texas to the Pacific Coast. Their contributions, which are hereby solicited, will be repaid in kind. Botanists who are willing to extend their aid and who are desirous of details, may communicate with the writer of this article, at Cambridge. The present fascicle, a thin folio volume, is devoted to the *E. vulgaris* type, in its various forms A good woodcut figure of corolla and stamens is given on the leading ticket of each species. A. G.

III. Miscellaneous Scientific Intelligence.

1. *The British Association at Montreal.*—The meeting of the British Association at Montreal will commence on Wednesday, August 27. The reception rooms will be open on the Monday preceding at 1 P. M., and on the following days at 8 A. M., for the issue of tickets to members and associates (and ladies), and for supplying information as to lodgings, etc. The general secretary of the executive committee is Mr. J. D. Crawford. The tickets will contain a map of Montreal, and particulars as to the rooms appointed for sectional and other meetings. A general meeting will be held Wednesday evening, opening at 8, at which President Cayley will resign the chair and the Right Hon. Lord Rayleigh, President-elect, will assume the presidency and deliver an address. On Friday evening there will be a discourse by Professor W. G. Adams, and on the evening of the following Monday a discourse on "The modern microscope in researches on the least and lowest forms of life," by the Rev. W. H. Dallinger; on Saturday evening a lecture on comets, for the citizens of Montreal, will be delivered by Professor R. S. Ball, of Dublin University.

Contributors of papers to the meeting are required (under an arrangement dating from 1871), to send to the "General Secretaries of the British Association," 22 Albemarle street, London, W., an abstract of the paper, suitable for insertion in the transactions of the association, together with the paper, with a statement as to the section for which it is intended, that the committee may decide, in advance of the time of meeting, as to the acceptance and time of reading.

The Local Executive Committee has issued the following circular with regard to membership and the enrolling of new members:

(1) Life members for a single payment of $50, which entitles them to all the privileges of membership for life, and to receive all reports which the association may publish after the date of payment.

(2) Annual members for a payment of $10 the first year ($5 of which is the entrance fee), and $5 each consecutive year thereafter, with the same privileges as life members.

(3) Associate members for a payment of $5. Associates are not eligible to hold office in, or to serve on any committees of the Association; nor do they receive the annual reports. All other privileges of membership for the year are open to them.

Persons who are already members of the Association may be re-enrolled by paying the annual dues of $5. Life members will be re-enrolled without payment. No person who is not a member is admitted to any of the meetings of the Association. The privilege of reduced fares by the railway and steamboat lines is limited to the life, annual and associate members. Applications for admission to membership may be addressed to Mr. J. D. Crawford, General Secretary of the Citizens' Committee, Post-office box 147, Montreal.

The Circular is signed by THOMAS CRAMP, Chairman, and DAVID A. P. WATT, Secretary, and dated Molsons' Bank Chambers, 198 St. James street, Montreal, April 15, 1884.

2. *American Association.* — The Philadelphia meeting of the American Association commences its session on the 3d of September, under the presidency of Professor J. P. LESLEY. The vice-presidents of the sections are: A, Mathematics and Astronomy, H. T. EDDY, of Cincinnati; B, Physics, JOHN TROWBRIDGE, of Cambridge; C, Chemistry, JOHN W. LANGLEY, of Ann Arbor; D, Mechanical Science, R. H. THURSTON, of Hoboken; E, Geology and Geography, N. H. WINCHELL, of Minneapolis; Biology, E. D. COPE, of Philadelphia; F, Histology and Microscopy, T. G. WORMLEY, of Philadelphia; H, Anthropology, E. S. MORSE, of Salem; I, Economic Science and Statistics, J. EATON, of Washington.

The Permanent Secretary of the association is Professor F. W. PUTNAM, of Cambridge; the General Secretary, ALFRED SPRINGER, of Cincinnati; the Assistant General Secretary, E. S. HOLDEN, of Madison; the Treasurer, WILLIAM LILLY, of Mauch Chunk.

3. *Peabody Museum of American Archæology and Ethnology of Cambridge, Mass., 16th and 17th Annual Reports.* Cambridge, 1884.—American Archæology is making rapid progress through the labors of Professor Putnam and the work and publications connected with the Harvard Peabody Museum. The volume issued contains various original papers besides the report of the curator. A few facts are here cited from it:

(1) The *meteoric iron* "found on the altar of mound No. 3, of the Turner group of earthworks in the Little Miami valley, Ohio, has been analyzed by Dr. L. P. Kinnicutt. One piece was found to have G.=6·42, and to consist of Iron 86·66, nickel 12·67, cobalt 0·33, copper *trace*, insoluble residue 0·10; the second specimen, to have G.=6·51, and to consist of Iron 88·37, nickel 10·90, cobalt 0·44, copper and phosphorus *traces*, insoluble residue 0·12. Each contains small crystals of olivine, and the former also a little bronzite. A polished piece of the first gave well-marked Widmannstättian figures, and the second appeared to be of the same character. The other specimens were similar, in containing nickel, proving that all the iron from the mound was of meteoric origin.

Another mass of iron weighing 767·5 grams, from the altar in mound No. 4, of the same group, contained large concretions of olivine, like the "pallasite" section of meteoric irons, and had a specific gravity, according to a determination by Professor Lattimore, of Rochester, N. Y., of 4·72. An analysis of the iron by Mr. Kinnicutt afforded Iron 89·00, nickel 10·65, cobalt 0·45, copper and phosphorus *traces;* of the olivine, Silica 40·02, iron protoxide 14·06, manganese protoxide 0·10, magnesia 45·60. Specific gravity of the olivine, 3·33; of the iron, 7·894. Small grains of bronzite were detected.

Mr. Kinnicutt states that the external resemblance of the specimen to those of the Atakama iron is striking. Buchner's analysis of the iron of the latter gave Iron 88·01, nickel 10·25, cobalt 0·70, phosphorus 0·33, sodium 0·21, potassium 0·15, and G.=7·44–7·66; which is very near that of the Ohio-mound iron. The olivine, according to an analysis by Schmid, contains only 36·92 per cent of silica; but the analysis needs revision, since the iron and manganese are given as sesquioxide, and if reckoned as protoxide (its condition in unaltered olivine), the analysis shows a large loss.

(2) *A human molar tooth* has been found by Dr. C. C. ABBOT *in the gravels near Trenton affording paleolithic implements.* It is a rolled and worn tooth, and is therefore of the same age with the implements. Dr. Putnam says that the discovery of the tooth removes the little doubt there was about the gravel-bed origin of the portion of a human skull obtained some years since at Trenton by Dr. Abbot from a person who stated that it was found in the gravel.

Professor Putnam, in the course of his report, adds a word on (3) *fraudulent antiques.* He says that Indian pipes, dishes and other relics are made for the ethnological market in Philadelphia; a large business has been done in Ohio in the so-called gorgets cut from slate and in hematite celts; and much Indian pottery has been put into the trade in southern Illinois. A carved stone representing a naked child was recently sent from Eureka, in Arkansas, to the Peabody Museum for sale, which "proved to be a child of the 'Cardiff Giant' family."

4. *The Güegüence, a comedy ballet in the Nahuatl-Spanish dialect of Nicaragua;* edited by D. G. BRINTON. 96 pp. 8vo. Philadelphia, 1883. *Aboriginal American Authors and their Productions;* by DANIEL G. BRINTON, A.M., M.D. 64 pp. 8vo. Philadelphia, 1883. Brinton's Library of Aboriginal American Literature.—These two volumes are works of much research and historical interest, by one of the ablest of American archæologists.

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* This Index contains the general heads BOTANY, GEOLOGY, MINERALS, OBITUARY, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.

H

R. S. Fellows 117 Whitney

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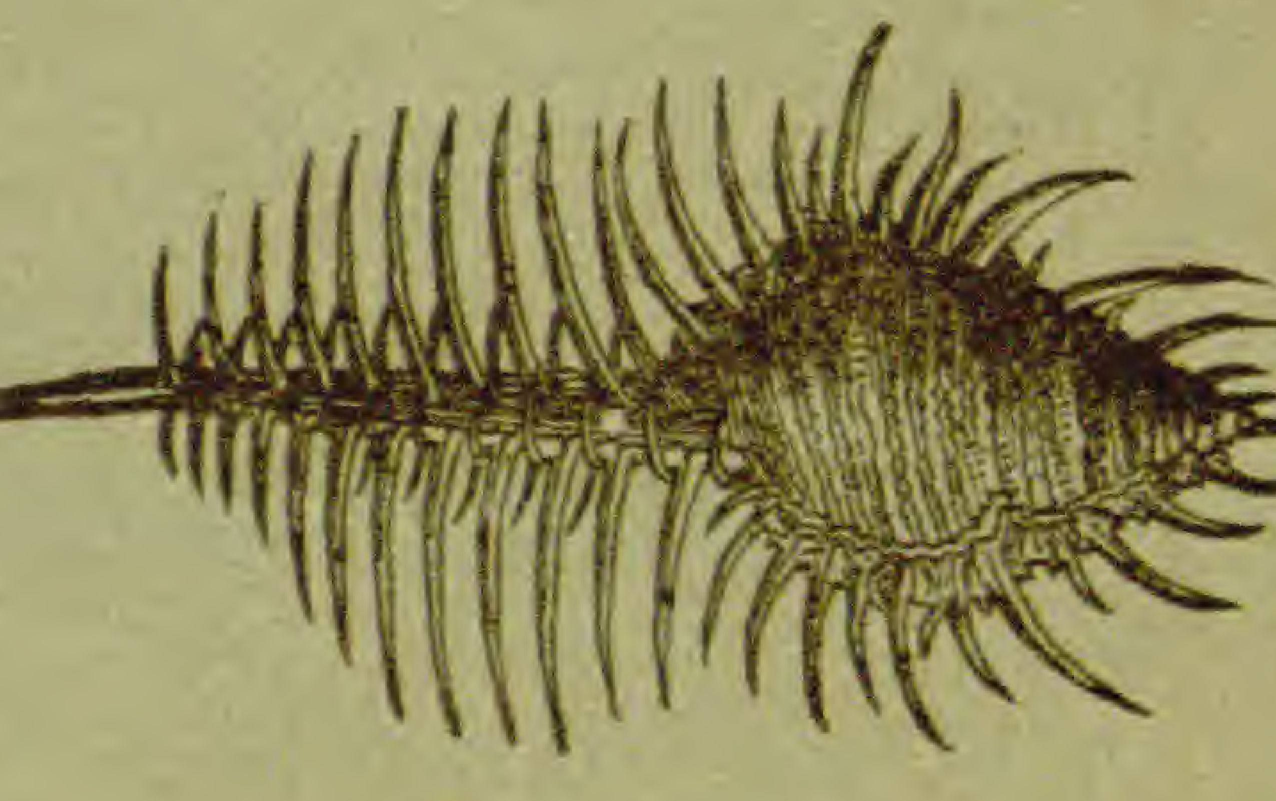

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