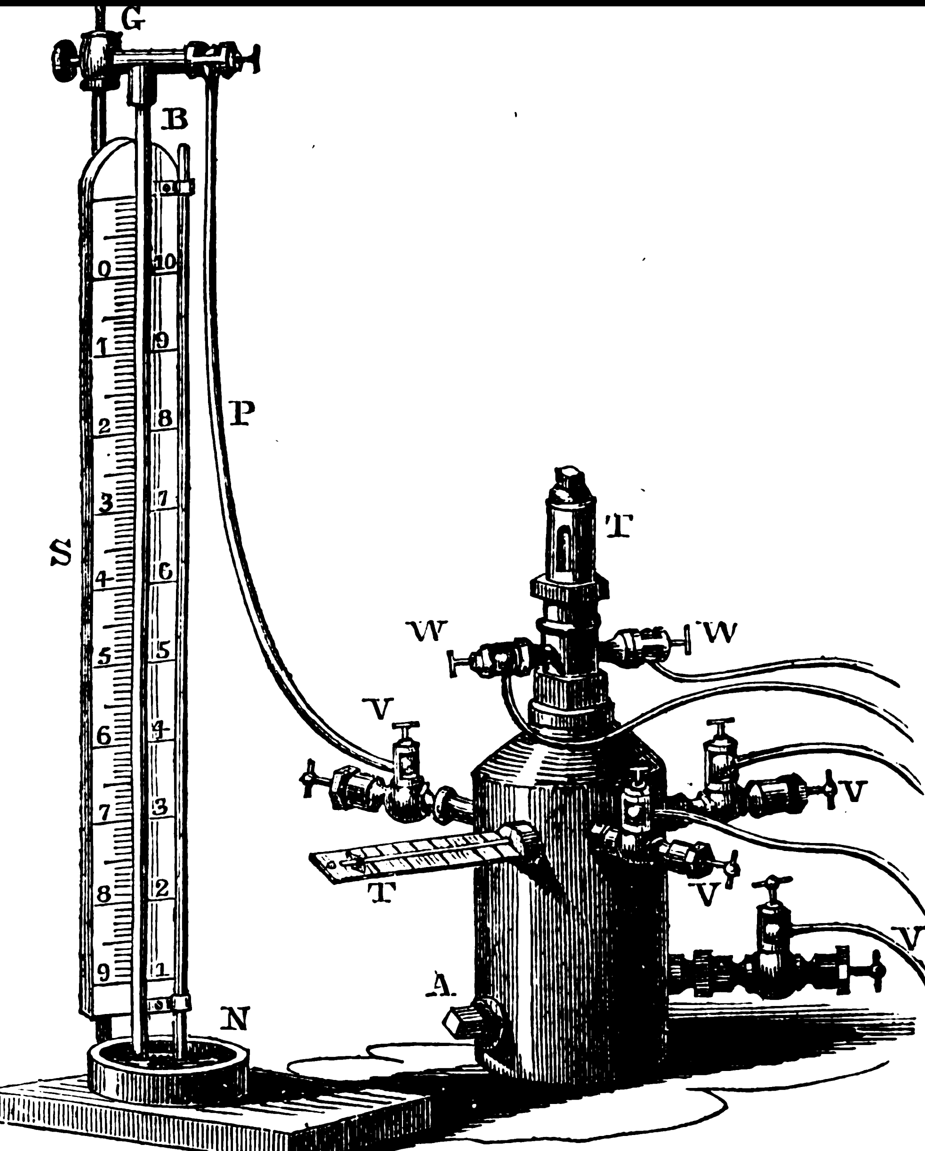

The American Journal of Science and Arts

ACKNOWLEDGMENTS TO CORRESPONDENTS, FRIENDS AND STRANGERS.

Remarks.—This method of acknowledgment has been adopted, because it is not always practicable to write letters, where they might be reasonably expected; and still more difficult is it to prepare and insert in this Journal, notices of all the books and pamphlets which are kindly presented, even in cases, where such notices, critical or commendatory, would be appropriate; for it is often equally impossible to command the time requisite to frame them, or even to read the works; still, judicious remarks, from other hands, would usually find both acceptance and insertion.

In public, it is rarely proper to advert to personal concerns; to excuse, for instance, any apparent neglect of courtesy, by pleading the unintermitting pressure of labor, and the numerous calls of our fellow-men for information, advice, or assistance, in lines of duty, with which they presume us to be acquainted.

The apology, implied in this remark, is drawn from me, that I may not seem inattentive to the civilities of many respectable persons, authors, editors, publishers, and others, both at home and abroad. It is still my endeavor to reply to all letters which appear to require an answer; although, as a substitute, many acknowledgments are made in these pages, which may sometimes be, as now, in part, retrospective.—*Ed.*

DOMESTIC.

An Address before the Law Association of the City of New York, by the Hon. James Kent. Two copies; one from the Author, the other from B. D. Silliman, Esq.

Report on a Geological Survey of the State of Ohio. Three copies, from Mr. Seabury Ford, R. Granger, Esq. and Dr. S. P. Hildreth.

Lecture before the Law Class of Transylvania University, by Geo. Robertson, LL. D. From J. G. Martin, Esq.

A Friend to the South. Boston, 1836.

Letter of Rev. Wm. E. Channing to James G. Birney. Author.

Essay on the influence of Tobacco upon life and health; by R. D. Mussey, M. D. Boston, 1836. From the Author.

A Catalogue of Plants and Shells, found near Milwaukee, on the shores of Lake Michigan; by J. A. Lapham. Two copies, one for Yale Nat. Hist. Society; from the author.

Address before the Alumni of Hanover College, Indiana; by M. A. H. Niles, A. M. From Prof. W. M. Dunn.

Providence Daily Journal, Vol. VIII, No. 141.

Connecticut Courant, Vol. IV, No. 50.

The Specie Circular—Speech of Mr. Webster, (of Mass.) From Hon. Abbott Lawrence.

Catalogue of Willoughby University, Lake Erie, Circular No. 4.

Catalogue of the Faculty and Students in the Medical School at Fairfield, Herkimer County, N. Y. 1836-37. From Dr. Mussey.

Catalogue of Books for 1837, chiefly published or imported by Hilliard, Gray & Co. Boston; from them.

Journal of the American Temperance Union, Nos. 1 and 2.

Temperance Recorder, No. 1.

A Compendium of Chemistry; by Robert Hare, M.D. Prof. of Chemistry, Univ. Penn. Third edition. From the Author.

Catalogue of Oberlin Institute, 1836-37.

First Annual Report of the Pennsylvania State Geologist. Two copies, from H. R. Trego, Esq. and E. Chauncey, Esq.

The Anti-Slavery Record, Vol. III. No. 1. E. Wright, Editor.

Correspondence of the American Bible Society, No. 7. From the Editor.

An Elementary Treatise on Astronomy, by John Gummere, A.M. Philadelphia, 1837. From the Author.

Mr. Cushing's Oration before the literary societies of Amherst College. From Mr. C. F. Smith.

Daily Buffalo Journal, with notices of the aurora and magnetism, Dec. 5, and Jan. 27 and 30, 1837. Mr. Haskins.

Boston Daily Advertiser, Vol. 42, Nos. 13,900 and 13,908, with notices of floating pumice stone on the coast of California.

New England Spectator, Boston, Vol. iii. No. 2. E. Thorp.

Gambier Observer, Vol. vii. No. 4.

Mr. Featherstonhaugh's Geological Report from Washington, by Green Bay and the Wisconsin Territory, to the Coteau de Prairie, &c. Two copies, one from Hon. S. Fowler, M. C. the other from Col. Abert.

Hints on the cultivation of the Mulberry, with some general observations on the production of Silk, by Lewis Tinelli, LL. D., C. L. Pavia, &c. The Author.

First Report on the Geological Survey of New York. Four copies, one to Am. Geol. Soc. one to Y. Col. Nat. Hist. Society. To the Editor, by E. Emmons, W. W. Mather and E. Briggs.

Another copy, from H. W. Taylor.

Report of Hon. Henry Clay on the address of certain British, and the petition of certain American authors on copyright. Hon. G. Tomlinson, S. U. States.

The Alabama Reporter, Vol. i. Nos. 4 and 5.

Columbia Telescope, Vol. xxiii. No. 7. From E. Adams, jr.

Genesee Farmer, Vol. vii. No. 5. Dr. Marsh, with meteorological observations.

Project and Act for a Statistical Society in New York. Ed. Williams.

Catalogue of the Medical College of S. C. Prof. C. U. Shepard.

Account of Saml. Raub, Jr.'s safety apparatus for steam boilers. Hon. G. Tomlinson, S. U. States.

Fourth Annual Report of the Trustees of the State Lunatic Hospital at Worcester. From the Superintendent, Dr. S. B. Woodward.

American Advocate of Peace, Hartford, Dec. 1836. F. Fellows, Editor.

Letter to Hon. W. H. Smith on School District Libraries, Genesee, 1837.

Laws of the University of Nashville, Tenn.

Catalogue of Indiana Theological Seminary and Hanover College, 1836-7. Prof. Dunn.

Jewett's Advertiser, Vol. ii. No. 10, and Vol. iii. No. 1 and 2. The Editor.

Milwaukee Advertiser, Vol. i. No. 29, with a map and notice of an ancient city in the Wisconsin Territory. J. A. Lapham.

The same in a Springfield paper, Illinois. J. W. Beach, Nashville, Illinois.

5th Annual Report of the Trustees of the New England Institution for the education of the blind—Boston, 1837. Dr. Saml. G. Howe.

Report of John L. Riddell, M. D. on a Geological Survey of Ohio. The Author.

Dr. Robley Dunglison's Address to the Medical Graduates of the Jefferson Medical College. The Author.

A second copy, from an unknown hand.

Annual Report of the Common Schools, Academies and Colleges of Pennsylvania, by Th. H. Burrowes, Superintendent.

First Report on the Geology of Maine, with an atlas of plates, by Dr. Charles T. Jackson. Two copies. The Author.

Summary of Meteorological Observations—last half of 1836—Lexington, Ky. By Dr. Robert Peters. The Author.

The Juvenile Lyceum, New Brunswick, N. J. Vol. i. Nos. 10 and 11.

FOREIGN.

Brighton Gazette and Lewes Observer. Nos. 822 and 825. From Dr. Mantell, Eng.

Brighton Herald, No. 1574, Feb. 18, 1837. The same.

Report addressed by the Royal Soc. of Northern Antiquaries to its British and American members. Copenhagen, 1836.

Annals of Electricity, Magnetism and Chemistry, conducted by William Sturgeon. London. Vol. i. No. 1, 1836. Oct. From the Author.

Researches on Heat. 2d series, 4to. By Prof. J. D. Forbes, Edinb. 1836. The Author.

On the application of Glass for metal balance springs in chronometers. From Messrs. Arnold & Dent, London.

Neues Jahrbuch sur Mineralogie, Geognosie, &c. 3 Nos. 1836. Prof. Leonhard & Bronn, Heidelberg, Germany.

A descriptive Catalogue of the Mantellian Museum, Brighton, Eng. 4th ed. 1836. Three copies. From Dr. Mantell.

Thoughts on a Pebble. London, 1836. Two copies. From Mr. W. B. D. Mantell.

Essay on the German Language and Literature. By G. F. Richardson, Esq. Brighton, Eng. From the Author.

A Letter to the School Masters and Governesses of England and Wales. By Sir Richard Phillips. London. From Dr. Mantell.

New Works and New Editions. Messrs. Longman & Co.

Proceedings of the Geol. Soc. of London. Vol. ii. No. 41. The Society.

Phillips' Aphorisms—a century of original ones.

The Mining Journal, &c. No. 63 to 71. Vol. iii. inclusive.

The same, No. 72 to 75, Vol. iv. The Editor.

Conjectures on the future effects of Locomotion by Steam. By Horace Smith, Esq. From Dr. G. Mantell.

Geology and Natural History of the Province of Kemaon, Calcutta, Bengal, 1835. By Asst. Surgeon McLelland. From the Author, through Otis, Broaders & Co. Boston, U. S.

L'Institut, Paris, Nos. 185 to 195 inclusive. 25th Nov. to Feb. 1837.

Bibliotheque Universelle, Geneva. No. 10. Oct. 1836.

Bulletin de la Société Geologique de France.

Tome vi. last part, feuilles 21—23.

Tome vii. three parts, feuilles 8 to 19. From the Society.

Annales de Chimie et de Physique. August and September, 1836.

THE

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BENJAMIN SILLIMAN, M. D. LL. D.

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NUMBER I. April, 1837.

MISCELLANIES.—DOMESTIC AND FOREIGN.

Appendix.

By Benjamin Silliman.

NUMBER II. July, 1837.

ERRATA.

The reader is requested to correct the following errata in Vol. XXX. of the American Journal of Science. The writer of that article, at the time of its publication was in the Indian country, on Red river, several hundred miles west of the Mississippi, where the proof sheets could not be sent to him; and it is only since his return from that part of the country, that he has seen the article in print. There are several errors in punctuation, but the verbal errors only will be noticed.

W. W. MATHER, *Mining Engineer.*

P. 326, l. 3 fr. bot. for *quality*, read *equality*.—P. 328, l. 9 fr. top, for *exhaustible*, read *expansible*; l. 11 fr. top, for *will thrust*, read *will be thrust*.—P. 329, l. 7 fr. top, for *those*, read *that*.

CORRECTION.

In Prof. Green's notice of Trilobites, in this No. p. 169, for *Asaphus Platypleurus*, read *Trimerus Platypleurus*, this correction being made in consequence of the examination of more specimens from the same locality.

Acknowledgments to Correspondents.

A letter addressed to the editor, from Key West, under date of August 14, 1836, by Lt. Benj. Alvord, of the army, mentions Ellicott's account, as published in his journal, of the meteors, which appeared near the Florida Reef, on the night of the 12th and 13th of of Nov. 1796. A copy of the Boston Columbian Centinel, dated May 14, 1803, forwarded to the editor by Mr. A. Shearman, contains an interesting notice of a great shower of meteors at Richmond, in Virginia, a little before the date named above. These communications were handed to Prof. Olmsted, of Yale College, who is well known as an ardent and successful investigator of the phenomena of meteors, and he assures us that the facts alluded to above, were before known to him, and have been cited in the accounts already published.

Several communications intended for this number, came too late, and many more are in hand; most of them will be inserted, but perhaps not without some delay.

THE

AMERICAN

JOURNAL OF SCIENCE, &c.

Art. I.—*General Remarks on the Temperature of the Terrestrial Globe and the Planetary Spaces;* by Baron Fourier.*

Translated from the French, by Mr. Ebenezer Burgess, of Amherst College.

The question of terrestrial temperature, one of the most remarkable and difficult in natural philosophy, involves very different elements which require to be considered in a general light. I have thought it would be useful to have condensed in a single essay, all the results of this theory. The analytical details here admitted, are found in works which I have already published. I was specially desirous of presenting to philosophers, in a concise table, a complete view of the phenomena and the mathematical relations which exist between them.

The heat of the earth is derived from three sources, which should first be distinctly mentioned.

1. The earth is heated by the solar rays; the unequal distribution of which causes diversities of climate.

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* TO PROFESSOR SILLIMAN.

Dear Sir—Although it is several years since they were published in France, I have never met with a translation of any of Baron Fourier's able papers on the temperature of the globe, nor seen in the English language a full view of the important principles which they develop. I have, therefore, requested Mr. Ebenezer Burgess, a tutor in Amherst College, to make a translation from the 27th No. of the *Annales de Chimie et de Physique*, of an article of Fourier, in which he gives a summary of the results to which he has come on the subject, by the use of mathematical analysis. And should your views of the value of this paper correspond with my own, I hope you may find a place for it, even at this late day, in your Journal.

With much respect,

Amherst College, July 4th, 1836. Edward Hitchcock.

2. It partakes of the common temperature of the planetary spaces; being exposed to the radiations from the innumerable stars which surround the solar system.

3. The earth preserves in its interior a part of that primitive heat which it had at the time of the first formation of the planets.

We shall separately examine each of these three causes, and the phenomena which they produce. We will show, as clearly as we are able in the present state of the science, the principal features of these phenomena. For the purpose of giving a general idea of this great question, and showing at a glance the results of our researches, we present them in the following summary, which is in some measure a synoptic table of the contents of this article, and of several which have preceded it.

The solar system is situated in a region of the universe, every point of which has a common and constant temperature, determined by the rays of light and heat which proceed from the surrounding stars. This low temperature of the planetary space, is a little below that of the polar regions of the earth. The earth would have only the same temperature with the heavens, were it not for two causes which are concurring to heat it. One is the internal heat which it possessed at its formation, a part of which only is dissipated through the surface; the other is the continued action of the solar rays, which penetrate the whole mass, and produce at the surface, the diversities of climate.

The primitive heat of the globe has no longer any sensible effect upon the surface: but it may be very great as we approach the center. The temperature of the surface does not exceed by the thirtieth of a centesimal degree, ($\frac{1}{15}$° Fahrenheit,) the lowest state to which it can ever be reduced. At first it diminished very rapidly: but at present with the greatest slowness.

The observations heretofore collected seem to show that the temperature of different points of the same vertical line, is proportional to the depth, and that this increase of temperature, as we advance towards the center, is about one degree for every thirty or forty meters. Such a result supposes a very high internal temperature. It cannot proceed from the action of the sun's rays; and it is naturally explained by the heat which belonged to the earth at its formation.

This increase of temperature, of about one degree for thirty-two meters will not always remain the same. It gradually diminishes; but many ages must elapse before it can be reduced to half its present value.

If other causes hitherto unknown, can explain the same facts, and if there exist other sources of terrestrial heat, either general or accidental, they will be discovered by comparing the results of this theory with those of observation.

The rays of heat which are continually proceeding from the sun to the earth, produce upon its surface two very distinct effects: one is periodical, and reaches no farther than the exterior crust. The other is constant. It is observed at great depths, say thirty meters, from the surface. The temperature of these places undergoes no sensible change in the course of the year; it is fixed. But it is very different in different climates; it results from the continual action of the solar rays, and from the unequal exposure of different parts of the surface between the equator and the poles. We can determine the time which must pass before the effect of the sun's rays could produce that difference in climate which now exists. All these results agree with those of the dynamic theories which have proved to us the stability of the axis of the earth.

The periodical effects of the solar heat, arise from the diurnal or annual variations. This order of facts is explained exactly, and in all its details, by the theory. The comparison of the results with the observations will serve to measure the conducting power of those substances of which the crust of the globe is composed.

The pressure of the atmosphere and bodies of water, has the general effect to render the distribution of heat more uniform. In the ocean and in the lakes, the coldest particles, or rather those whose density is the greatest, are continually tending downwards, and the motion of heat depending on this cause is much more rapid than that which takes place in solid masses in consequence of their connecting power. The mathematical examination of this effect would require exact and numerous observations. These would enable us to understand how this internal motion prevents the internal heat of the globe from becoming sensible in deep waters.

Liquids are very poor conductors of heat; but they have, like aeriform media, the property of carrying it rapidly in certain directions. This is the same property which, combining with the centrifugal force, displaces and mingles all parts of the atmosphere as well as the ocean, and maintains in them regular and immense currents.

The interposition of the air very much modifies the effects of the heat upon the surface of the globe. The solar rays traversing the atmospheric strata which are condensed by their own weight, heat them very unequally: those which are rarest are likewise coldest, because they extinguish and absorb a smaller part of the rays. The heat of the sun, coming in the form of light, possesses the property of penetrating transparent solids or liquids, and loses this property entirely, when by communication with terrestrial bodies, it is turned into heat radiating without light.

This distinction of luminous and non-luminous heat, explains the elevation of temperature caused by transparent bodies. The mass of waters which cover a great part of the globe, and the ice of the polar regions, oppose a less obstacle to the admission of luminous heat, than to the heat without light, which returns in a contrary direction to open space. The pressure of the atmosphere produces an effect of the same kind: but an effect, which, in the present state of the theory, and from want of observations compared with each other, cannot be exactly defined. Whatever it may be, we cannot doubt that the effect which should be attributed to the impression of the solar rays upon a solid body of very large dimensions, by far surpasses that which would be observed in exposing a common thermometer to the same rays.

The radiation of the most elevated strata of the atmosphere, the cold of which is very intense and almost constant, has an influence upon all the meteorogical facts of our observation; it can be rendered more sensible by reflexion from the surface with concave mirrors. The presence of the clouds which intercept these rays, mitigates the cold of the nights.

We see that the surface of the terrestrial globe is placed between a solid mass, the central part of which may surpass that of matter heated to whiteness, and an immense girdle, whose temperature is below that requisite for the congelation of mercury.

All the preceding results can be applied to other planetary bodies. They can be considered as placed in a medium whose constant and common temperature is little below that of the terrestrial poles. This same temperature of the heavens is that of the surface of the most distant planets; for the impression of the rays of the sun, even when augmented by the disposition of the superficies, would be too feeble to occasion sensible effects; and we know by the condition of the terrestrial globe, that, in the planets whose formation cannot be less ancient, there exists upon the surface no longer any elevation of temperature to be attributed to internal heat.

It is equally probable, that in respect to most of the planets, the temperature of the poles is little above that of the surrounding space, with respect to the temperature which each of these bodies owes to the sun, it is not known; because it may depend on the pressure of an atmosphere and the condition of the surface. We can only approximate to the truth in assigning the mean temperature which the earth would have acquired situated in the place of the planet.

After this exposition, we shall examine successively, the different parts of this question. We would first make a remark which has a relation to all these parts, because it is founded upon the nature of differential equations of the motion of heat. It is this: the effects of each of the three causes we have mentioned, may be calculated separately, as if it had no connection with the others. It is sufficient afterwards to unite these partial effects: *ils se superposent librement comme les dernieres oscillations des corps.*

We shall describe in the first place the principal results of the prolonged action of the solar rays upon the terrestrial globe.

If a thermometer is placed at a considerable depth below the surface of the solid earth, forty meters for example, the instrument indicates a fixed temperature. This fact is observed in every part of the globe. This temperature of deep places is always the same in the same place; but it is not the same in different climates. It generally decreases as we advance towards the poles.

If we observe the temperature of points much nearer the surface of the earth, for example, at the depth of one, five, or ten meters, we see very different effects. The temperature varies during a single day or year. But we can suppose the crust or envelop in which these variations take place, to be removed, and consider the fixed temperatures of the points of the new superficies of the globe.

We can conceive that the state of the mass has varied continually in proportion to the heat received from the origin of heat itself. This variable state of internal temperature has changed by degrees, and has approached nearer and nearer to a final state, which is subject to no change. Then each point of the solid sphere has acquired, and preserves, a temperature, a fixed temperature, which depends only on the situation of the point itself.

The final state of the mass, the heat of which has penetrated all its parts, can very justly be compared to that of a vessel which receives by openings at the top, liquid from some constant source, and permits exactly an equal quantity to escape by orifices.

Thus the solar heat has accumulated in the interior of the globe and is there continually renewed. It penetrates the parts of the surface near the equator, and is dissipated through the polar regions. The first question of this kind which has been submitted to the calculus, is found in a memoir which I read to the French Institute, at the close of the year 1807, Art. 115, page 167. This article is deposited in the archives. I then took up this first question to exhibit a remarkable example of the application of the new theory exposed in the memoir; and to show how the analysis points out the tract followed by the solar heat in the interior of the earth.

If now we replace this exterior envelop of the earth, whose points are not sufficiently deep to have a fixed temperature, we remark an order of facts more compound, the complete expression of which is given by our analysis. At a moderate depth, as three or four meters, the temperature observed does not vary during each day, but the change is very perceptible in the course of a year; it varies and and falls alternately. The extent of these variations, that is, the difference between the *maximum* and *minimum* of temperature, is not the same at all depths; it is inversely as the distance from the surface. The different points of the same vertical line do not arrive at the same time at the extreme temperatures. The extent of the variations, the times of the year, which correspond to the greatest, to the mean, or to the least temperatures, change with the position of the point in the vertical line. There are the same quantities of heat which fall and rise alternately; all these values have a fixed relation between themselves, which are indicated by experiments and expressed distinctly by the analysis. The results observed are in accordance with those furnished by the theory; no phenomenon is more completely explained. The mean annual temperature of of any point whatever in the vertical line, that is, the mean value of all those which might be observed in the course of a year, at this point, is independent of the depth. It is the same for all points of the vertical, and consequently that which would be observed immediately below the surface; it is the fixed temperature which exists at great depths.

It is evident that in the enunciation of this proposition, we make no account of the internal heat of the globe, and those accessory causes which would modify this result in a particular place. Our principal object is to ascertain general phenomena. We have before remarked that the different effects can be separately considered.

We ought likewise to observe respecting all the numerical values mentioned in this memoir, that they are presented here only as examples of the calculus. The meteorological observations proper for furnishing the necessary data, those which would show the capacity for heat and the permeability of the substances which compose the globe, are too uncertain and too limited, to enable us, by the calculus to deduce accurate results. But we mention these numbers to show, how formulas ought to be applied: and however much they may differ from true results, these values are much more suitable for giving a correct idea of the phenomena, than general expressions without their numerical application.

In those parts of the crust nearest the surface, the thermometer rises and falls during each day. These diurnal variations cease to be sensible at the depth of two or three meters. Below this we can perceive only annual variations, and these again become insensible at a still greater depth.

If the rapidity of the motion of the earth around its axis were to be infinitely increased, and the same were supposed to take place respecting its motion round the sun, the diurnal and annual variations would no longer be observed, the points of the surface would have acquired and would preserve the fixed temperatures of places at a great depth. In general the depth which we must reach in order that the variations may become insensible, has a very simple ratio to the duration of the period which reproduces the same effects at the surface. This depth is exactly proportional to the square root of the period. It is for this reason that the diurnal variations penetrate only to one nineteenth of the depth at which the annual variations are observed. The question of a periodical motion of the solar heat was examined for the first time, and resolved in a separate paper, submitted to the French Institute in October, 1809. I again brought forward this solution in a paper submitted at the close of 1811, and printed in the collection of our memoirs.

The same theory furnishes the means of measuring the quantity of heat which in the course of a year determines the succession of the seasons.

The design of this example of the application of formulas is to show that there exists a necessary relation between the laws of periodical variation and the whole quantity of heat which effects this variation: so that this law being known by observations made in a given climate, we can determine the quantity of heat which penetrates the earth and returns into the air. Considering, therefore, a law similar to this, which is established of itself in the interior of the globe, I have obtained the following results.

In one eighth of a year after the temperature at the surface is raised to its mean value, the earth begins to be heated; the rays of the sun penetrate it during six months. Then the heat of the earth takes an opposite direction; it comes out and is dissipated in the air and external space. Now the quantity of heat which undergoes these variations in the course of a year is expressed by the calculus. If the crust of the earth was formed of a metallic substance of forged iron, (the substance which I have chosen for an example, after having measured the specific coefficients,) the heat which produces the succession of the seasons, would be for the climate of Paris, and for a square meter of surface, equivalent to what would melt a cylindrical column of ice, having for its base this square meter, and a height of about three meters and one tenth. Although the value of the coefficients for substances of which the globe is composed, has not as yet been measured, we can easily see that they would give a result much less than we have just mentioned. It is proportioned to the square root of the product of the capacity for heat, considered in relation to volume and the permeability.

We will now consider the second cause of terrestrial heat, which, as we think, resides in the planetary spaces. The temperature of this space exactly defined, is that which a thermometer would indicate, supposing the instrument placed in any part of the space occupied by the solar system, and the bodies which compose this system annihilated.

We shall give a detail of the principal facts from which we have ascertained the existence of this heat, peculiar to the planetary spaces, which is independent of the presence of the sun, and of the original heat which the earth has preserved. To obtain a knowledge of this singular phenomenon, it is necessary to ascertain what would be the thermometrical state of the terrestrial mass, if it received only the heat from the sun. To facilitate this enquiry we may at first leave the atmosphere out of the account. Now if there existed no cause sufficient to give the planetary spaces a common and constant temperature, that is, if the earth and all the bodies of the solar system, were placed in space deprived of all heat, the phenomena observed would be altogether contrary to what we now witness. The polar regions would be subject to an intense cold and the decrease of temperature from the equator to the poles would be incomparably more rapid and extended.

In this hypothesis of the absolute cold of space, if it is possible to conceive of it, all the effects of heat which we observe at the surface of the earth, should be attributed to the presence of the sun. The least variations in the distance of that body from the earth, would occasion very considerable changes of temperature. The interruption of day and night, would produce effects sudden and totally different from what we observe.

The surfaces of bodies, would be exposed all at once, at the commencement of night, to a cold of infinite intensity. Animals and vegetables could not resist the sudden and powerful change which would be produced at the rising of the sun.

The primitive heat preserved in the interior of the earth could not increase the external temperature of space, and would prevent none of the effects which we have just described; for we know with certainty, by theory and observation, that the effect of this central heat has long since become insensible at the surface, although it may be very great at a moderate depth. We conclude from these observations, and chiefly from the mathematical examination of the subject, that there exists a physical cause always present which modifies the temperature at the surface of the earth, and gives this planet a fundamental heat, which is both independent of the action of the sun and that internal heat preserved in its own center. This fixed temperature, which the earth receives from space, differs but little from that which is measured at the poles. It is necessarily less than that of the coldest regions; but in this comparison we ought to admit only accurate observations, and should not consider the accidental effects of a very intense cold which may be caused by evaporation, by violent winds, and extraordinary dilatation of air.

After ascertaining the existence of this fundamental temperature of space, without which the effects of heat observed upon the surface of our globe could not be explained, we proceed to remark, that the origin of this phenomenon, thus to call it, is evident. It is to be attributed to the radiation from all the bodies in the universe, whose light and heat can reach us; the stars visible to the naked eye, the innumerable multitude of telescopic stars or opaque bodies, which fill the universe, the atmospheres which surround these immense bodies, the rare matter disseminated through every part of space, concur in forming rays which penetrate every part of the planetary regions. We cannot conceive of the existence of such a system of luminous and heated bodies without admitting that any point of space whatever which contains these bodies acquires a fixed temperature.

The immense number of bodies compensates for the inequalities in their temperatures, and renders radiation sensible and uniform.

This temperature of space is not the same in different regions of the universe; but it does not vary in the regions in which are situated the planetary bodies; because the dimensions of this space are incomparably smaller than those distances which separate it from the radiating bodies; for example, in all points of the orbit of the earth this planet finds the same temperature.

It is the same with other planets of our system: they all equally participate in the common temperature, which is more or less augmented for each one of them, by the rays of the sun, according to the distance of the planet from that body. Respecting the inquiry what must be the temperature of each of the planets, the principles which must settle it, furnished by an exact theory, are as follows. The intensity and distribution of heat on the surface of these bodies results from the distance of the sun, the inclination of the axes of rotation to the orbit, and the state of the surface. It is very different even in its mean value, from what would be indicated by a thermometer insulated in the place of the planet, for the solid state, the very great dimensions, and doubtless the presence of an atmosphere and the nature of the surface, determine the mean value.

The original heat which has been preserved in the interior, has long since ceased to have a very sensible effect upon the surface. For the present state of the crust of the earth shows us that the primitive heat of the surface is almost entirely dissipated. From the constitution of the solar system it is very probable that the temperature of the poles of each planet, or at least of the greatest part of them, is little less than that of space. This polar temperature is the same for all these bodies, although their distances from the sun may be unequal.

We can determine with some degree of precision, the temperature which the earth would have acquired if situated in the place of each of the planets; but the temperature of the planets themselves, cannot be ascertained; for in order to that we must know the state of the surface and the atmosphere. However, this uncertainty no longer exists as to the bodies which are placed at the extremities of the solar system like the planet Uranus. The impression of the solar rays upon this planet is evidently insensible. The temperature of the surface differs therefore, very little from that of planetary spaces, or from that which is observed at the poles of our globe. We have made known this last result in a discourse recently delivered before the Academy. It is evident we can apply it only to the most distant planets. We know of no means of assigning with any precision the mean temperature of the other planetary bodies. The motion of the air and waters, the extent of the seas, the elevation and form of the surface, the effects of human industry and all the accidental changes of the earth's surface, modify the temperatures of each climate. The character of phenomena attributable to general causes exists: but the thermometrical effects observed at the surface are different from what they would be without the influence of accessory causes.

The motion of the waters and of the air, tends to modify the effects of heat and cold.

It renders their distribution more uniform, but it would be impossible for the atmosphere to supply the place of that universal cause which supports the common temperature of the planetary spaces; and if this cause did not exist, we should observe, notwithstanding the atmosphere and seas, an enormous difference between the temperatures of the equatorial and polar regions.

It is difficult to know how far the atmosphere influences the mean temperature of the globe; and in this examination we are no longer guided by a regular mathematical theory. It is to the celebrated traveller, M. de Saussure, that we are indebted for a capital experiment, which appears to throw some light on this question.

The experiment consists in exposing to the rays of the sun, a vessel covered with one or more plates of glass, very transparent, and placed at some distance one above the other. The interior of the vessel is furnished with a thick covering of black cork, proper for receiving and preserving heat. The heated air is contained in all parts, both in the interior of the vessel and in the spaces between the plates. Thermometers placed in the vessel itself and in the intervals above, mark the degree of heat in each space. This instrument was placed in the sun about noon, and the thermometer in the vessel was seen to rise to 70°, 80°, 100°, 110°, (Reaumur,) and upwards. The thermometers placed in the intervals between the glass plates indicated much lower degrees of heat, and the heat decreased from the bottom of the vessel to the highest interval.

The effect of solar heat upon air confined within transparent coverings, has long since been observed. The object of the apparatus we have just described, is to carry the acquired heat to its *maximum*; and especially to compare the effect of the solar ray upon very high mountains, with what is observed in plains below. This experiment is chiefly worthy of remark on account of the just and extensive inferences drawn from it by the inventor. It has been repeated several times at Paris and Edinburgh, and with analogous results.

The theory of the instrument is easily understood. It is sufficient to remark, 1st, that the acquired heat is concentrated, because it is not dissipated immediately by renewing the air; 2d, that the heat of the sun, has properties different from those of heat without light. The rays of that body are transmitted in considerable quantity through the glass plates into all the intervals, even to the bottom of the vessel. They heat the air and the partitions which contain it. Their heat thus communicated ceases to be luminous, and preserves only the properties of non-luminous radiating heat. In this state it cannot pass through the plates of glass covering the vessel.

It is accumulated more and more in the interval which is surrounded by substances of small conducting power, and the temperature rises till the heat flowing in, shall exactly equal that which is dissipated. This explanation might be verified, and the results made more apparent, by varying the conditions and employing colored or blackened glasses, and exhausting the air from the intervals which contain the thermometers. When this effect is examined by the calculus, results are obtained in exact accordance with those of observation. It is necessary to consider attentively this order of facts, and the results of the calculus when we would ascertain the influence of the atmosphere and waters upon the thermometrical state of our globe.

In short, if all the strata of air of which the atmosphere is formed, preserved their density with their transparency, and lost only the mobility which is peculiar to them, this mass of air, thus become solid, on being exposed to the rays of the sun, would produce an effect the same in kind with that we have just described. The heat, coming in the state of light to the solid earth, would lose all at once, and almost entirely, its power of passing through transparent solids: it would accumulate in the lower strata of the atmosphere, which would thus acquire very high temperatures. We should observe at the same time a diminution of the degree of acquired heat, as we go from the surface of the earth.

The mobility of the air, which is rapidly displaced in every direction, and which rises when heated, and the radiation of non-luminous heat into the air, diminish the intensity of the effects which would take place in a transparent and solid atmosphere, but do not entirely change their character. The decrease of heat in the higher regions of the air does not cease, and the temperature can be augmented by the interposition of the atmosphere, because heat in the state of light finds less resistance in penetrating the air, than in repassing into the air when converted into non-luminous heat. We shall now consider that peculiar heat which our globe had at the time of the formation of the planets, and which continues to be dissipated at the surface under the influence of the low temperature of the planetary space.

The opinion of an internal fire as a perpetual cause of many remarkable phenomena, has been renewed in every age of philosophy. The end we have in view at this time, and which the latest progress of mathematical science enables us to reach, is to ascertain exactly by what laws a solid sphere heated by a long immersion in a medium, would discharge that primitive heat if it were transported into a space of a constant temperature inferior to that of the first medium. The design of the experiment is, to ascertain if the present temperature of the surface of the globe can yet undergo any sensible changes. The form of the terrestrial spheroid, the regular order of the lower strata, made manifest by experiments with the pendulum, their density increasing with the depth, and divers other considerations, concur in proving that a heat of very great intensity has at some previous period penetrated every part of the globe. This heat is dissipated by radiation into surrounding space, which has a temperature much below that of the congelation of water. Now the mathematical expression for the law of cooling shows that the primitive heat contained in a spherical mass of as great dimensions as the earth, diminishes much more rapidly at the surface than in parts situated at a great depth. These latter preserve almost all their heat for an immense period of time. There can be no doubt respecting the truth of these results, because we have calculated these times for metallic substances, which have a greater conducting power than those of which the globe is composed.

But it is evident that theory alone can only teach us the laws to which phenomena are subject. It remains now to inquire whether in penetrating the earth, we find any indications of a central heat.

We must ascertain, for example, whether the temperature increases with the depth as we go below those points whose diurnal and annual variations have ceased to be sensible. Now all observations collected and examined by the most learned philosophers of our day, show us that such an increase actually exists. It has been estimated at about one degree for thirty or forty metres. The experiments with which we have lately entertained the Academy, relating to the heat of springs, confirm the results of preceding observations.

The object of the inquiry we propose, is to discover the certain consequences of this single fact, admitting it to be given by direct observation; and to prove that it determines, first, the situation of the source of heat, and, secondly, the excess of temperature which still exists at the surface.

It is easy to conclude, (and the same result is obtained from an exact analysis,) that the increase of temperature as we go towards the centre cannot be produced by a prolonged action of the sun's rays. The heat proceeding from that body is accumulated in the interior of the earth; but the progress has almost entirely ceased, and if the accumulation was still continued, we should observe that increase in a direction precisely contrary to what we have mentioned. The cause which gives to deep strata a higher temperature, is, therefore, an internal source of constant or variable heat, situated below where man has been able to penetrate. This cause raises the temperature of the surface above what it would have been from the simple action of the sun's rays. But this excess of temperature of the surface has become almost insensible. Of this we are assured, because there exists a mathematical ratio between the value of increase by metre and the quantity, by which the temperature of the surface still exceeds that which would be found, if the internal cause of which we are speaking did not exist. To measure the increase by unity of depth, is the same thing as to measure the excess of temperature at the surface.

In a globe of iron the increase of a thirtieth of a degree per metre, would only give a fourth degree of actual elevation of temperature at the surface. This elevation is in direct ratio to the conducting power of the substance of which the crust is formed, all other conditions remaining the same. Thus the excess of temperature, which the terrestrial surface has at present, in consequence of this internal source, is very small; it is probably below the thirtieth of a centesimal degree, ($\frac{1}{17}$° Fahrenheit.) We ought to remark that this last result can be applied to all suppositions which can be made upon the cause, whether it be regarded as local or universal, constant or variable.

When we examine all the observations relative to the figure of the earth attentively, and according to principles of dynamics, we cannot doubt that the earth received at its origin a very high temperature. On the other hand, thermometrical observations show that the actual distribution of heat in the crust of the earth, is precisely what it would be if the earth had been formed in a medium of very high temperature, and had afterwards been left gradually to cool. It is important to notice the agreement of these two kinds of observations.

The question of terrestrial temperature has always appeared to us as one of the most important inquiries relating to cosmogony; and we have had this principally in view in establishing the mathematical theory of heat. From the commencement of our researches we have been desirous of ascertaining the laws of internal temperature in a solid sphere, heated at first by immersion in a medium, and afterwards left to cool in a medium of lower temperature. The memoir of 1807, before cited, contains a complete solution of that question, which was never before examined.

We have therefore determined the variable state of a globe, of a substance whose specific qualities we know, by experiment, and which after being immersed for some time in a heated medium, is transported to a colder space. We have considered likewise the variable state of a sphere which, having been plunged successively and for some time in two or more media of different temperatures, should undergo a final cooling in a medium of constant temperature.

After having noticed the general consequences of the solution of that question, we have examined particularly the case in which the primitive temperature acquired in a heated medium, might become common to the whole mass. And supposing the solid sphere to be of very great dimensions, we have endeavored to ascertain the law of progressive diminution of temperature in those strata nearest the surface. If we apply the results of this analysis to our globe, to ascertain what would be the successive effects of a primitive formation like that we have just supposed: we find that the increase of a thirtieth of a degree per metre, considered as the resultant of central heat, has in former periods been much greater, and that this increase is now almost a constant quantity, since more than thirty thousand years must elapse before it would be reduced to half its present value.

Respecting the excess of temperature at the surface, it varies according to the same law. The quantity by which it diminishes each century, is equal to the present value divided by double the number of centuries which have elapsed since the cooling process commenced: and since the limit of this number is given by historical monuments, we conclude that, from the Greek school at Alexandria, till the present time, the temperature of the surface has not diminished, on this account, the three hundredth part of a degree, ($\frac{1}{160}$° Fahrenheit.) Here again we find that stability which the great phenomena of the universe every where present. This stability, furthermore, is a necessary result, and independent of the primitive state, since the present excess of temperature is extremely small, and will diminish for an infinite length of time.

The effect of the primitive heat which our globe still preserves, has become nearly insensible at the surface of the crust; but it becomes more sensible at accessible depths, since the temperature augments with the distance from the surface. This augmentation, considered by unity of measure, would not have the same value for depths very much greater. It diminishes with this depth; but the same theory shows that the excess of temperature, which is almost nothing at the surface, can become enormous at a distance of some thousands of metres, so that the heat of the intermediate strata would exceed by far that of substances heated to whiteness.

The course of centuries will produce great changes in these internal temperatures; but at the surface these changes are at an end, and the continual loss of internal heat cannot hereafter occasion any cooling of climate.

It is important to remark, that the mean temperature of any place may undergo, from other accessory causes, variations more sensible by far than those which are produced by the continued cooling of the globe.

The establishment and progress of human society, and the action of natural powers, may, in extensive regions, produce remarkable changes in the state of the surface, the distribution of the waters, and the great movements of the air. Such effects, in the course of some centuries, must produce variations in the mean temperature for such places; for the analytical expressions contain coefficients which are related to the state of the surface, and have a great influence on the temperature.

Although the effect of internal heat may be no longer sensible at the surface, the sum total of this heat which escapes in a given time, as in a year or a century, is measurable, and has been ascertained. That which escapes in a century through a square metre, and is dissipated in the celestial space, would melt a column of ice, of which the base should be a square metre, and height three metres.

This result is derived from a fundamental proposition, which can be applied to all questions relating to the motions of heat, and especially to that of terrestrial temperature. I allude to the differential equation, which expresses for each moment the state of surface. This equation, the truth of which is plain, and easily demonstrated, establishes a simple relation between the temperature of an element of the surface and the normal motion of heat. What renders this result of theory very important, and more valuable than any other for throwing light upon the questions which form the subject of this article, is, that it exists independent of the form and dimensions of bodies, and of the nature of the substances, whether homogeneous or not, of which the internal mass may be composed. The results of this equation are absolute: they are the same, whatever may have been the material constitution or original state of the globe.

We have published in the "*Annales de Chimie et de Physique,*" the abstract of a memoir, which has not yet been printed, and the object of which is to apply to the terrestrial globe the analyses of the motions of heat in a sphere or plane solid, of great dimensions. In that extract the principal formulas were exhibited, particularly those which express the variable state of a solid uniformly heated at a determinate and very great depth, or in its whole depth. If the original temperature, instead of being the same to a very great depth, results from successive immersions in several media, the consequences are not less simple or remarkable. But this case, and several others which we have considered, are comprised in the general expressions which have been mentioned.

After having explained separately the principles of the inquiry respecting the temperature of the earth, in order to form a correct idea of these phenomena united, we ought to give, in a general statement, all the effects we have just described.

The earth receives the rays of the sun, which penetrate its mass, and are converted into non-luminous heat: it likewise possesses an internal heat with which it was created, and which is continually dissipated at the surface: and lastly, the earth receives rays of light and heat from innumerable stars, in the midst of which is placed the solar system. These are three general causes which determine the temperature of the earth. The third, that is, the influence of the stars, is equivalent to the presence of an immense hollow sphere, with the earth in the center, the constant temperature of which should be a little below what would be observed in the polar regions.

We might, doubtless, suppose radiating heat to possess properties hitherto unknown, which might, in some way, take the place of this fundamental temperature, which we attribute to space. But in the present state of physical science, all known facts are naturally explained without having recourse to other properties than those derived from actual observation. It is sufficient to represent the planetary bodies as occupying a space, the temperature of which is constant. We have endeavored, therefore, to ascertain what this temperature ought to be, in order that the effects on the thermometer should be what we now observe. Now they would be entirely different if we were to admit an absolute cold in space: but if we progressively increase the common temperature of the girdle or hollow sphere which encloses this space, we should see effects produced similar to what we now witness. We can, therefore, affirm, that the actual phenomena are such as would be produced if radiation from the stars was giving this temperature to all points of the planetary space. The primitive internal heat which is not yet dissipated, produces now but a very slight effect upon the surface of the earth: it manifests itself by an increase of temperature at great depths. At still greater distances from the surface it may exceed the highest temperatures which have ever been measured.

The effect of the solar rays is periodical in the superficial strata of the terrestrial crust. It is fixed in all points of great depths. This fixed temperature of the internal parts is not the same for all points. It depends principally upon the latitude of the place.

The solar heat has accumulated in the interior of the globe, the state of which has become unchangeable. That which penetrates in the equatorial regions is exactly balanced by that which escapes at the parts around the poles. Thus the earth gives out to celestial space all the heat which it receives from the sun, and adds a part of what is peculiar to itself.

All the terrestrial effects of solar heat are modified by the interposition of the atmosphere and the presence of water. The great motions of these fluids render the distribution more uniform. The transparency of the waters appears to concur with that of the air in augmenting the degree of heat already acquired, because luminous heat flowing in, penetrates, with little difficulty, the interior of the mass, and non-luminous heat has more difficulty in finding its way out in a contrary direction.

The succession of the seasons is maintained by an immense quantity of solar heat, which oscillates in the crust of the earth, passing below the surface during one half of the year, and returning into the air in the other half. Nothing can contribute more to throw light upon this part of the inquiry than the experiments, the object of which is, to measure with precision the effects of the solar rays upon the earth's surface. For this reason, we heard with the greatest interest the reading of the memoir presented by Prof. Pouillet; and if in the course of this article we have not mentioned his experimental researches, it is simply from the wish not to anticipate the report which will soon be made.

I have united in this article all the principal elements of the analysis of terrestrial temperature. It is made up from the results of my researches long since given to the public. When I began the investigation of such questions there existed no mathematical theory of heat, and we might well have doubted that such a theory could be possible. Those memoirs and treatises in which I have established this theory, and which contain the exact solution of the fundamental questions, have been submitted and publicly read, or printed and analyzed in the "*Recueils Scientifiques,*" of the last few years. The object of this last article is to invite attention to one of the most important questions of natural philosophy, and to present general views and results. It would be impossible to resolve all doubts connected with a subject so extensive; which comprises, besides the results of a new and different analysis, physical considerations very varied in their natures. Exact observations will hereafter be multiplied. The laws on which depends the motion of heat in liquids and air, will be studied. Perhaps other properties of radiating heat will be discovered, or causes which modify the temperatures of the globe. But all the principal laws of the motion of heat are known. This theory, which rests upon immutable foundations, constitutes a new branch of mathematical science. It is composed, at present, of differential equations of the motion of heat in solids and liquids, and of the integrals of these first equations, and theorems relative to the equilibrium of radiating heat.

These theories will be hereafter much farther extended, and nothing will contribute more to bring them to perfection than numerous series of exact experiments; for mathematical analysis can deduce from general and simple phenomena, the expressions of the laws of nature; but the application of these laws to very complicated effects, requires a long course of accurate observations.

ART. II.—*Account of an Excursion to Mount Katahdin, in Maine;* by J. W. BAILEY, Acting Professor of Chemistry, &c. U. S. Military Academy, West Point.

TO PROFESSOR SILLIMAN.

Sir—During a short visit which I made this summer to Waterville, in Maine, my curiosity was excited by the accounts I read and heard concerning Mount Katahdin, the highest mountain in the State. Its elevation and isolated position, together with the traditionary legends of the Penobscot Indians, that Katahdin is the residence of evil spirits, have given to this mountain considerable local celebrity. It has, however, been visited by few white men, and of their observations no accurate accounts have been published. Not being aware of the proposed geological survey of the State, (which, since my return, I learn has been assigned to able hands,) and in hopes that by visiting this mountain some interesting geological and botanical observations might be made, I proposed to Prof. Keely of Waterville College an excursion, on which Prof. Barnes of the same institution promised to accompany us.

In this communication, the object of which is to give a sketch of our journey and observations, I have purposely entered into some details, which may appear too trivial for admission into a scientific journal, but I believe these will be useful, by giving to any persons who may wish to visit Katahdin some idea of the manner of life they may expect to lead, the preparations to be made, and the route to be pursued.

Having procured a light wagon, Mr. Keely and myself proceeded on Saturday, the 6th of August, for Bangor. Our route lay through Clinton, Dixmont and Hampden. The rock passed over this day was argillite or graywacke slate, divided into very thin, nearly vertical laminæ, slightly dipping to the southeast. The direction or