TRANSACTIONS

OF THE

NEW YORK ACADEMY OF SCIENCES.

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TRANSACTIONS

OF THE

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TRANSACTIONS

OF THE

NEW YORK ACADEMY OF SCIENCES.

October 4, 1886.

REGULAR BUSINESS MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Forty-four persons present.

The Report of the Council was received and adopted, recommending the acceptance of the resignation of Mr. George A. Plimpton, and the payment of certain bills.

The secretary presented a resolution proposing the following changes in the By-laws:

I. To insert in Chapter IV. the following section, to be numbered Section 5, and the other sections to be renumbered accordingly:

5. The librarian shall have the immediate supervision and care of the library, under the general authority of the library committee of the council. All accessions to the library shall pass through his hands, and he shall enter the titles to the same in a suitable book kept for that purpose. He shall indelibly stamp every book, pamphlet, paper, or other matter, with the stamp of the society, as prescribed by the library committee or council. He shall periodically make a detailed report of accessions, and on the fourth Monday in February shall make an annual report on the condition of the library.

II. In Chapter VIII., Section 1, to change the term "*five dol-*

lars" to "*ten dollars*" wherever it designates the amount of fees or dues.

III. To append to Section 4, Chapter VIII., the following: By a two-thirds vote of the members and fellows present at any regular business meeting of the society, provided that such action shall have been recommended by the council, and at least one month's notice given in writing to the delinquent to show cause why such erasure should not be made.

IV. In Chapter IX., Section 1, to change the word "Proceedings" to "Transactions."

V. In Chapter XIV., to insert the following as "Section 4:" The rules of order as set forth in "Cushing's Manual of Parliamentary Proceedings," shall be accepted as authoritative in the meetings of the society.

VI. To insert as Section 2, in Chapter XVI., the following: Any member or fellow may be censured, suspended, or expelled for violation of the Constitution and By-laws, or for any other offense deemed sufficient, by a vote of three-fourths of the members and three-fourths of the fellows present at any regular business meeting, *provided* that such action shall have been recommended by the council at a regular business meeting, and one month's notice of such recommendation and of the offense charged shall have been given the member accused.

MR. WILLIAM E. HIDDEN read an informal paper on

A NOTABLE DISCOVERY OF PRECIOUS STONES IN ALEXANDER COUNTY, N. C.

On the 2d and 9th of last August, discoveries of emeralds and hiddenites were made at the mine of the Emerald and Hiddenite Mining Co., which are well worth noting before this Academy.

Not since 1882 has such an important "find" been made at this mine, and in several respects the last discovery exceeds all previous record of this mine's output.

Up to this year, the largest crystal found of the emerald-green spodumene, known in the gem-markets as hiddenite and lithia emerald, had only furnished a gem of two and five-eighths karats weight, valued at about $300; but the "find" of August 2d will yield gems of perhaps double this weight, of very beautiful color. One twin crystal (which is here exhibited) weighs one-half ounce in its rough state, and has been appraised at $900 valuation by a competent and well-known dealer in precious stones. Several of the best crystals are more than one inch long, and are twinned like the last-mentioned crystal. In all about ten ounces of good material was found, out of which twenty to thirty pieces will cut fine gems of high market value.

This "find" was made at a depth of only six feet, and at a place distant about five rods from the old original discovery site. As in previous cases, the associated minerals were quartz crystals, rutile, and mica (?), with a vein filling of lithomarge in which the gem crystals were imbedded.

On August 9th, at a place yet nearer the shaft of this company, a discovery of emeralds was made which in themselves were the greatest encouragement that this locality (Alexander Co.) has ever given, as proving the existence in that region of fine emerald gems. A narrow ledge of outcropping opaque quartz was worked down upon to a depth of fifteen feet, where the quartz became clearer, and a "pocket" began to show itself. Crystals of quartz and of muscovite (?) in profusion were found within the next foot of the vein, imbedded in lithomarge (kaolin-like clay of a light-brown color), all in rare perfection of form and material. In the next three feet of the vein (it was once an open pocket), imbedded in the lithomarge, I took out eight of the best crystals of emerald which the locality has furnished since 1882. In point of uniform color, and of crystallographic interest, the "find" was peculiar to itself. The best emerald weighed eight and three-quarter ounces, was one and three-quarter inches thick, and three inches long. All the crystals of emerald were wholly or in part doubly terminated and of pure hexagonal forms, with a flat terminal plane. Two crystals had a very low pyramid occurring partly developed, which may be new to science when its angle is measured. Faces of the secondary prism and of secondary pyramids were only present in traces. The crystals had a very uniform thickness, of about two-thirds their length, with end faces of superb polish. One crystal, the second in size, had implanted upon a prismatic face a crystal of rutile in perfectly parallel position (axially) to that of the emerald. This is curious, for the reason that the two minerals are so diverse in composition and so dissimilar in form. Altogether, the eight crystals of emerald weighed twenty-one ounces.

Shortly before these "finds" were made, a pocket, the sixth in regular succession of a vein of "pockets," was opened at a depth of forty-three feet in the old shaft, and among a handful of inferior emeralds one was found which yielded a fine-cut gem of four and five-eighths karats weight, which gem is very probably the finest cut emerald exhibited in the United States.

The value, intrinsically, of these gem discoveries is not far from $5,000, which is a most tangible encouragement for future work. Of interest, perhaps, is the fact that for the past four years all the work done at this mine has been a source of profit to the Emerald and Hiddenite Mining Company, and thus with good reason we can feel proud of this new undertaking in mining *exclusively for gems.* Of interest to mineralogists, besides the beautiful emeralds and spodumenes, there were also found this past season, in the near vicinity of this mine, some few very remarkable crystals of highly modified quartz, with planes not before credited to the region. In the species rutile and monazite, new discoveries have been made of exceedingly beautiful crystals.

It seems to me that we have in the Piedmont region of the Southern States the counterpart of the Ural mineral district in Russia and the Minas Geraes district of Brazil. All are foot-hill areas of very similar features geologically. If the South seems to be behind these other regions just mentioned, it is probably due to the fact that the South presents a newer field to the investigator than the others. Though this foot-hill region of the South is only thirty-six hours journey from New York, it receives less attention from mineralogists, geologists, and other scientists than localities thousands of miles distant. My own personal experiences in these southern regions during the past eight years have convinced me that nowhere have we more promising fields for the discoverer in any branch of science.

DR. T. STERRY HUNT spoke of the mineralogy of the locality referred to by Mr. Hidden, and discussed with him Prof. Kerr's theory of "frost-drift."

Mr. GEORGE F. KUNZ read a paper

ON THE NEW ARTIFICIAL RUBIES.

(Illustrated with specimens and microscopical preparations.)

The subject of artificial gems is at the present moment of considerable interest, not only financially, but also as furnishing an example of the manner in which the microscope is constantly called into use by almost every profession. Early this summer, the Syndicate des Diamants et Pierres Precieuses were informed that certain stones, which had been sold as rubies from a new locality, were suspected to be of artificial origin. They were put upon the market by a Geneva house ; and it was surmised that they were obtained by the fusion of large numbers of small rubies, worth at the most a few dollars a karat, into one fine gem worth from $1,000 to $2,500 a karat.

Some of these artificial stones were kindly procured for me by Messrs. Tiffany & Co. I was not, however, permitted to break them for analysis, to observe the cleavage, or to have them cut so that I could observe the optical axes more correctly. I would at any time have detected the artificial nature of this production with a mere pocket lens, as the whole structure is that peculiar to fused masses. Examination elicited the following facts: The principal distinguishing characteristic between these and the genuine stones is the presence in them of large numbers of spherical bubbles, rarely pear-shaped, sometimes containing stringy portions showing how the bubbles had moved. These

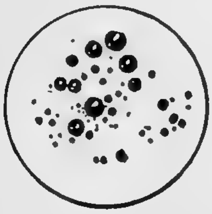

FIG. 1.—Spherical cavities in artificial ruby as seen at one time (enlarged 75 diameters).

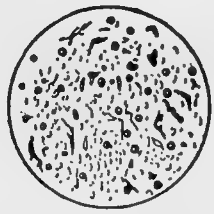

FIG. 2.—Spherical and irregular cavities in artificial ruby as seen at one time, evidently from the lower part of the crucible (enlarged 25 diameters).

bubbles all have rounded ends, and present the same appearance as those seen in glass or other fused mixtures. They are nearly always in wavy groups or cloudy masses. When examined individually they always seem to be filled with gas or air, and often form part of a cloud, the rest having the waviness of a fused mixture. Some few were observed inclosing inner bubbles, apparently a double cavity, but empty. In natural rubies, the cavities are always angular or crystalline in outline, and are usually filled with some liquid, or, if they form part of a "feather" as it is called by the jewelers, they are often arranged with the lines of growth. Hence the difference in appearance

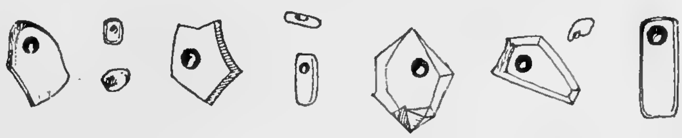

FIG. 3.—Liquid cavities in natural ruby and sapphire (enlarged 100 diameter.)

between the cavities in the natural gem and those in the fused gem is very great, and can readily be detected by the pocket lens. I have failed to find in any of the artificial stones even a trace of anything like a crystalline or angular cavity. Another distinguishing characteristic is that in many genuine rubies we find a silky structure (called "silk" by the jewelers), which, if examined under the microscope, or under a $\frac{4}{10}$ to $\frac{8}{10}$ inch objective, we find to be a series of cuneiform or acicular crystals, often iridescent, and arranged parallel with the hexagonal layers of the crystal. When in sufficient number, these acicular and arrow-shaped crystals produce the asteria or star effect, if the gem is cut in *en cabochon* form with the center of the hexagonal prism on the top of the cabochon. I have failed to find any of them in the stones under consideration, or even any of the marking of the hexagonal crystal which can often be seen when a gem is held in a good light, and the light allowed to strike obliquely across the hexagonal prism. Dr. Isaac Lea has suggested[1] that these acicular crystals are rutile, and interesting facts and illustrations have been published by him. From my own observations on many specimens, I believe there is little doubt of the truth of this hypothesis.[2] My explanation is, that they were deposited from a solution, either heated or cold, while the corundum was crystallizing, and I doubt very much whether they will ever be found in any substance formed by fusion.

The hardness of these stones I found to be about the same as that of the true ruby, 8.8, or a little less than 9, the only difference being that the artificial stones were a trifle more brittle. The testing point used was a Siamese green sapphire, and the scratch made by it was a little broader but no deeper than on a true ruby, as is usually the case with a brittle material. After several trials I faintly scratched it with a chrysoberyl, which will also slightly mark the true ruby.

The specific gravity of these stones I found to be 3.93 and 3.95. The true ruby ranging from 3.98 to 4.01, it will be seen that the difference is very slight, and due doubtless to the presence of the included bubbles in the artificial stones, which would slightly decrease the density. As a test, this is too delicate for jewelers' use ; for if a true ruby were not entirely clean or a few of the bubbles that sometimes settle on gems in taking specific gravities were allowed to remain undisturbed, it would have about the same specific gravity as one of these artificial stones.

I found, on examination by the dichroscope, that the ordinary image was cardinal red, and the extraordinary image a salmon red, as in the true ruby of the same color. Under the polariscope, what I believe to be annular rings were observed. With the spectroscope, the red ruby line, somewhat similar to that in the true gem, is distinguishable, although perhaps a little nearer the dark end of the spectrum.

The color of all the stones examined was good, but not one was as brilliant as a very fine ruby. The cabochons were all duller than fine, true stones, though better than poor ones. They did not differ much in color, however, and were evidently

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[1] Proc. Philad. Acad. Sc., Feb. 16, 1869, and May, 1876.
[2] Paper on star garnets, N. Y. Acad. Sc., May, 1886.

made by one exact process or at one time. Their dull appearance is evidently due in part to the bubbles. The optical properties of these stones are such that they are evidently individual or parts of individual crystals, and not agglomerations of crystals or groups fused by heating.

In my opinion, these artificial rubies were produced by a process similar to that described by Fremy and Feil (*Comptes Rendus*, 1877, p. 1029), by fusing an aluminate of lead in connection with silica in a siliceous crucible, the silica uniting with the lead to form a lead glass, and liberating the alumina, which crystallizes out in the form of corundum in hexagonal plates, with a specific gravity of 4.0 to 4.1, and the hardness and color of the natural ruby, the latter being produced by the addition of some chromium salt. By this method rubies were formed that, like the true gem, were decolorized temporarily by heating.

It is not probable that these stones were formed by Gaudin's method (*Comptes Rendus*, xix., p. 1342), by exposing amorphous alumina to the flame of the oxyhydrogen blowpipe, and thus

FIG. 4.—Acicular crystals in sapphire (enlarged 100 diameters).

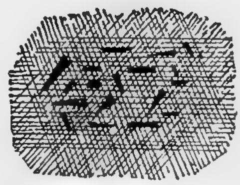

FIG. 5.—Cuneiform crystals in ruby and sapphire (enlarged 200 diameters).

fusing it to a limpid fluid, which, when cooled, had the hardness of corundum, but only the specific gravity 3.45, much below that of these stones. Nor is it at all likely that they were produced by fusing a large number of natural rubies or corundum of small size, because by this process the specific gravity is lowered to that of Gaudin's product. The same also holds good of quartz, beryl, etc.

The French syndicate referred the matter to M. Friedel, of the Ecole des Mines, Paris, supplying him with samples of the stones for examination. He reported the presence of the round and pear-shaped bubbles, and determined the hardness and specific gravity to be about the same as in the true ruby. On analysis, he found them to consist of alumina, with a trace of chromium for the coloring matter. The cleavage was not in all cases distinct, and the rough pieces given to him as examples of the gem in its native state had all been worked, so that nothing could be learned of their crystalline structure. When properly cut according to axes, they showed the annular rings. The extinction by parallel light was not always perfect, which he believed to be due to the presence of the bubbles. He states that he himself has obtained small red globules with these inclusions by fusing alumina by oxyhydrogen flame; and, although having no positive evidence, he believes these stones to be artificially obtained by fusion.

On the receipt of M. Friedel's report, the syndicate decided that all cabochon or cut stones of this kind shall be sold as *artificial*, and not precious gems. Unless consignments are so marked the sales will be considered fraudulent, and the misdemeanor punishable under the penal code. All sales effected thus far, amounting to some 600,000 or 800,000 francs, shall be cancelled, and the money and stones returned to their respective owners.

The action taken by the syndicate has fully settled the position which this production will hold among gem dealers, and there is little reason to fear that the true ruby will ever lose the place it has occupied for so many centuries. These stones show the triumph of modern science in chemistry, it is true; and although some may be willing to have the easily attainable, there are others who will almost want, what the true ruby is becoming to-day, the unattainable. One will be nature's gem, and the other the gem made by man.

The[1] following recapitulation of the progress made from time to time by the different investigators in the artificial reproduction of ruby and sapphire, may be of more than passing interest at this moment: Gaudin (C. R., 1857, Vol. IV., p. 999, and 1857, Vol. XLIV., p. 716.—L'Inst., t. XXV., p. 110—J. pr. Chem., LXX., p. 381—Bibl. univ. de Genève, t. XXXIV., p. 68. —Jahrb. f. Min., 1857, p. 444) was the first to reproduce corundum, which he did by heating before the oxyhydrogen blowpipe a closed crucible containing equal parts of alum and sulphate of potash and charcoal. It was fired for fifteen minutes and then slowly cooled. The mass was then lixiviated and attacked with diluted aqua regia, which left a sand formed of small corundum crystals, 1 mm. long and $\frac{1}{3}$ mm. thick. They were hexagonal plates having bases striated in three directions parallel to the sides. Some very fine included microliths resembling sillimanite were also observed in these crystals.

Elsner (J. pr. Chem., t. XVII., p. 175), operating in the same way, by fusing before the oxyhydrogen blowpipe anhydrous alumina with bichromate of potash obtained red crystalline grains as hard as rubies.

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[1] See "Encyclopedie Chimique," Tome II., Reproduction Artificielle des Mineraux, par M. L. Bourgeois.

De Sènarmont (C. R., 1851, t. XXXII., p. 762.—L'Inst., 1851, p. 165.—Ann. Chem. Pharm., t. LXXX., p. 214.—Pharm. Centr., 1851, p. 518) has applied the wet way to the crystallization of alumina. He heated in a sealed tube, at 350° C., a solution of chloride of aluminum, or of nitrate of alumina, and produced rhombohedrons with truncated edges.

Almost at the same time Ebelmann obtained corundum (Ann. de Phys. et de Chim., 1851, t. XXXIII., p. 34) by a totally different process. He heated in a porcelain kiln a platinum crucible containing one part of amorphous alumina with three or four parts of borax. After a few days of heating all the borax was volatilized, and at the bottom of the crucible crystals of corundum were found, and on the edges long bluish needles of borate of alumina, which he separated by the action of chlorohydric acid. The corundum thus obtained was in hexagonal plates like specular iron of volcanic origin, and was quite similar to that obtained by Gaudin.

The base is striated by three systems of lines parallel to the sides. Numbers of very irregular vitreous inclusions were noticed in them, as well as microliths resembling sillimanite. The density of the crystals was 3.98, and, like the natural stone, they scratched topaz; they have, as in natural specimens, a ′ p. = 122° 35′.

Carbonate of baryta added to the mixture facilitates the formation of the crystals and the development of rhombohedral faces, which thus attain a length of several mm. Carbonate of lime may be added or the borax wholly replaced by carbonate of soda, but hexagonal or dodecahedral plates will still be obtained. Ebelmann colored his product by small quantities of metallic oxides. For example, violet was obtained by oxide of manganese (Oriental amethysts). It was noted that boracic acid alone could not replace the borax. Sainte-Claire Deville and Caron (C. R., 1858, t. XLVI., p. 764.—L'Inst., 1858, p. 133.—Ann. Chem. Pharm., t. CVIII., p. 55.—Dingl. pol. J., t. CXLVIII., p. 372.—J. pr. Chem., t. LXXIV., p. 157) obtained magnificent specimens of corundum by a different method. They placed anhydrous fluoride of aluminum ($Al_2 F_6$) at the bottom of a charcoal crucible, and suspended in the centre of this a cupel of the same substance filled with boracic acid. The whole apparatus was allowed to remain at white heat for an hour, and on opening the crucible they found the interior lined with large thin hexagonal plates of corundum, presenting the combination a^1 p e^2. There were no striæ on the bases, but only hexagonal rosettes projecting, and brown arborescences. Vitreous inclusions of boracic acid with bubbles of gas were observed, often arranged in crowns, and fine microliths were also noticed, as already mentioned. They found that by adding a little fluoride of chromium to that of aluminum, and using a clay crucible with cupels of platinum, they could produce rubies together with a little sapphire. When they increased the quantity of fluoride of chromium they obtained green crystals (Oriental emeralds).

Debray (C. R., 1861, t. LII., p. 985.—L'Inst., 1861, p. 165.—Ann. Chem. Pharm., t. CXX., p. 184.—Jahrb. f. Min., 1861, p. 702.—Bull. Soc. Chim., 1865) describes several methods of obtaining corundum. He passed a slow current of chlorohydric acid over aluminate of soda at a red heat or over a mixture of phosphate of alumina and lime. In the latter case calcic wagnerite was also produced. M. Debray has also produced crystals of alumina by melting phosphate of alumina with three or four times its weight of sulphate of potash or soda, and thus producing an alkaline phosphate.

Quite recently H. Grandeau (C. R., 1882, t. XCV., p. 921) has had occasion to apply the preceding method to various oxides, and has found that particularly with alumina, after several hours of heating, a crystallized double phosphate of alumina and potash is obtained at the same time as the corundum.

The mineral-producing qualities of fluohydric acid have been well employed by M. Hautefeuille in reference to alumina. It was only necessary to make the vapor of this acid (Ann. Chim. Phys., 1865, t. IV., p. 153.—Jahresb., 1814, p. 206) pass slowly over the amorphous alumina heated to a bright red heat in a platinum tube, previously diluting it with nitrogen and steam. On the hottest part of the tube foliated hexagonal plates of corundum will form, resembling very much specular iron of volcanic origin. The more the operation is prolonged the more beautiful these become, for the smaller crystals are destroyed to make way for larger ones.

M. Gaudin (C. R., 1869, t. LXIX., p. 1342), in 1869, gave a second method of producing corundum by exposing amorphous alumina to the flames of the oxyhydrogen blowpipe. This oxide melts into a very clear, fluid glass, which in cooling hardens into a crystalline globule as hard as corundum.

MM. Fremy and Feil (C. R., 1877, t. LXXXV., p. 1029) have produced specimens of corundum remarkable for the size of the individual crystals and the weight of the crystalline masses, by means of a double decomposition in a dry way. They melted at a bright red heat in a large crucible of very siliceous material equal weights of alumina and minium, producing thereby a fusible aluminate of lead, which is soon destroyed by the silica of the crucible, giving place to a still more fusible silicate and liberating the alumina, which crystallizes in the body of the liquid. Part of the lead is also volatilized or reduced by the gas of the furnace. Breaking the crucible, they found a superficial vitreous layer of silicate of lead, and underneath a mass of corundum crystals grouped in magnificent geodes. By the addition of a little bichromate of potash rubies were obtained, and sapphires by the further addition of a little oxide of cobalt. These are the most beautiful crystals of ruby and sapphire that have ever been obtained, but their hexagonal tabular form unfits them for cutting. They have the properties of corundum; D=4.0 to 4.1. The rubies, like natural stones, were temporarily decolorized by heating. MM. Fremy and Feil have also added fluoride of barium to the aluminate of lead in the preceding experiment. The two reagents were mixed in equal parts with the addition of a little bichromate of potash, and heated in a siliceous crucible surmounted by another reversible crucible. In the lower crucible they obtained a geode of ruby with vitreous inclusions, while the upper one was lined with long needles of a silicate of alumina and baryta. According to the analysis of L. M. Ferreil, this product is probably a barium anorthite.

MM. Fremy and Feil endeavored to retard the reactions in this experiment so as to increase the size of the crystals. M. Stanislas Meunier (C. R., 1880, t. XC., p. 701), decomposed in a red-hot tube chloride of aluminum by the use of steam. In several experiments magnesium or zinc were also used as reagents. Corundum was thus produced in hexagonal plates or crystalline grains. MM. Fouqué and Michael Levy accidentally observed the formation of corundum in beautiful hexagonal plates while they were fusing microcline feldspar with fluorite. The corundum by sublimation lined the platinum cover of the crucible in which the experiment was made.

Last of all, M. F. Parmentier (C. R., 1882, t. XCIV., p. 1713), in a work relative to the action of molybdates upon oxides by dry process, has announced that the fusion of amorphous alumina with bimolybdate of potash will furnish corundum in plates like tridymite. It is important to keep the temperature of the crucible high, for if it is lowered an inverse reaction takes place.

Dr. T. Sterry Hunt remarked upon the character of these artificial rubies, and upon the artificial production of minerals in general, and compared their properties with those of the natural minerals.

President Newberry announced the death of Mrs. Erminnie A. Smith, which occurred June 9, 1886. Prof. D. S. Martin, Mr. George F. Kunz, and Mr. B. B. Chamberlin were appointed a committee to prepare memorial resolutions.

October 11, 1886.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Thirty-six persons present.

MR. GEORGE F. KUNZ exhibited artificial rubies from Paris, as supplementary to his paper read at the preceding meeting.

PRESIDENT NEWBERRY stated that the library of the Society had been removed, during the summer, under the authority delegated to the President and Secretary, from the American Museum of Natural History to the Herbarium room in the Library Building of Columbia College. That the conditions under which the College received the library on deposit were, the continued and absolute ownership of the library by the Academy, with the privilege of terminating the contract at any time ; and the College to bind and otherwise care for the library equally with its own.

Dr. N. L. Britton read the announced paper,

ADDITIONAL NOTES ON THE GEOLOGY OF STATEN ISLAND.

On April 4th, 1881, I had the honor of presenting to the Academy the results of my studies on the Geology of Richmond County, New York. On December 12th, of the same year, I presented some additional notes on the same subject, and on November 24th, 1884, read a paper on the Glacial and Pre-Glacial Drifts of Staten Island. I now desire to bring forward other data, obtained by myself and associates since this last communication.

No new outcrops of granite or gneiss have been discovered; those at Tompkinsville have, indeed, been partially covered by the embankment for the Rapid Transit Company's railroad, and only a small ledge is now to be seen. It is to be noted that this coarse granite contains oligoclase feldspar in addition to its orthoclase, and the probability is that the outcrop is the exposed top of a mass, perhaps a vein, similar to those of common occurrence on New York Island and in Westchester County.

In my communication of December 12th, 1881, allusion was made to an exposure of hornblende-rock on the shore of the Upper Bay at Brighton Point. This is an extremely tough, fibrous tremolite, hardly any other mineral being present in it. The outcrop showed no bedding planes; it is now wholly concealed by the made land around the railroad terminus at Saint

George. The rock is very similar to that from the bottom of the deep well at Bischoff's Brewery.

The serpentine and talcose rocks which form the ridge through the central part of the island have been re-examined with considerable care. It will be remembered that in my first communication I regarded these as metamorphosed magnesian limestones. In the course of the discussion which followed my second paper, Dr. Julien expressed his opinion, based on microscopical studies of the rock, which revealed the presence of much partially altered amphibole, that they are derived from hornblende schist, and the specimens from the deep well-boring above alluded to, being certainly partially hydrated and otherwise altered, gave support to his hypothesis. It now seems to me probable that both of these suppositions are in a measure correct: that the serpentines and associated rocks have been produced by the extensive alteration of both limestones and hornblendic, or rather tremolitic, strata, and that schists as well have furnished some of the material for their construction. This conclusion is now reached from the following considerations:

1. There is no proof whatever that these serpentines are metamorphosed igneous rocks. We have failed to detect any olivine-like minerals in them; and in this respect they appear to differ from the area near Baltimore recently described by Prof. Williams in Bulletin No. 28 of the United States Geological Survey. Messrs. Whitney and Wadsworth, in their discussion of azoic rocks in the Bulletin of the Museum of Comparative Zoology, Vol. VII., pp. 464–465, state that it seems more reasonable to them to ascribe an igneous origin to the rock in the region under consideration, because a large part of the thoroughly studied serpentines of the world have been proved to be the result of the metamorphism of igneous masses. It does not appear that these writers have ever visited the area, nor, indeed, that they have examined any of the rock. As it has been stated on good authority that the concluding portions of Messrs. Whitney and Wadsworth's paper, dealing with a proposed classification of pre-Silurian rocks, were not meant to be taken as their actual ideas on the subject, but intended as a joke (though if this be so, it would have saved much unnecessary thought and trouble had they designated it thus), and as the general tendency of their paper appears to be to criticise every investigator's work without furnishing any more valuable suggestions than have been advanced, we must confess to some doubt as to Messrs. Whitney and Wadsworth's actual position.

2. There is abundant evidence that these rocks are stratified, though this feature cannot be made out in every outcrop. The

following observed dips and strikes from various portions of the area will indicate the truth of this statement :

Near corner of Westervelt avenue and Second avenue, New Brighton, Str. N. 45 E., Dip 70 NW.; summit of the northwest side of Pavilion Hill, Str. N. 45 E., Dip 70–85 NW.; eastern side of Pavilion Hill, 900 feet west of the granite outcrops on the shore, Str. N. 45 E., Dip 70 NW. to nearly vertical; here the rock is delicately crumpled; west of Garretson's Station, Str. N. 60 E., Dip 20–80 SE. and much contorted, apparently lying in several gentle folds ; west of Grant City, Str. N. 60 E., Dip 55–70 NW.; Ravine near Egbertville, Str. N. 75 E., Dip 85 SE.; on Meissner avenue, near Richmond, Str. N. 80 E., Dip. 80 N.; one-fourth mile northwest of this outcrop, strike and dip same; in valley of brook one mile north of Egbertville, Str. N. 50 E., Dip. 40–50 NW.

3. All the serpentine areas of Southeastern New York and vicinity, such as those of Staten Island, Hoboken, West 59th street and vicinity, New York Island, New Rochelle and Rye, Westchester County, lie in the same general line of strike and appear to occupy a well-defined belt in the surrounding gneisses and schists. These outcrops may, indeed, be but portions of the same strata alternately buried by the pitch of the folds and again brought to the surface by faults of vertical throw; this structure has been conclusively demonstrated in the highlands of New Jersey, and may well apply to the rocks now under consideration. The crystalline limestone areas of New York Island and Westchester County lie parallel, or nearly so, with this serpentine belt, as may be seen on the excellent map published by Professor Dana in the *American Journal of Science*, vol. XX. These limestone outcrops are of the same general shape as those of the serpentine and its associated minerals, and their detached occurrence is probably due to the pitch and fault structure above noted. Crystalline limestone occurs in and with the serpentines at the West 59th street area and at New Rochelle; at West 59th street, parts of the rock are indistinguishable from parts of the Staten Island material, and here is found in great abundance the "hydrous anthophyllite," which is very much like some specimens from the deep well on Staten Island. Many of the crystalline limestones contain tremolite, and in some of them this mineral is extremely abundant ; specimens obtained by Mr. Kemp from near King's Bridge are at least one-half tremolite. It is not alone in pure masses, but is scattered through the rock in fine crystals, and at Pleasantville, Westchester County, forms "mountain leather." The serpentine of Staten Island contains much amianthus, doubtless the altered state of tremolite, and Mr. B. B. Chamberlin has found this matted into a substance

similar to "mountain leather" on Staten Island. The cleavage of the serpentine is much like that of the limestones, and on the cleavage faces of the latter there is often seen a development of tremolite, while on the serpentine faces there is considerable amianthus.

The parallel metamorphism of schists in the production of these serpentines is indicated in the occurrence on Todt Hill, Staten Island, of a very soft, schistose rock, apparently now chloritic, containing altered crystals of tourmaline, a mineral quite abundant in the schists of New York Island.

As regards the relative position of the serpentine to the granitic rocks on Staten Island, I have no new observations to record and do not think that the exposures admit of more plausible explanation than the hypothesis advanced by me in my original communication, where the serpentine was regarded as overlying the other rock, and is so represented in my diagrammatic sections. There is certainly no other rock exposed within the serpentine area laid down on my map. Of course, this consideration applies to the Staten Island outcrops alone ; elsewhere they are inclosed by the gneisses, etc., and this superposition does not occur. Doubtless the Staten Island rocks were originally deposited in a conformable sequence, but the serpentines were left on top in the folding of the strata. The idea advanced by me that the serpentine ridge is an anticlinal fold must be abandoned in the light of more recent investigations; it is quite evidently made up of a series of smaller folds which, collectively, are more probably of synclinal structure, though the exposures are not sufficient to satisfactorily settle this question.

In my original paper, I stated that these crystalline rocks of Staten Island probably extend southwestwardly across New Jersey to Trenton, forming an axis which marks approximately the junction of the Triassic and Cretaceous formations. This imaginary axis was indicated on the accompanying maps and sections. Proof of the general truth of this hypothesis is now furnished from a well recently bored near Perth Amboy, which reached gneiss at a depth of seventy feet. This was immediately overlaid by Triassic red shale, about twenty feet in thickness, the latter covered by Cretaceous clay and sand, pre-glacial drift and morainal deposits. A note on this well may be found in the annual report of the State Geologist of New Jersey for 1885. It will be noticed that here the Triassic strata are comparatively thin, and this point is doubtless very near its southeastern margin.

I have regarded these metamorphic rocks as Archæan, and have thus alluded to them. I am well aware that they are by others considered to be of Lower Silurian age, and that this theory is supported by no less authority than that of Professor Dana. But after a careful and prolonged examination of most of the localities on which this theory is based, I am of the opinion that the occurrences can be more satisfactorily explained, and adhere to my belief that they are Archæan. It may here be remarked that Mr. Merrill is about undertaking a critical study of Westchester County, and that we may promise ourselves the presentation ere long of evidence which will go far towards proving the truth of one or the other hypothesis.

Triassic Rocks.—No additional exposures of shales, sandstones, or trap have come to light since my first communication. The wells of the Crystal Water Company are within the area surmised to be underlaid by the Triassic red rocks, being between the southwestern end of the trap dyke and the serpentine hills, but were bored in the drift.

Cretaceous Strata.—Here also there are no additional exposures to record. The kaolin and fire-clay continue to be mined in considerable quantity near Kreischerville. From the known outcrops and exposures, there must be a large tract of territory underlaid by these valuable materials, though much is deeply covered with glacial drift. The discovery of vegetable fossils similar to those of Woodbridge and South Amboy, N. J., has already been announced to the Academy and noted in the Transactions, Vol. V., p. 28. No opportunity has since been afforded for the collection of additional material at this locality. If, however, the vegetable remains in the ferruginous sandrock at Tottenville are, as they appear to be, Cretaceous, it should be recorded that Mr. Hollick has obtained a considerable addition to his previous collections from that point. He has described the occurrence of these fossils in the "Proceedings of the Natural Science Association of Staten Island" of Dec. 8th, 1883, and compared them with the specimens from Glen Cove, Long Island, in the Museum of Columbia College, which Dr. Newberry has already exhibited to the society.

Pre-Glacial Drift.—Mr. Hollick has recently found an additional outcrop of this interesting formation. It is near the village of Woodrow and at considerable elevation, though not as high up as the great deposit on Todt Hill.

Deposits of Limonite.—Owing to the low prices obtainable for iron ore, but little work has recently been done on these deposits. Very little material has been excavated, and no new beds have been explored. On Todt Hill there is a small amount of pyrite associated with the limonite, which in its decomposition produces *Copperas;* and this mineral may be noted as new to Staten Island. Dr. Hunt visited the Todt Hill mine with me some three years ago, and has since expressed his opinion that the ore is the result of the decay of the underlying serpentine. I had regarded it as a deposit from springs, but am now inclined to believe that Dr. Hunt is correct in his view, and that these ores have originated in a similar manner to that which has produced other Appalachian limonites ; though the presence of much siliceous matter with the ore and of magnetic iron sand in some of the deposits indicate that deposition from solution may have produced some of the material, and the black sand must have been mechanically washed in.

Glacial Drift.—On my geological map published in the Annals, Vol. II., plate xv., the southern boundary of the Glacial Drift is indicated by a dotted line. I have since retraced this line, but have no essential alterations to make in it.

The construction of the deep cutting and tunnel for the Staten Island Rapid Transit Railway, at Tompkinsville, has exposed a most interesting section through the Glacial Drift. This is seen to be truly morainal in its upper portion, consisting of large angular boulders and pebbles irregularly imbedded in unassorted clay and sand. The lower part of the bank is, however, beautifully stratified and the materials composing it are sorted into bands and layers of different substances, strata of sand of several degrees of coarseness, others of clay, and still others of pebbles ; very few boulders occur in this lower part, and these are in special well-marked bands and are more rounded than those above.

While this exposure is of great interest as illustrating the difference between morainal and stratified drift at a glance, it is of much greater importance as furnishing a measure of the depression of the coast at this point during the Glacial Epoch : for the altitude of the upper line of stratification above tide gives us the comparative position of the coast as regards its position in Glacial times. This is between 25 and 30 feet. Hence we may safely conclude that during the presence of the great ice sheet the shores of New York Harbor stood at least that amount lower.

As is well known, the coast is at present suffering depression. How much higher it has been since the retreat of the glaciers, or to how many oscillations it has been subjected since that time, are fair subjects for speculation, but cannot now be satisfactorily answered. I have observed the stratification of the drift at other places in the vicinity, but nowhere have I seen such a beautiful exhibition of it as here.

Nearly Driftless Areas North and West of the Terminal Moraine.—This is a feature of the glaciation of the region which was not apparent to me until a year or so ago. There are at least two of these on Staten Island. One is on Pavilion Hill, at Tompkinsville Landing, where there are but very few erratic boulders over a limited area, and the shattered serpentine comes directly to the surface. This hill is by no means the highest ground in the vicinity, but the ice-sheet appears to have flowed around it, there being well-marked moraines on all sides. The highest points on the island are farther southwest, and here the terminal moraine is heaped up on the serpentine ridge. The hill under consideration is near the western edge of the Upper Bay, and it would seem as though the glacier had been diverted by it eastwardly towards the Narrows, it not being overridden by the ice.

The other area alluded to is west and southwest of Woodrow, on the high ground of the southwestern portion of the island. This is of much greater extent than the one above described, and there is scarcely a boulder to be seen within its limits. I have not had opportunity to define its boundaries, but am well satisfied of its occurrence. The soil is sandy and may be part of the Pre-Glacial Drift system; the outcrop of this recently found by Mr. Hollick is within its bounds. It is not appreciably yellow, however, and it is possible that it is underlaid by one of the cretaceous sand beds. More field observations are needed to settle this question.

The subject was discussed by the PRESIDENT, MR. MERRILL, PROFESSOR MARTIN, and MR. McDONALD.

October 18, 1886.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

One hundred and twenty-nine persons present.

PRESIDENT NEWBERRY read a paper on

EARTHQUAKES, WHAT IS KNOWN AND BELIEVED ABOUT THEM BY GEOLOGISTS.

From all quarters have come to me inquiries about the earthquake in Charleston. Because I am a teacher of geology it has been taken for granted, quite gratuitously, that I know or ought to know, all about the earth of which the structure and history are the geologist's special objects of study. That he knows more about these than other people is possible, but that he knows all about them is unfortunately far from true. It is, however, natural that I should be appealed to for information in regard to what is the most striking of all terrestrial phenomena; and while I do not claim nor accept the title of "Professor of Earthquakes," which one correspondent seriously gives me, I acknowledge it as apart of my duty to satisfy, as far as I am able, the demand which has been made by the public. I shall, therefore, present a brief review of what is known and believed in regard to the phenomena and causes of earthquakes, by those whose opinions on this subject are most worthy of confidence.

There is something particularly unsettling and terrifying in the upheavals and undulations of what we call *terra firma*, because it has been accepted as the type of stability. To men of all countries and ages, civilized and savage, the earthquake has been a peculiar terror and mystery. Even the most stoical and reasonable have lost their self-possession when they have felt the solid earth heaving and groaning beneath them; and in the countries where earthquakes are most common, the horror and dread they inspire are never lessened by familiarity, but every new shock produces fresh and increased alarm. It is not surprising, then, that in a region like Eastern North America, which has been supposed to be exempt from serious catastrophes of this kind, the occurrence of such an event as that which recently took place at Charleston, has produced a profound and widespread sensation. It has not only called out strong expressions of sympathy with the sufferers, but has excited the keenest desire to know all that can be known of this and similar phenomena. It has been the common subject of conversation throughout the land. The journals have been full of descriptive details. Scientists of all kinds have been interviewed, and been made to give their views, if they had any; if not, they have been supplied to them. As a consequence, many wild and contradictory statements have been made, and so many theories advanced, that the public has hardly known what to believe.

Yet earthquakes are neither novel nor mysterious, but are among the most common and simple of terrestrial phenomena; they have certainly recurred at frequent intervals throughout all geological time of which we have any record, and it is probable that now, not an hour, perhaps not a minute, passes, but more or less violent vibrations take place somewhere on the earth's surface. In later years, earthquakes have been carefully studied in many countries by geologists and physicists, and the conclusions reached have been so generally harmonious that there is now very little difference of opinion as to their cause, and the manner in which this cause operates.

Briefly told, *an earthquake is a movement caused by a shrinking from the loss of heat, of the heated interior of the earth, and the crushing together and displacement of the rigid exterior as it accommodates itself to the contracting nucleus.*

I cannot, in the limited space now at my disposal, give anything more than a summary of the facts upon which this statement rests, but I may say that they are so numerous and significant that the conclusion deduced from them, enunciated in the above paragraph, is not only convincing, but inevitable. I will briefly notice some of these facts.

From observations in mines, and from deep borings, from hot springs and volcanoes, we have learned that the interior of the earth is intensely hot. The most satisfactory data for this conclusion are furnished by wells and mines. These are located in all the great divisions of the earth's surface; China, India, Australia, Africa, Europe, and North and South America, all have their mines or deep borings, which give fairly harmonious testimony upon this subject. They prove that after passing the plane of invariable temperature, beyond which the alternations of the seasons are not felt, the heat increases about 1° Fahr. for every fifty feet; for example, the well in the grounds of the Lunatic Asylum at St. Louis is 3,843 feet in depth; at 3,200 feet, where the temperature was last observed, it was 107°; the State House well, at Columbus, Ohio, is 2,775 feet deep, and at 2,575 feet the temperature is 88°. The artesian well at Louisville, Kentucky, is 2,080 feet deep, and the temperature at the bottom is 82°, summer and winter. Other wells bored in the Valley of the Mississippi and in the Eastern States furnish similar data.

In Europe, many deep mines and wells have afforded facts coincident with those I have reported from this country; for example, the well of Grenelle, at Paris, is 1,800 feet deep, and the water which flows from it has a temperature of 82° Fahr., while the mean annual temperature at the surface is 51°. A well bored at Sperenberg, Germany, to the depth of 4,172 feet has a temperature, at 3,390 feet, of 115.5° Fahr., while a well at Schladenbach, 5,286 feet deep, has a temperature at bottom of about 131°. Wells in China, India, and Australia show a corresponding increase of temperature in descent, although few quantitative observations have been made there.

There are some exceptions to the rule that the temperature increases at the rate of 1 degree for every 50 feet in descent; for example, in the mines on the Comstock Lode, Nevada, at the depth of 3,200 feet the temperature is 160° Fahr., an increase of about 1 degree for every 29 feet of descent. This case and similar ones at Monte Massi, in Tuscany, and at Buda-Pesth, Hungary, are quoted by Professor Judd, in his *Volcanoes*, and are considered of sufficient importance to invalidate the evidence of thousands of other mines and wells. But the exceptions only prove the rule. The wells mentioned are located in regions which not long since, geologically speaking, have been the scenes of violent volcanic action. The surface of the country is occupied by vast sheets of lava, hot springs abound there, and it is evident that the subterranean fires are not yet extinguished. A boring on the flanks of Mt. Etna would be a still more striking exception to the rule of one degree for every 50 feet, and would be equally legitimate evidence against it.

Excluding these abnormal cases, which really have no bearing on the question, the irregularities in the rate of increase in temperature are not greater than those which might be caused by differences in the conductivity of the rocks passed through. The deep wells of Sperenberg and Schladenbach—which were bored in part to test this question, and have been the most carefully observed of any—have given the most convincing evidence of the truth of the theory of intense internal heat.[1] The case cited by Professor Judd (*Volcanoes*, p. 341), "a deep well in Buda-Pesth, in which there was a decline of temperature below 3,000 feet," is probably a mistake or a fraud. The same thing happened at the deep well at St. Louis, in which the temperature increased regularly to the depth of 3,200 feet, where it was 107° Fahr. Below that the contractor reported the temperature declining, *because the directors were about to stop the work, partly on account of the warmth of the water!* To prevent exposure of the fraud, iron rails were dropped into the well.

It may then be considered as established that all over the earth's surface, except in volcanic districts, the temperature increases about one degree Fahr. for every 50 feet descent. It is evident that should this rate of increase continue, the temperature at the depth of 50 miles would be sufficient to melt all known substances; and the first conclusion from the observation of temperature in mines and wells was that the solid portion or crust of the earth could not be more than 40 or 50 miles in thickness, and it was proclaimed that we were living on a film of solid matter, floating on a sea of molten rock. The comparative stability, however, of the earth's figure—the little

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[1] Some of the temperatures in the Schladenbach well are as follows:

Depth in Metres.	Temp. Fahr.	Réaum.
1266	113.5°	36.2°
1296	115.°	36.9°
1326	116.8°	37.7°
1356	119.3°	38.8°
1386	121.3°	39.7°
1416	122.9°	40.4°
1506	127.2°	42.3°
1566	128.3°	42.8°
1596	130.1°	43.6°
1626	131.°	44.°

effect produced by the attraction of the sun and moon—have led to the conclusion that the earth's crust is thicker than this, and it has been suggested that while the accuracy of the observations on the increase of temperature to the depth of one mile cannot be questioned, it is possible that the rate of increase to that depth is not constant below; that the increment may diminish, and therefore the temperature of fusion may only be reached at a greater depth than has been supposed.

It has also been shown that the melting point of many substances is raised by pressure, and therefore, that the enormous weight of the overlying rocks, equivalent to 792,000 lbs. to the square foot for every mile, may hold in coerced rigidity a considerable zone of the earth's mass composed of materials that would melt and flow on the surface at a much lower temperature than that which they now endure in a solid form. Accepting, then, the conditions imposed on the old theory of the state of the interior of the earth by pressure and the possible diminution of the increment of temperature, we may suppose that the solid crust is considerably thicker than was formerly supposed. That it is relatively thin, however, is indicated by facts which will be cited further on.

The increase in temperature observed in mines and deep borings means that the heat of the interior of the earth is constantly escaping to the surface, where it is radiated into space. If the outer crusts were a perfect non-conductor, the materials within it would always maintain a condition of thermal equilibrium throughout. It is thus evident that the process of refrigeration is progressive, and from the time when the first film of solid matter dimmed the brightness of the "glittering globe of liquid fire," the crust formed at the surface has been constantly increasing in thickness, while by the loss of heat, which is an expansive force antagonistic to gravity, the volume of the earth has been as constantly diminishing. But since the outer crust has lost its inherent heat and has become solid it no longer shrinks, though the loss of volume goes on incessantly in the intensely heated, but gradually cooling interior. As the nucleus contracts the solid crust cannot accommodate itself moment by moment to the loss of volume, for it resists by its rigidity and is brought into a state of strain. This is relieved from time to time, whenever it passes the resistance of the materials composing the crust, by a crushing together and displacement of the surface rocks. These are *faulted* or *folded;* that is, are either thrown into great waves by lateral pressure, or the arches are broken and fissures are produced at right angles to the line of thrust. The rocks forming the sides of these fissures slide on each other, forming what geologists call *faults,* in which the "throw" or displacement sometimes amounts to many thousand feet. Earthquakes, mountain chains, and volcanic eruptions may all be considered as consequences of this readjustment. Mountain chains are great lines of fracture in the earth's crust along which rocks before nearly horizontal are raised into ridges by lateral pressure. They have been compared, not inaptly, to the wrinkles formed in the rind of a fruit when it loses its volume by drying. Every mountain chain shows many folds and faults; in the Alleghanies the folds are noticed by every traveller, and few better examples of folded strata are seen anywhere than those which border the gorge which cuts through the ridges from Cumberland to Frostburg, Maryland. The faults are less conspicuous and would hardly be detected except by a geologist, but they are very numerous, and in some of them the displacement is more than 20,000 feet. The Wasatch Mountains in Utah —one of the boldest ranges on the continent—owe their relief mainly to a fault which runs nearly north and south through the middle of the Territory. The country west of this fault is thrown down and that on the east raised to form a wall 5,000 to 7,000 feet high.

It is evident that the folds and fractures seen in every mountain belt could not have taken place without great disturbance of the surrounding country. And as they have been formed, not all at once, but each by itself, and each one by many paroxysms, an almost infinite series of earthquakes is recorded in the structure of every mountain chain. A large number of earthquakes of modern times have been attended by changes of topography which have remained as evidences of the displacements which caused the vibrations. Sometimes a line of coast was raised above the ocean level, sometimes mountains or cliffs split and fell, sometimes fissures and faults were formed many miles in length.

Another thing about mountain chains is not so generally known as that they are lines or belts of folded and fractured rocks; and that is that they are the products not of moments or even years, but of ages. The lines of fracture which are marked by mountain chains are ever, after the first disruption, lines of weakness, where the resistance to lateral pressure is diminished, and where the strain of large unbroken areas is relieved from time to time by displacements, necessarily attended by earthquakes. I have sometimes compared them to hinges on which the great tables of the earth's crust turn with constantly changing angles. Generally mountain chains may be said to grow by the constant or paroxysmal elevation of their arches, the increase in the throw of their faults. This growth would be much more apparent than it is, if it were not that the mountain chains receive a far greater precipitation of moisture than the lowlands, and erosion, which is the opposing force to elevation, counteracts its effects. The East Indian geologists estimate that in the Himalayas the process of elevation is going on constantly, and that it is at least equal to the loss from denudation.

The application of all that has gone before to the Charleston earthquake is simply this: that we learn from the facts cited that displacements are constantly taking place in the crust of the earth the world over, and as these affect rigid and resistant masses of rock they are produced *per saltum*, that is, in paroxysms. The strain accumulating until it overcomes the resistance is released in one or many efforts, each of which is attended by an earthquake vibration of greater or less force. The country bordering a disturbed belt is sure to feel the effects of subterranean movements more frequently than plains and plateaus removed from mountains. Every year we hear of local disturbances in the Southern Alleghanies, and Bald Mountain has been the scene of so many that it has come to be looked upon with awe and apprehension by the people in the vicinity. So along up the Atlantic slope of the Alleghanies there have been many earthquakes since the country was occupied by whites. Not a year passes that we do not hear of several in New England, the Middle or Southern States. As the population increases, the number of observers is multiplied and the number of structures liable to damage constantly added to; so that such phenomena now attract more attention and cause greater destruction than formerly. In New England the best record of earthquakes has been kept, and if any one will look over a file of newspapers published at Boston or Hartford, he will find that within the last century a very large number of earthquake shocks or vibrations are noticed. Earlier than that, we must depend upon town records or private correspondence. From these we learn that in 1727 the country about Newburyport, Mass., was shaken up, very much as Charleston has recently been, but in that region there were then but few buildings and those of wood; so that the damage was comparatively small.[1]

Two years ago, New York City suffered an earthquake shock, but fortunately not a severe one. It occurred about two o'clock Sunday afternoon, the 10th of August. I was sitting alone in my room in the College, where all was perfectly still; suddenly I heard a heavy rumbling sound like that of a passing loaded

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[1] Since this paper was written I have received "Historical Notes on the Earthquakes of New England from 1638 to 1869," by William T. Brigham, published in the Memoirs of the Boston Society of Natural History, 1868. This contains notes upon two hundred and thirty-one earthquakes, with many interesting details.

wagon ten times magnified. At the same time the building began to vibrate, the windows rattled and some light objects were disturbed and fell to the floor. I was sensible of a tremor that not only jarred, but swayed my body and caused my book to vibrate and swing in my hand. I recognized the nature of the phenomena at once, observed the time and made a note of it. Subsequently, going into the geological cabinet, I found palpable evidence of the force of the vibrations. In a case occupied by specimens of marble, many of which were set on edge against the back of the case, all such were thrown down and some were broken. As the back of the case was toward the north, this proved that some of the vibrations were from that direction. This earthquake was noticed by a number of observers, and their testimony showed that the area affected was, as usual, elliptical in outline, and extended from Washington, D. C., to Portsmouth, Me., and from Harrisburg, Pa., to the Atlantic.

In the Old World, observations on earthquake vibrations have been reduced to a system, and instruments called seismographs or seismometers have been devised, which make an automatic record of the time, direction, and force of the vibrations. Where such instruments are scattered over a country it is evident that the outline of the area affected by an earthquake shock, as well as the geographical position and depth of the centre of motion, may be accurately determined.

In Japan, where earthquake vibrations are almost incessant, an extended system of observations has been instituted by Prof. Milne, which are likely to throw much light upon this subject.

In this country there are few seismometers, and no carefully regulated system of observation has been yet adopted, but it is probable that one good effect of the Charleston earthquake will be to excite an interest in such phenomena that shall result in the organization of a thorough system of observation. The officers of the Geological Survey and Signal Service Bureau are taking an active interest in the matter, and it is probable that observations on the movements of the earth will be added to those they are now making on the movements of the atmosphere.

When the data already collected in regard to the Charleston earthquake shall have been tabulated, it will doubtless be found that the displacements which occasioned the vibrations were located along a line parallel with the Alleghanies and at a depth of 10,000 to 20,000 feet, not under, but westward of the city.

Inasmuch as no great change took place on the surface of the land in South Carolina, it has been suggested that the seat of the movement was under the ocean, and that important changes may have taken place in the topography of the sea bottom. It is quite certain, however, that such was not the case; for any considerable movement beneath the ocean in the vicinity would have resulted in a great wave upon the shore, such as have attended many other earthquakes, viz., that of Kingston, Jamaica, in 1692, of Lisbon in 1755, or that of Arica, Peru, in 1868. No wave at all is reported on the coast of South Carolina, though a distinct shock was felt on board a ship which had just left Charleston. This proves that the seat of the disturbance was not under the sea, but on the land, the vibrations passing from the land seaward. It is reported that a slight change in the depth of the water in Charleston Harbor has resulted from the earthquake, but no accurate observations have been made to test the truth of the report. In all probability the movement was in the old crystalline rocks beneath the comparatively modern deposits which underlie the surface, and consisted in a yielding to lateral thrust which ruptured and slipped some of the beds over others. Such fracture and movement would produce vibrations which would take the form of successive waves passing vertically, upward and outward in every direction from the focus of action. As the older rocks which underlie this region dip toward the east and have a strike north and south, an impulse produced by disruption would move north and south in continuous strata, and east and west through a succession of beds which would be less good conductors. Hence the area of vibration will doubtless be found to be an ellipse with its longest diameter north and south.

One fact reported from Charleston is very interesting if true, and that is that the railroads leading westward were shortened; the rails being arched much out of line. To straighten the roads, it is said to have been necessary to cut out "here one foot," there two feet," etc., of the rails. This shortening, if verified and measured, would give a clue to the location and extent of the subterranean movements which produced the vibrations.

The determination of the depth of the focus of action in earthquakes is generally a difficult problem from the lack of accurate observations. Where the angle of emergence of the earthquake waves can be ascertained, even along a few lines, it is easy to fix the point where these lines intersect. In this way the depth of focus of many earthquakes has been determined. Mr. Mallet, who has made the most elaborate study of earthquake phenomena, gives the maximum depth at $8\frac{1}{2}$ geographical miles and the minimum depth at $2\frac{3}{4}$ miles; but Dr. Oldham, late director of the Geological Survey of India, estimated the focus of action in the great Cachar (Bengal) earthquake of 1869 to be from twenty-five to thirty miles in depth.

The bursting out of temporary springs or fountains of water carrying quantities of sand has been mentioned as a remarkable feature in the South Carolina earthquake, but this is a phenomenon common to many earthquakes, and is specially noticed in the accounts we have of those of Newburyport of 1727, and New Madrid, 1811. It is, doubtless, due to the pressure exerted by the earthquake-wave on subterranean reservoirs of water, or the compression of water-bearing strata.

Another circumstance, which has excited some curiosity, is the twisting of chimneys and monuments on their foundations. This has been noticed among the consequences of many earthquakes, and it has been generally attributed to a gyratory movement of the earth, but Mr. Mallet has shown that this is not a necessary conclusion, but that an adhesion to one part of the foundation would cause a revolution of the superstructure about this point.

It will be noticed that, in the reports which have been given of the Charleston earthquake, there is an absence of all reference to the explosions which have been among the most striking and destructive phenomena of earthquake action in some localities. Thus, in the description of the great earthquake of Riobamba, Equador, in which 40,000 persons perished, it is said that the bodies of many of the inhabitants were thrown upon a hill which rose to the height of 100 feet on the other side of a stream; and, during the earthquake of Chili, 1837, a mast, planted 30 feet deep, was thrown out so that a round hole remained behind. These, which are called explosive earthquakes, have been confined to the vicinity of volcanoes and to districts bordering on the sea, and it is supposed that, by the disruption of the rocks, large quantities of water have been suddenly brought into contact with melted lava. Steam has played an important part in most volcanic eruptions, though as a secondary, and not, as often supposed, a primary cause. Masses of molten matter, welling up through fissures in the earth's crust, must necessarily come in contact with subterrean reservoirs of water, or with strata saturated with moisture. In the vicinity of the sea, too, where most volcanoes are located, water may be admitted in the manner just described. In all these cases, steam would be generated in such quantities as to make this an efficient adjuvant to the lava flood in producing disruption, upheaval, and vibrations of the rocks. The absence of these violent features in the earthquakes of the country bordering the Alleghany belt proves that volcanic action has had nothing to do with them, and shows that, like a vast majority of earthquakes elsewhere, these have been, as Dana says, "incidental phenomena in the process of mountain building;" that is, they are sensible signs of the lateral movement of the earth's crust which results in the crushing, folding, faulting, elevation, and metamorphism which are distinctive features of all mountain belts and chains. Where this action takes place on a grand scale, and involves the entire thickness of the earth's crust, mountain chains of great elevation, length, and breadth are the result, and, through profound fissures opened to the zone of molten material below, lava rises and overflows. In the Triassic age, such deep fissures were opened along the Atlantic border of the continent, as is attested by the trap sheets and dikes which extend interruptedly from Nova Scotia to the Carolinas. At that time, the whole coast must have been shaken with earthquakes of great violence, and much of it devastated by lava-floods. Since then, the earth's movements have been only the relatively gentle vibrations caused by the yielding of the flexed and fractured rocks of the upper portion of the crust to the ever acting and resistless thrust of the great unbroken tables of the Mississippi Valley and the Atlantic basin.

EARTHQUAKES AND VOLCANOES AS MEASURES OF THE THICKNESS OF THE EARTH'S CRUST.

As is mentioned in the early part of this article, the first result of the discovery of the law of increase of temperature in going toward the centre of the earth was the conclusion that the solid crust was not more than 50 miles in thickness, and below that was a sea of fluid or semifluid molten matter. Then mountain chains were supposed to be the result of the crushing together of solid sheets of rock as they followed the cooling and shrinking interior. The coat becoming too large, and adhering to the body, must wrinkle as the body shrank. Volcanic eruptions were supposed to be the oozing out of molten matter from the not distant zone of fused material, and all was harmonious in the geological world. Then came Professor Hopkins, Archdeacon Pratt, and Sir William Thomson, in the character of disturbers of the public peace; they said that the crust would be broken up by tides if it was as thin as supposed; that the shell would be pulled about on the fluid nucleus by the attraction of the moon on the equatorial protuberance; and, finally, that the tenacity with which the figure of the earth is maintained under the varying pull of the sun and moon made it necessary to suppose that it was, as a whole, as rigid as a globe of glass, or even of steel. Sir William Thomson conceded, with some hesitation, that the crust of the earth might not be more than 2,500 miles in thickness; further than that he would not go. Since that time, awed by his great and well-deserved fame, geologists have generally accepted the conditions he imposed upon them, and there has been a terrible struggle to reconcile volcanoes, earthquakes, and the flexibility of the earth's crust with a solid interior. Some have gone back to Sir Humphry Davy's theory, that volcanoes were the product of intense chemical action in certain circumscribed portions of the earth's mass; and others have supposed that, between a thick external crust and a solid interior there was an intermediate zone of fused matter from which volcanic ejections emanated. Mallet, who has displayed great learning and ability in his various papers on volcanoes and earthquakes, forbidden by Sir William Thomson's dictum from drawing molten matter from the interior of the earth to operate his volcanoes, contrived a method of manufacturing it on the spot. He proposed a theory that all the phenomena of vulcanism are due to the arching of the exterior strata composing the earth's crust, their final yielding to gravity and crushing down on to the contracting interior; the conversion of motion into heat producing all the thermal phenomena.

A fatal defect in this theory is that it gives no reason for the localization of the heat along the line of fissure from which the lava flows. All parts of the masses on either side must share in the motion and should also share in the heat, and we must look elsewhere for an explanation of the phenomena.[1]

There would have been no question of the truth of the old theory of vulcanism if it had not been raised by the physicists whose names have been mentioned, and it can now be seen that their objections have little force. Delaunay, of Paris, and Hennessy, of Dublin, have shown that the premises assumed by Thomson, Hopkins, and Pratt in their attempted refutation of the old theory of a comparatively thin crust are not those of nature, and that their conclusions are, as a consequence, irrelevant and valueless. Their objections were aimed at an incompressible fluid interior and an elastic crust; conditions which do not and could not exist. Beside this there must be a viscous zone of considerable thickness in which the transition from the solid crust to the liquid interior is very gradual; and it is highly probable that the matter of this viscous zone is not only not it-

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[1] In a review of Mr. Clarence King's report "On the Geology of the Country Bordering the Fortieth Parallel," the writer in 1879 suggested a simple explanation of the phenomena of vulcanism, viz., A slight arching of the crust of the earth along lines of fracture and elevation, in a measure relieves the pressure by which highly heated matter below is kept in coerced solidity. This relief of pressure causes the potential fluidity of this compressed matter to become actual, and thus reservoirs of lava are called into existence beneath the lines of fracture and arching. Finally the pressure from gravity being maximum under the tables of unbroken strata on either side, and minimum beneath the crown of the arches, this unequal pressure causes the lava to rise along the fissures and flow out in volcanic eruptions.

self affected by tidal movements, but that it acts as a buffer between the liquid interior and the solid crust. It should be remembered that the moon's attraction—the chief motor in oceanic tides—is a force applied to a surface moving at the equator about a thousand miles an hour. Even a fluid as thin as water refuses to obey instantly an attracting body. The tidal wave of the ocean is always considerably behind the moon, and in some places where obstructed by topographical features it does not reach its destination until some time the next day. It is easy to see that in a tarry, pitchy mass the response to the moon's attraction would be far less prompt, and also that the tidal waves in zones of different depths and densities would not coincide, and might completely neutralize each other.

Every boy knows that if a flat rock is thrown from a cliff on to water some distance below, it is shattered almost as though it fell upon a solid; but the velocity of a falling body *in vacuo* is 16 feet the first second, 48 the second, etc., and with the resistance of the air, it is doubtful whether a stone thrown from a cliff 100 feet high reaches the water with a velocity greater than 50 feet a second, while the velocity of impact, if we may use the expression, of the moon's attraction is nearly 30 times greater than that, or 1,466 feet per second. The resistance which the internal friction of a viscous body would offer to a force applied with such velocity would be enormously greater. Hence we must conclude that the tidal movement in such a mass even at the earth's surface must be very small, and if, as is the case in the interior of the earth, that mass were condensed and constrained by the weight of a crust even a hundred miles in thickness, it would be inappreciable. It should be remembered that the force of gravity acting upon a column of matter one foot square and having the density of the materials composing the earth at the surface, that is $2\frac{1}{2}$ times that of water, is 792,000 lbs. for every mile, or 79,200,000 lbs. at the depth of 100 miles. Such a pressure must greatly increase the density of matter of any kind. The average density of the earth is $5\frac{1}{2}$ times that of water, and it is plain that in matter of this density and so situated not only a tidal wave would be impossible, but any attraction which is constantly and rapidly changing its point of bearing must be practically powerless to distort the figure of the earth.

FLEXIBILITY OF THE EARTH'S CRUST.

It is difficult to imagine how the advocates of the theory of a solid globe can account for the formation of mountain chains, the loftiest and longest of which are quite modern; and it is not perhaps too much to say that these themselves are a refutation of their theory. It is evident that a heated solid globe, as it lost its heat, would either contract bodily as a red-hot cannon ball does, or by the more rapid cooling of the outer surface, that would shrink faster than the interior, and crack in every direction; a process just the opposite from that which we find recorded in the earth's crust.

But there are other evidences of the flexibility of the earth's crust which are incompatible with the theory which ascribes to it great thickness. (1.) The lines of volcanoes which crown most great mountain chains are located along fissures which seem to be continuous for thousands of miles, and there is apparently good evidence that these fissures penetrate through the entire thickness of the solid crust. Sometimes the volcanoes are in simultaneous action for several hundreds of miles, and the materials ejected, though showing much variety, are often identical: facts incomprehensible on any other supposition than that they have been drawn from a common reservoir.[1]

(2.) Along all the coast lines the evidences of local changes of level now in progress, or included in the records of past time, are so numerous and striking that the term *terra firma* seems singularly ill-chosen ; for example, the shores of the Mediterranean abound in evidences of local depressions or elevation, or both, since it has been occupied by civilized man. Of these the temple of Jupiter Serapis at Baiæ is one of the most famous, but by no means the only example.

On our own continent, the southern portion of Greenland has been gradually sinking for several hundred years; Labrador and Newfoundland are rising ; Prince Edward's Island and Cape Breton, according to Gesner, have sunk many feet since they were first occupied by the whites. In Nova Scotia the land is rising ; in Northern Maine it is sinking, as also at Cape Cod and Martha's Vineyard and on the shore of Long Island and New Jersey. Here the subsidence has locally varied from two to twelve feet during the last century. In the West Indies, there are many evidences of local change of level ; in some cases, of elevation, others, of subsidence. In California, we find traces of recent and local flexures of the coast which are very striking ; at San Diego is an old beach strewn with shells which have not yet lost their colors, twenty feet above the present sea-level. At San Pedro, the port of Los Angeles, the limestone rocks which form the sea cliffs are bored by *Pholas* eighty feet above the water ; on the south shore of San Pablo Bay, at a height of twenty

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[1] Darwin mentions ("Trans. Geol. Soc.," March, 1838), that in the Andes the volcanoes Osorno, in lat. 40° S., Concagua, in 32° S., and Coseguina, in lat. 13° N., burst into eruption simultaneously on the 20th January, 1835. The more remote of the three are 3,700 miles apart.

feet above the water, is a bank of oyster shells, four feet in thickness; this descends toward the south, and disappears beneath the surface of San Francisco Bay. Puget Sound, with its many branches, is only the submerged valley of a great river which ran out to sea through the Straits of Fuca when the coast was much higher than now; but the shores are terraced to the height of 1,600 feet above the present water-level; showing that, in recent times, they have been much lower than now. Similar facts with these have been reported from the shores of all the continents, and the islands afford more striking examples of the changes of level; the Windward Islands are only the summits of a lofty mountain chain which was once all above the sea-level, as is shown by the community of species in animals and plants. The Islands of the South Pacific are, also, the summits of mountains which have been gradually submerged, as has been shown by Dana and Darwin. Coral reefs which are formed only within 150 feet of the surface now extend down in continuous walls, 2,000 feet below the water; the growth of the coral having kept pace with the gradual subsidence. Elisée Reclus, in *La Terre,* and Professor Prestwich, in his *Geology,* give maps, showing the fluctuations of level now in progress along coast lines; and whoever will examine these maps will find it difficult to reconcile these oscillations of the land with a globe solid to its centre, or even with a thick crust. But the changes of level now taking place proceed so slowly that the record of one hundred and fifty years, during which geological observations have been made, or even that of the long period covered by human history, is insignificant, compared with that of the geological ages. Indeed, historical geology is, for the most part, but a transcript from the monuments left by successive and local subsidences of the land, influxes of the sea, and the deposition of strata containing relics of the marine and terrestrial life of the epochs in which these inundations occurred. Scarce any portion of any continent is without traces of the presence of the sea, and, while some of these submergences were, doubtless, caused by great tides which ebbed and flowed from one hemisphere into the other, in the manner suggested by Adhemar, it can be easily shown that most of them were occasioned by local subsidences of the land.

All these lines of evidences, furnished by earthquakes, mountain chains, volcanoes and terrestrial oscillations, converge to one point, and, in combination, go far to prove that the earth's crust is relatively thin, and that its interior is fluid or viscous.

A priori considerations confirm this conclusion. If, as all believe, the earth was once a globe of molten matter which has cooled by radiation from the exterior, it seems impossible that the first formed crust could have sunk to the centre, and there-laid the foundation of a solid structure, subsequently built up to the surface. Because, first, there is no probability that the superficial crust had a higher specific gravity than the underlying fluid; and, second, if its gravity were greater, and when broken up its fragments sank, they must soon have been melted by the greater heat below; and when, by this process, the outer zone of the earth had acquired a pasty consistence, its cohesion could not have been overcome by sheets of crust, even if a little denser. Hence, a cool, external crust, a hot, viscous zone, and a hotter fluid nucleus seem logical necessities.

PROXIMATE CAUSES OF EARTHQUAKES.

Atmospheric Conditions.—If it is true, as claimed on the preceding pages, that earthquakes are the vibrations attending the folding and breaking of rocks which have been in a state of strain, it is evident that the provoking cause of any special paroxysm might be a comparatively trifling affair—some feather that should break the camel's back. Thus, we have reason to believe that atmospheric conditions may precipitate these catastrophes. The pressure of the atmosphere on the earth's surface is 14.7 pounds to the square inch—that is, a little over 2,000 pounds to the square foot, or about 30,000,000 tons to the square mile. Now, it sometimes happens that the mercury oscillates two inches in the tube of a barometer in connection with some violent storm; and it is true that the areas of low and high pressure change position quite rapidly. Hence, if it should happen that the underlying rocks were from lateral pressure in a state of strain that had nearly reached the limit of resistance, a change of atmospheric pressure equivalent to two, or even one inch of mercury (equal to 1,000,000 or 2,000,000 tons per mile), might be the cause of a rupture. So, the popular belief, that peculiar atmospheric conditions have had an influence in causing earthquakes, is not so absurd as it might seem.

Accumulation of Sediments.—Another cause which has certainly operated to disturb the static equilibrium of the earth's crust, is the transfer of the products of erosion from the land to the bottom of an adjacent sea basin. Over all land areas where the rainfall is considerable, there is a constant wearing away of the surface by chemical and mechanical agents. About one-fourth of the material removed is dissolved and may be carried to the opposite side of the earth before it is precipitated; but the other three-fourths, in the form of gravel, sand and clay, are simply held in suspension by running waters and are deposited as soon as their motion is arrested. Rivers, rivulets, and shore waves are constantly engaged in transporting material from the land to the deeper water bordering the coasts; there spreading it to make new series of sedimentary deposits. As these accumulate they not only impose new burdens on the underlying rocks, but by acting as blankets and preventing the escape of heat, they promote the softening and weakening of a belt of sea bottom. This process has produced great changes in the surface topography of many continents, and it is credited with the formation of a number of littoral mountain chains. The blanketed belt of off-shore sea bottom, softened by heat, yields to lateral pressure, and is forced up in a series of faults and folds. There is little doubt that the loading of the sea bottom with the products of erosion has been one cause of the earthquake vibrations which have been so frequent along our Atlantic coast.

Periodicity of Earthquakes.—Very naturally an effort has been made to connect earthquakes with the changing relations of the sun and moon. M. Perrey, of Dijon, France, has tabulated the records of 2,225 earthquakes which occurred between the years 306 and 1845. Of these he found that 1,712 took place in winter and spring, and 1,335 in summer and autumn. By Mr. Robert Mallett between 6,000 and 7,000 earthquake shocks are enumerated as having taken place in Europe only. Judging from all these it seems that earthquakes are a little more frequent when the attractions of the sun and moon are combined or opposed—that is at new and full moon—and when the earth is nearest the sun.

These data, although still defective, tend to support the theory of the fluidity of the interior of the earth, and confirm the testimony of volcanoes and of the secular oscillations of the earth's crust.

Areas of Exemption.—Probably no part of the earth's surface has been always free from earthquakes. Nevada, Utah, New Mexico and Arizona were in Tertiary times more completely broken up and devastated by earthquakes and volcanoes than any other country known to us, but in that same region profound peace prevailed from the Cambrian to the Cretaceous ages, many millions of years. Since the Tertiary, the Colorado plateau has been remarkable for its stability. This is shown by the sandstone pillars several hundred feet high standing at the mouth of the Cañon of Chelly, and in the Colorado valley near the junction of the Grand and Green Rivers. These columns have been formed by the slow removal of the material around them, a work of ages; and earthquakes would have brought them down in ruins, as they have shattered the monuments of Baalbeck, Tanis and Karnak.

Bibliography.—"First Principles of Observational Seismology," Robert Mallett; "The Facts and Theory of Earthquake Phenomena," R. Mallett, Reports of British Association, 1850–

58; Various papers on earthquakes, by R. Mallett, in the Philosophical Transactions and Transactions of the Royal Irish Academy; "Geological Theories of Elevation and Earthquakes," W. Hopkins; "Report Brit. Assoc." for 1847; Oldham and Mallett on "The Cachar Earthquake," Quarterly Jour. Geo. Soc., 1872, p. 255; Scrope's "Volcanoes;" Lyell's "Principles of Geology," vol. ii.; Prestwich, "Geology," vol. i.; Milne, "Earthquakes," 1886; "Catalogue of Earthquakes of Europe and Adjacent Countries," J. P. O'Reilly, Dublin, 1886; "Underground Temperatures," J. Prestwich, Proc. Roy. Soc., 1886; "Water in Volcanic Eruptions," Prof. J. Prestwich, Proc. Roy. Soc., 1886; "Internal Fluidity of the Globe," M. Delaunay, Geol. Mag., vol. v., p. 507; "Figure of the Earth," Archdeacon Pratt, 1860; "Rigidity of the Earth," Sir Wm. Thomson, Phil. Trans., 1863; "Inequalities of the Earth's Surface," Rev. O. Fisher, Phil. Trans., vol. xii.; Dana, "Geology;" LeConte, "Geology;" L'Apparent, "Geologie;" Hartwig, "Subterranean World."

October 25, 1886.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Forty-two persons present.

Mr. F. J. H. MERRILL read a paper entitled

NOTES ON THE GEOLOGY OF BLOCK ISLAND AND NANTUCKET.
(Published in the Annals, vol. IV.)

PRESIDENT NEWBERRY remarked upon several matters of geological interest in the vicinity of New York.

Mr. H. HENSOLDT, a visitor, stated that he had discovered in a meteorite, which lately fell at Braunfels, near Wetzlar, Germany, liquid carbonic acid in cavities in supposed quartz; and he discussed this and other facts concerning meteorites in their bearing upon the question of the earth's interior.

The subject was further discussed by Mr. L. E. CHITTENDEN and the PRESIDENT.

November 1, 1886.

REGULAR BUSINESS MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Fifty-two persons present.

The Report of the Council was received and adopted, which recommended the payment of a bill, and the election of REV. STEPHEN D. PEET, of Clinton, Wisconsin, as a Corresponding Member, and of the following persons as Resident Members:

REV. ANSON P. ATTERBURY,
MR. AUGUSTIN P. BJERREGAARD,
MR. JAMES S. GIBBONS,
MR. JOHANNES ROELOFFS,
MR. ORLIN MEAD SANFORD.

MR. L. E. CHITTENDEN, in continuing the discussion of the subject of earthquakes, following the paper read by the president at the meeting of October 18th, made observations upon a large number of celebrated earthquakes and their phenomena, with a view to some generalizations as to their causes.

After citing numerous reports given by Herodotus and Pliny, showing the frequency of such convulsions, but hardly mentioning any details, Mr. Chittenden passed over the long period of the middle ages, in which there is but little recorded, and beginning with the close of the seventeenth century, gave brief accounts of some of the most important earthquakes among the many since then known. Those of 1692 in Jamaica, of 1693 in the East India islands and in Sicily, and of 1699 in Java, all extremely destructive, were mentioned. An outline was given of the phenomena attending the well-known earthquake at Lisbon in 1755, which convulsed a tenth part of the earth's surface, reaching the great lakes of America, the West Indies, Scotland, Sweden, and the Baltic.

Mr. Chittenden briefly referred to the earthquake of 1762, central near Bengal, where sixty square miles of earth sank into the sea, of Java in 1772, where four thousand feet in height of a mountain were truncated; of Calabria in 1783, with its terrible details, continuous for nearly four years; of Sumbawa in 1815, attended by volcanic explosions heard one thousand miles away, and affecting all the islands within a radius of three hundred miles; of Cutch in 1819, where ever two thousand square miles sank permanently, and a new and navigable outlet of the Indus was formed; and those of Ischia in 1828 and 1882.

Like reference was made to some of the typical American earthquakes:—to those of 1602 and 1791, central in the St. Lawrence valley, in the first of which the shocks continued for months over an area of three hundred leagues; and to a number of those on the west coast of South America so destructive in Peru and Chili, and frequently accompanied by volcanic activity, at points both near and remote in the Andean chain.

The earthquake of 1811, known as that of New Madrid, was most violent in the Mississippi valley. It was followed by shocks at short intervals until March, 1812, when one of great severity destroyed the city of Caraccas, in Venezuela.

Accepting the nebular hypothesis, the evidence points to an earth crust from twenty to fifty miles thick, resting upon the plastic, semifluid contents of the interior. Volcanoes are the vents of this interior. Where earthquakes occur in the volcanic regions of Southern Italy, of Java, of the Moluccas, and of the region of the Andes, as the greater number do, they seem to have an intimate association with the volcanoes. The quantities of matter suddenly ejected from these volcanoes, attended by explosions and the conversion of masses of water into superheated steam, must create cavities of the fluid contents, into which the flexible crust settles by gravity or pressure, causing surface elevations and depressions. Mere shrinking by cooling would not produce rugged mountain chains of their present form. Combined with these dynamic forces, more active in earlier cosmic ages, they were quite adequate to elevate the Andes or the Himalayas. All the phenomena of earthquakes in volcanic regions indicate their deep-seated origin and their connection with disturbances of the fluid interior of the earth.

There was another group of earthquakes which occurred in regions of slight or no volcanic activity, some of them too remote from volcanoes to have any connection with them. If attended by volcanic eruptions, these never preceded, and always ceased with the convulsions. Yet they were gigantic in their phenomena—terrible in their devastating effects. What and whence was their origin? Were they due to the expansive force of vapors in subterranean cavities; to a slipping of sections of the earth crust upon each other; or to forces within the crust itself, and not more than 10,000 or 20,000 feet from its exterior surface?

These earthquakes usually, it might almost be said always, occurred or were most severe in the deltas of great rivers or in such proximity to them as to point to some association of such rivers with their origin. Such were the earthquakes of Cutch at the mouth of the Indus, of Lisbon at the outlet of the Tagus of of 1662 and 1791, in the gulf of St. Lawrence, of New Madrid in 1811 in the valley of the Mississippi. Even those of Chili were most destructive at river-mouths, like that of 1837 described by Darwin, which destroyed Concepçion in the valley of the Biobio River. It might even be possible to include in the group the so-called Charleston earthquake of 1886.

To learn what happens at the outlet of a great system of river drainage, we could have no better example than the Mississippi. With its branches it is the longest, its tributaries are the most numerous and the largest, and it drains the greatest area of any upon the earth. If the computations of engineers are reliable, it has in the past deposited a delta which commences above the Ohio River, has a superficial area of 13,600 square miles and an average depth of five hundred and twenty-eight feet. Every year it gathers up its burden from a vast plain, transports one thousand miles southward and deposits in the regular basin, called the gulf, 3,702,758,400 cubic feet of solid matter. At thirteen cubic feet to the ton, the annual tonnage of this carrier by water is 284,827,569 tons.

Such a weight added year by year, principally deposited around and not far from the outlet, must in time become too great to be sustained by the earth crust beneath and the crust must give way. When it does, there will be a depression into the fluid below, which must be compensated by an elevation elsewhere.

If the subsidence is gradual, there may be no surface disturbance. But the crust is not homogeneous, is more rigid and less flexible in some places than in others. Suppose it resists the pressure in some places and yields to it in others for a time, and then at the weakest point suddenly gives way. That point may be anywhere within a circle large enough to include Charleston. Wherever it is, there will be a sudden disturbance of levels, not only on the surface, but in the interior contents. It will give birth to an earthquake wave which, once set in motion, will, like all waves in fluids, be followed by others of less magnitude, until the levels are all adjusted and the equilibrium is perfectly restored.

In conclusion, Mr. Chittenden maintained that the theory, that there was a class of earthquakes resulting from wave movements of the fluid interior, accounted better than any other for the successive shocks of diminished force; it conformed to the evidence that true fissures extend through the crust, and that volcanic vents communicate directly with the interior contents; it was consistent with the inferred thickness and known flexibility of the crust, and accounted for the large area of surface sometimes involved. He did not contest the agency of shrinkage as a powerful factor of earthquakes; he presented these conclusions of his own mind from an examination of the accessible evidence, that there was a class of earthquakes resulting from movements in the fluid contents below the earth crust, caused by changes on the surface due to river transportation.

Dr. N. L. Britton said he was informed that the series of posts placed along the New Jersey coast to show changes of level were not perceptibly changed by the recent earthquakes.

Mr. H. T. Woodman and the President also spoke.

November 8, 1886.

Stated Meeting.

The President, Dr. J. S. Newberry, in the chair.

Fifty-four persons present.

Mr. B. B. Chamberlin exhibited pink dolomite from Morrisania, found near the north end of the Madison avenue bridge.

Mr. A. P. Bjerregaard stated that he had analyzed it and regarded it as ferruginous dolomite or ankerite.

Dr. J. J. Friedrich exhibited muscovite from West 87th street, which was apparently folded and crushed as if by the yielding of the strata.

Mr. George F. Kunz showed the cast of a diamond from North Carolina, which was probably the finest known from the

United States. He also exhibited gold ornaments from the mounds of Orange Co., Florida. The metal was ninety-eight fine, and might have been obtained in North Carolina. One disc had a bullion value of sixty dollars; another was a casting. Ornaments of silver were also shown.

Mr. Kunz also referred to the discovery of fine pink spodumene at Andover, Maine; and a fine golden beryl at Litchfield, Conn.

In reply to questions, Mr. Kunz said that the Cherokee gold ornaments were of low grade gold, averaging 400 to 600 fine, and many were plated.

The President said that some of the "plated" ornaments were produced by "pickling" in acids an alloy of gold and baser metals, and then burnishing the surface to leave there a layer of pure gold.

Dr. Henry A. Mott read a paper on

A LIMIT TO THE HEIGHT OF THE ATMOSPHERE.

The subject was discussed by President Newberry and Prof. W. P. Trowbridge.

November 15, 1886.

Stated Meeting.

The President, Dr. J. S. Newberry, in the chair.

Fifty-six persons present.

Mr. Chittenden, referring to the gold ornaments exhibited by Mr. Kunz at the previous meeting, suggested the possibility that the gold might have been obtained from a Spanish ship which was wrecked on the Florida coast in the year 1640, laden with a large amount of gold from Central America. Chroniclers had mentioned that some of the gold was in possession of the natives of the coast.

Dr. Charles E. Pellew read a paper on

RECENT INVESTIGATIONS ON THE MITIGATION OF PATHOGENIC BACTERIA.

The subject was discussed by Mr. Lucius Pitkin, Prof. C. F. Chandler, Mr. L. E. Chittenden, and the President.

November 22, 1886.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Forty-one persons present.

MR. A. P. BJERREGAARD exhibited galena from shaft 22 of the new aqueduct, Fordham Heights; and the PRESIDENT remarked upon the occurrence and origin of the mineral.

The SECRETARY spoke of the discovery by Prof. Branner, of Indiana, as announced in the November number of the *American Journal of Science,* of undoubted glacial striæ upon the summit of Elk Mountain, the highest point in Northern Pennsylvania, it being 2,700 feet above tide.

The thickness of the ice-sheet of the Glacial Epoch was discussed by the PRESIDENT; also its work and the evidences of more than one ice period. He referred to the recent discovery in India of supposed glaciated boulders in clay slates, which lie at the base of tertiary strata, and the added force which this discovery gives to the theory of cosmic causes of the climatic changes.

PROF. D. S. MARTIN thought that in deposits of ice periods due to astronomical causes could be found a key to the length of geologic time.

The subject of the peculiarities and amount of glacial erosion was discussed at length by MR. L. E. CHITTENDEN, MR. F. J. H. MERRILL, and the PRESIDENT.

PROF. D. S. MARTIN in behalf of a special committee read a memorial sketch of

Mr. Rufus Prime.

November 29, 1886.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Thirty-seven persons present.

MR. J. J. FRIEDRICH exhibited malachite, with its associated minerals, from 117th street, between Fourth and Madison avenues, also quartzite containing a large proportion of disseminated tourmaline.

MR. L. E. CHITTENDEN stated that he had found proof in old records that the Natchez Indians smelted the gold of Georgia.

MR. P. H. DUDLEY showed a fine instantaneous photograph of a railway train moving at the rate of forty-eight miles an hour.

PROF. ALBERT R. LEEDS read a paper on

THE AMERICAN SYSTEM OF PURIFICATION OF THE WATER SUPPLIES OF CITIES.

Acting under instructions from the Aqueduct Boards of Newark and Jersey City, I spent the past summer in examining the water supplies of the large cities in England and Scotland. Many of these cities have already passed through crises in the history of their water supplies, similar to those at present agitating American communities. It is of systems of purification which they have adopted, and of a quite different American system designed to meet the different requirements of climate, character of water supplies, labor and capital in our own country, that I propose to speak this evening.

Our modern manufacturing towns increase in population with such rapidity that they soon find their local sources of water supply insufficient in quantity, and dangerous to health from pollution by sewage and factory waste. Then follows a more or less prolonged period of bitter controversy. It matters not how plain the fact of gross pollution may be, the fact is denied. In case the chemical testimony agrees with that of the senses, and water which is dirty, foul-smelling, and bad-tasting is found by the chemist to be impure, his honesty and ability are assailed. Either his results are declared false, or it is asserted that they mean just the reverse of what he himself says. Other experts are employed, and the local water supply, though it may contain the sewage of ten or a hundred thousand people, like that of Albany, Newark, Jersey City, and Philadelphia, is *joyfully discovered to be extremely wholesome, and second in purity to none in the country.* But at last, after years of denial, during which the public health has severely suffered, the fact of pollution is admitted, and the community resorts to one or more of the three following remedies:

1st. It abandons local for remote sources, such as springs, lakes, rivers, or areas of upland drainage.

2d. It sinks artesian wells, or deep wells, or subterranean galleries.

3d. It purifies the polluted local supply.

In the study of this subject, there is no source of information more valuable than the blue books containing the minutes of inquiry before the Royal Commissions of 1851 and 1868 upon the supply of London. It is there stated that at first London drew its supply directly from the Thames where it flowed through the town, at London Bridge. This was in 1581, and a century later (1691) the Thames was again drawn upon at Charing Cross, and this intake remained in use as late as 1829. Again, in 1723, the Chelsea water works were established, and in 1785 those at Lambeth. Whilst some part of the water supply was derived from springs in the chalk formation at Chadwell (brought in through a canal called the New River, in 1613), and another part from the river Lee (introduced by the East London Water Works Co. in 1806), yet as late as the year 1829, the metropolis was principally supplied by water taken from the Thames within the reach of the tidal flow. But in 1829, a Royal Commission, consisting of Telford, Brande and Roget, was appointed to inquire into "the description, the quality, and the salubrity" of the water. They reported "that the Thames water, when free from extraneous substances, was in a state of considerable purity; but as it *approached the metropolis it became loaded with a quantity of filth which rendered it disgusting.* It appeared, however, that a very considerable part, if not the whole, of this extraneous matter might be removed by filtration through sand, and the Commission decided that it was perfectly possible to filter the whole supply with the requisite rapidity and within reasonable limits of expense." Stimulated by this report, and alarmed probably at the prospect of a sweeping change of the sources of supply, the companies directed their attention to the purification of the water by filtration. It was soon found that the only appropriate material for mechanical filtration on a large scale, was fine sand; but the great practical difficulty was to prevent the sand from becoming clogged, and to find an easy, practical, and cheap method for its renewal. After long experimentation, a means was discovered of getting over these difficulties. It was found that by far the greater quantity of the impurities was held in suspension by the agitation and motion of the water, and that, if it was allowed to stand for some time at perfect rest, in a reservoir, *the heavier and grosser particles were deposited by simple subsidence,* leaving only a small proportion of lighter and finer matters to be dealt with by filtration. It was also found that when the water was allowed to filter downwards through a porous bed of sand, held up in its place by underlying layers of coarse gravel, the dirt did not penetrate into its mass, but was stopped at its upper surface, so that the *whole cleaning operation necessary was to scrape this surface off to a slight thickness*, and, when it had become too much diminished, to put on fresh sand.

In accordance with these suggestions, the first large filter, which had an area of one acre, was put into use by the Chelsea Co. in 1829.* It worked well, so well indeed that it led to the well-nigh universal practice of filtration in England. Our failure to do the same in this country shows that in this respect we are behind the age.

But about the time of this first use of filters in England, the disturbing ideas of modern sanitary science took their rise; that unspeakable abomination, the domestic cesspool attached to a city house, began to be abolished; drainage and sewerage works were established, and the amount of impurities carried to and fro under London Bridge was increased enormously.

This agitation kept on growing until, in the year 1834, the engineer, Mr. Telford, recommended that the Thames should be abandoned. This was not done, but in 1851 a Royal Commission, consisting of Profs. Graham, Miller, and Hoffman, recommended that while the supply should still be drawn from the Thames, the points of intake should be removed above the influence of tidal flow (*i. e.*, above Teddington lock). They made other recommendations which were incorporated into an Act passed in 1852, regulating the water supply of the metropolis. In this act the two clauses of greatest significance to us are, first: That every storage reservoir within five miles of St. Paul's should be covered; and, secondly, That all water supplies for domestic use *should be effectually filtered, unless it is pumped from wells direct into covered reservoirs.*

A mere statement of the law which was passed after a quarter of a century of discussion by the most eminent engineers, chemists, and law-makers of England, is a more emphatic testimony to the fundamental importance of the provisions therein contained than any argument I am able to make.

This law led to certain results throughout England, which I trust will become universal. These are:

1st. The education of public opinion to such a point as to demand sources of city water supply, actually and visibly free from pollution. The wealthiest communities, like Glasgow, Manchester, and Liverpool, have deemed it a wise investment of great sums of money to obtain sources absolutely free from suspicion and reproach.

2d. The construction of large, and in some cases vast, reservoirs with the object, not merely of safety, but also of allowing

* Royal Comm. Water Supply, 1868.

opportunity for the dissolved organic matters to oxidize, and to be carried by subsidence along with the suspended mineral matters to the bottom.

3d. Effectual filtration. And it should be noted that, when the act of 1851 required the London companies to filter the water, under very heavy penalties, the water referred to was that taken from the Thames above Teddington lock, which water the Commission had previously found to be "perfectly wholesome, palatable and agreeable." Still more striking instances of the estimate put upon filtration, as a process indispensable to the excellence of city water supply, were frequently brought under my personal observation, and some I shall mention later.

4th. The preservation of the water, after it has been filtered, in covered storage reservoirs.

The good effects of the act of 1851 speedily became apparent. The water companies expended 2,500,000 pounds, with the result, according to the examinations of Prof. Hoffman and Mr. Blyth made in 1856, of bringing about "a very positive and considerable diminution in the amount of organic matter. This, though doubtless due chiefly to the removal of the intake above the tideway of the Thames, was also attributed in great degree to the considerable improvement which had taken place in the collection, filtration, and general management of the supply of water."

But, fortunately, the public was not satisfied. In pursuance of the recommendations of the Royal Commission of 1865, on the pollution of rivers, the admission of sewage or any other offensive or injurious matter into the Thames, or into any tributary, stream, or water course within three miles of its junction with the Thames, was declared illegal, with heavy penalties. In 1866, 5,596 lives were destroyed in London by cholera, and although this visitation was subsequently attributed to the polluted water of the Ravensbourne and the foul unfiltered water from the reservoirs at Old Ford on the river Lee, yet it so alarmed the community that the Commission of 1866 was appointed to make a far more extended inquiry than ever before, and to ascertain what supply of unpolluted and wholesome water could be obtained, by collecting and storing water in the high grounds of England and Wales, either by the aid of natural lakes or by artificial reservoirs, at a sufficient elevation for the supply of London and the principal towns of England. Now it is a well-known fact that the recommendations of the very distinguished engineers came to naught, so far as London was concerned, though they are at present bearing fruit in connection with Manchester and Liverpool.

It is well worth our while to inquire why such was the case.

Mr. Bateman's plan was to bring the waters collected from the drainage areas at the head of the river Severn in Wales (including the drainage area of the Vyrnwy) by gravitation through an aqueduct 180 miles in length, and capable of conveying 230,-000,000 gallons per diem. Messrs. Hemans and Hassard proposed to bring the waters of lakes Thirlmere, Ullswater, and Haweswater through conduits, tunnels, and pipes equivalent in their carrying capacity to a river 30 feet wide and 10 feet deep, over a length of 270 miles. These plans, which were considered the best, were reported upon unfavorably, principally on account of the cost, the estimated expense of Mr. Bateman's scheme being 55,000,000 pounds, and that of the Cumberland Lake scheme still greater.

This report decided the future supply of the metropolis and confined it to local sources. The supply from *Lake Thirlmere has already been appropriated* by the city of Manchester. The water will be brought in a tunnel nine feet square to the reservoirs at Prestwich on one side of Manchester, a distance of 95 miles, and continued thence to reservoirs on the other side of Manchester, a distance of 110 miles. Mr. Hill, the engineer of the new supply, informed me that the first ten million gallons are estimated to cost two million pounds, inasmuch as the tunnels of full size are to be constructed at once, and connected by a forty-inch iron pipe where siphons are necessary. The second ten million gallons are estimated to cost only 400,000 pounds. The land damages to persons living around the lake and along the tunnel are 225,000 pounds.

The supply from Vyrnwy Lake has been appropriated by Liverpool. This artificial lake is to be created by a dam which at its top will have a length of 1,173 feet, and will rise to a height of of 144 feet above the bed rock and 84 feet above the bed of the existing river. Its length will be four miles and three-quarters, its area 1,165 acres, and its greatest depth of water about 84 feet. The aqueduct from the lake to the existing Prescot reservoir, 9 miles east of the Liverpool Town Hall, is 68 miles. It will consist mainly of tunnels through which the ultimate supply of 40,000,000 gallons a day may be passed without filling them, and of three lines of pipes each having an internal diameter varying according to the fall of the sections from 39 to 42 inches. All this *very poor water from the Welsh mountains will be subjected to filtration through sand-filters,* the Oswestry reservoir and the three reservoirs for filtered water having an aggregate storage capacity of 54,540,500 gallons.

In one very important particular the Commission of 1866 was certainly in error. It thought a probable increase of population to 4,500,000 or 5,000,000 would have to be provided for, and a maximum daily supply of 200,000,000 gallons, though the time for such an extended provision would be very remote. As a matter of fact, the population supplied by the companies in May of this year was 5,274,542, and the average daily supply during the month was 160,388,316 gallons. Of this more than half, or 82,366,466 gallons, came from the Thames, and the balance from the river Lee, and from certain chalk springs in the valleys of the Lee and Thames, and from 21 deep wells sunk into the chalk formation to the north and south of London. There are 44 *subsiding reservoirs for unfiltered water,* with an area of 465 acres, and an available capacity of 1,290,100,000 gallons, and 53 *covered reservoirs for storage of the water after filtration* with a capacity of 160,002,000 gallons. The number of filter beds is 99, with an area of 98 acres. Of this surface, 92 acres were cleansed during the month of May, some of the filter beds being cleansed once and partly gone over again during the month. The maximum permissible rate of filtration is two feet per hour and per square foot of surface, but as a matter of fact the actual rate in the month of May last was generally much smaller than this, some filters passing only $1\frac{1}{3}$ feet. The construction of the filters varies greatly, the top layer, however, being in all cases fine sand, in depth from 2 to $4\frac{1}{2}$ feet.

From the published analyses it appears that the quality of the water supplied to London is usually satisfactory, though at times results are obtained adverse to that portion of it which is derived from the Thames. The population of the drainage area of the Thames is very large, and although the towns located therein are compelled to purify their sewage, yet much polluting material from them and from the floating population on the river finds its way into the river.

Though the importance, and in many places the necessity, of purifying our water supplies by artificial methods have been well recognized, yet the great first cost of construction of the English system of filter-beds, the number of laborers required to keep them in efficient action, and their failure to satisfy all the requirements which are essential to an entirely satisfactory system of water purification has prevented their coming into use in this country. There has grown up, by the labors of our own chemists and engineers, *a system which is designed to meet our peculiar needs, and which may be most conveniently and accurately designated as the* AMERICAN SYSTEM OF WATER PURIFICATION. It comprises three distinct features:

1. Artificial aëration under pressure.
2. Precipitation of dirt, sewage, hardening constituents, and coloring-matters by harmless precipitants: *i. e., assisted precipitation.*

3. Mechanical filtration through filters capable of rapid reversal of current, and cleansing by mechanical means.

ARTIFICIAL AERATION.

One of the easiest and most inexpensive methods of improving the quality of water is by means of artificial aëration. The importance of natural aëration has been recognized from time immemorial, and the effect of tumbling down natural falls and rapids, passing over artificial dams, and of agitation by winds and storms, in keeping water lively and sweet, is too well known to need more than passing mention. It is of especial interest to us that this mode of improving water was *first applied to city water supply* in consequence of the extremely offensive taste and odor of the Schuylkill water in January and February, 1883. The fact that the analyses revealed the presence of a large amount of sewage in the Fairmount water did not explain its peculiar offensiveness at that season, for there have been times, before and since, when it contained even more sewage and was not so unpalatable. But it appeared to me very noteworthy that the oxygen which ought to be present in a state of solution was largely deficient. Much of it had been used up in the oxidation of the sewage, and the river, being ice-bound from its source to Fairmount Dam, had no opportunity of taking from the atmosphere sufficient oxygen to replace that which had been lost.

Reflecting upon these facts, I thought it worth while to try the effect of submitting the disgusting samples from Fairmount Pool to artificial aëration. I found that they not only took up from the air forced to them the oxygen they lacked, but also that much of the sewage to which their offensiveness was due was destroyed. These experiments suggested to me the idea of pumping air into the lower ends of the mains at the pumping-stations. This way of introducing the air was not only the easiest and simplest, but it also afforded an opportunity of placing the mixture of air and water under a maximum pressure. Air, as is well known, consists of twenty-one parts by volume of oxygen and seventy-nine parts of nitrogen; but the oxygen is more soluble in water than the nitrogen, and therefore the greater the pressure to which a mixture of air and water is subjected, the larger is the relative amount of oxygen made to enter into solution.

The study of the subject received fresh impetus from the condition of the water supply of Hoboken in the latter part of July, 1884. At that time, the oxygen, in a number of samples from the Hackensack River, whence the supply of Hoboken is derived, fell to 3.87 c.c. per litre, and the total dissolved gases to 14.93 c.c. Contemporaneously, the same waters, when impounded in the reservoir, became covered with a scum several inches in thickness, consisting largely of *Oscillariæ.* These quickly died, and yielded up a dark-blue coloring-matter (*the Phococyan of Cohn*). Finally, this great accumulation of vegetable growth passed into a state of active decomposition, attended with the formation of white foam, and the liberation of large volumes of carbonic acid and other gases. The water, for ten days previous, had been too nauseous to drink, but the whole succession of phenomena above described took place within twenty-four hours, the vast development of algæ, their breaking-up with evolution of green and blue coloring-matter, and their final decomposition occurring with astonishing rapidity. The entire reservoir had the appearance of an enormous dying vat, covered with dark-green and blue dye-stuffs.

A repetition of the same disastrous sequence of events was threatened on September 14th, when the percentage of dissolved oxygen fell to 4 c.c., and at the same time a growth of algæ began in the reservoir. But meanwhile arrangements had been perfected in anticipation of this catastrophe, and by pumping air under pressure into the mains, the percentage of total dissolved gases was raised from 15.9 c.c. to 21.2 c.c. The green scum on the reservoir disappeared, and the taste and smell of the drinking-water became satisfactory.

In November, 1884, a preliminary experiment was instituted at the Fairmount Pumping Station of Philadelphia, an air pump being attached to the main at that point. The aërated water was pumped into the Corinthian Basin through the forty-eight-inch main, a distance of three thousand feet. The results of this experiment were so encouraging, that the chief engineer, Col. Ludlow, obtained air-compressors for all the pumping-stations. At only one of them, however, has the process been applied, namely, at Belmont, the other mains being too leaky to permit of its being used.

At this station the water has been charged with twenty per cent of its volume of air, and the change in composition thereby effected is strikingly illustrated in the following results, which give the composition of the water before it enters the pumping-main and as it is discharged therefrom:

	Parts per 100,000.	
	Non-aërated.	Aërated.
Free Ammonia,	0.017	0.004
Albuminoid Ammonia,	0.011	0.007
Oxygen required to oxidize organic substances,	0.133	0.117
Nitrous Acid,	0.0008	none

Nitric Acid,	0.45	0.54
Total Solids,	9.00	8.70

It will be seen that the albuminoid ammonia has diminished nearly forty per cent; and, what is the most noteworthy feature of all, the nitrous acid has undergone complete oxidation, none being present in the aërated sample. At the same time, by oxidation of the nitrogenous portions of the organic matter, the nitric acid has been increased twenty per cent; and by oxidation of the organic constituents in general, the total solids have been diminished from 9 parts per 100,000 to 8.7 parts.

The process has now been applied to the entire water-supply of Hoboken, amounting to four million gallons per diem, for more than two years, and during this time the unpleasant taste which caused its first application has never reappeared.

A similar experience in Brooklyn has caused the process to be used in connection with the water obtained from driven wells. This driven-well water has been used in the Greenwood Cemetery to feed a number of artificial lakes arranged to beautify the grounds. Last summer I was asked to examine the water in the reservoir into which the driven-well water is first pumped, and to devise a means, if possible, for preventing the enormous growth of plants therein. The growth, on examination, proved to be *diatomaceæ,* particularly of the species *Navicula viridis,* and the green vegetable substance which by its decay rendered the water offensive was the slime secreted by these diatoms. Two facts were prominent. The one was that the diatoms could be made to grow very rapidly when exposed in open jars to sunlight; the other, that the water of the reservoir was very deficient in dissolved oxygen. It contained only 2.32 cubic centimetres of oxygen in the litre, and the enormous amount of 4.97 cubic centimetres of carbonic acid. I advised the covering of the reservoirs to exclude sunlight. The authorities were opposed to so doing, because it destroyed the very result aimed at in providing the reservoir and ponds, which was to beautify the park. Then I advised the use of an air-compressor. This was installed, and the result is given in the following letter from the consulting engineer:

NOVEMBER 27TH, 1886.

Dr. Albert R. Leeds.

DEAR SIR:—In answer to your inquiry concerning the trouble at the Greenwood Cemetery reservoir, I would state: that the water, fresh from driven wells, when delivered into the reservoir began to develop decaying vegetation, which, in a short time, rendered the water offensive to taste and smell; that immediately on receipt of your report and recommendation last June, I set up an ordinary compressor, and pumped air into the mains under a pressure of about eighty pounds to the square inch, allowing it to escape through the reservoir, with this result: At first there was no perceptible effect, but upon increasing the amount of air supplied to the water, to the extent of about ten per cent of the free air to an equal volume of water, the trouble in the reservoir disappeared. Since that time, air has been freely supplied whenever there appeared to be any recurrence of the growth of vegetation in the reservoir, and there has been no return of the offensive taste and smell.

Respectfully submitted, CHAS. B. BRUSH,
Con. Eng. Greenwood Cemetery.

Similar troubles, and the development of a variety of odors chronicled as "fishy," "pig-pen," "cucumber," and the like, have been reported as affecting, at one time or another, the water supplies of most of our towns. There is good reason to suppose that these complaints will continue as long as water which, on standing, has lost most of its dissolved oxygen and has become stagnant, is exposed to our burning suns, and allowed to rise to a temperature of 70° and upwards, in uncovered reservoirs. Either it should be covered, so as to exclude light, and kept cool, or, if its temperature is allowed to rise above 70° and it is exposed to the sun, it should be charged with air and kept moving. *In our own country, prevention of stagnation by adopting the latter method has proven more economical and efficient than the covering of the reservoirs.*

Before leaving this part of the subject, I shall state that when I introduced the use of compressed air for water purification, I did not do so for the reason that the air brought about a direct chemical oxidation or burning up of the organic impurities. In my various reports to the Water Department of Philadelphia, relative to the new water supply of that city (volumes for the year 1883, 1884, and 1885), and also to the Special Water Commission, appointed by the State of New York (1885), charged with providing a new water supply for the city of Albany, I have advocated the use of air under pressure for other reasons. They were:—1st, Because the disagreeable taste and odor in unpotable water are frequently due to gaseous and volatile impurities, which can be largely swept out of the water by the use of an excess of air acting mechanically as a deodorizer and disinfectant, thereby exerting a sweetening action in the manner of a water-scrubber; 2d, because the chemical and biological analyses contained in these reports show that where sewerage is being broken down, it is in presence of large numbers of bacteria, which grow and multiply upon a pabulum of sewage. Through the agency of the vital processes of bacteria, oxygen is rapidly absorbed and carried to the decomposing sewage which is broken up into nitrites, nitrates, carbon dioxide, and other partially or wholly oxidized compounds. As a result, where the amount of incoming sewage is large, the number of microbes is great, and so likewise the quantities of the oxidized products of decomposition, the nitrates and carbon dioxide especially. At the same time, the oxygen which should always be present in notable quantity in good water, was shown to have undergone a process of exhaustion, and to have fallen below its normal amount. When we replace the oxygen so absorbed, we supply the bacteria with something essential to their beneficent labors, and without which a portion of the sewage remains unoxidized. After the work of these oxygen-absorbing microbes is completed, they either perish or remain as resting spores, and *then they should be removed together with the products of their labors by filtration.*

ASSISTED PRECIPITATION.

Recourse is had to this process under the following conditions:

1st. When the particles of clay and other suspended matters are so minute that they pass through the pores of a filter without being arrested.

2d. When lime, magnesia, and other salts are present in such large amounts that the water is *hard,* rendering it unfit for laundry use, and making scale in boilers.

3d. When the water is discolored, and more especially when the discoloration is the dark yellow stain due to peaty matters.

After trials upon a great number of substances, sulphate of alumina has been found to be the best precipitant for substances of the first and third class. It throws down both the suspended matters and the peaty coloring substances by forming with them an insoluble coagulum. The alumina salt is decomposed into a basic aluminic sulphate which, being itself insoluble, is precipitated at the same time, and is filtered out along with the substances it has united with and thrown down, *no alumina remaining in the water.* The action of clay, which is the hydrated silicate of alumina, in purifying drinking waters is well known, the clay having a strong affinity for organic coloring matters and the ammoniacal and albuminoid substances arising from the putrescent decomposition of animal and vegetable substances. But precipitation and clarification by the hydrated silicate of alumina is too slow for *mechanical* purification, and the sulphate must be employed, or the double sulphate of alumina and ammonia, which is common alum. The amount of alum requisite is extremely small, one grain to the gallon being ordinarily sufficient. It communicates no taste to the water, nor does it have any effect upon the digestion or health of the persons using such aluminated water. On the contrary, its use, under the circumstances mentioned, is highly beneficial. It removes the insoluble alumina compounds originally present in the water. The insoluble coagulum or clot thus formed carries down with it the products of putrescent decomposition, which are always present in natural waters, except such as come from deep-seated sources like wells and springs. And at the same time there are precipitated in this coagulum the microbes, or so-called disease germs. In fact, *there is no process so practical and effectual for removing these germs and putrescences as the use of alum in small quantities followed by filtration.* Long-continued boiling destroys them, but it is costly and impracticable. It renders the water bad-tasting, destroys its liveliness by expelling the dissolved gases, and makes the water unfit for domestic use. Freezing leaves much of the organic matters in the water, destroys only a portion of the germs, and is impracticable. But by the use of the above means, river waters which were originally yellow and turbid from the presence of mud and finely divided silt, and disgusting from sewage and organic filth, have been rendered clear, safe, and palatable.

For softening hard water, the precipitant used is lime, the lime carbonate thrown down being removed by filtration. Estimating the hardness in degrees, and taking one degree as that equivalent to the hardening produced by one grain of lime carbonate dissolved in one gallon of water, the hardness has been successfully reduced from twenty-six degrees to three degrees, or from very hard to soft water. Not only is the water thereby rendered fit for use in boilers and in washing, but it is more wholesome. Soft water in itself is more wholesome than hard, and moreover, in the process of softening in this manner, the coagulum of lime carbonate carries down with it the micro-organisms of disease.

In the way of overcoming difficulties this result, striking as it is, is not so significant to the chemist as the removal of the deep coffee-colored dye imparted to the water by juniper swamps. I give here the analysis of such a water from a southern swamp, which by the use of alum and lime, and subsequent filtration, was changed from a deep yellow, peaty tasting and boiler corroding water, to a perfectly colorless, limpid, sweet water.

COMPOSITION OF WATER FROM JUNIPER SWAMPS.

PARTS PER 100,000.

Free ammonia,	0.0095
Albuminoid ammonia,	0.0335
Oxygen required to oxidize organic substances,	4.05

Oxygen required to discharge the peaty color,	3.30
Nitric anhydride,	0.231
Chlorine,	0.406
Total hardness,	3.5
Total solid residue at 110° C,	11.20
Volatile matter at red heat,	10.25
Fixed mineral matter,	0.95

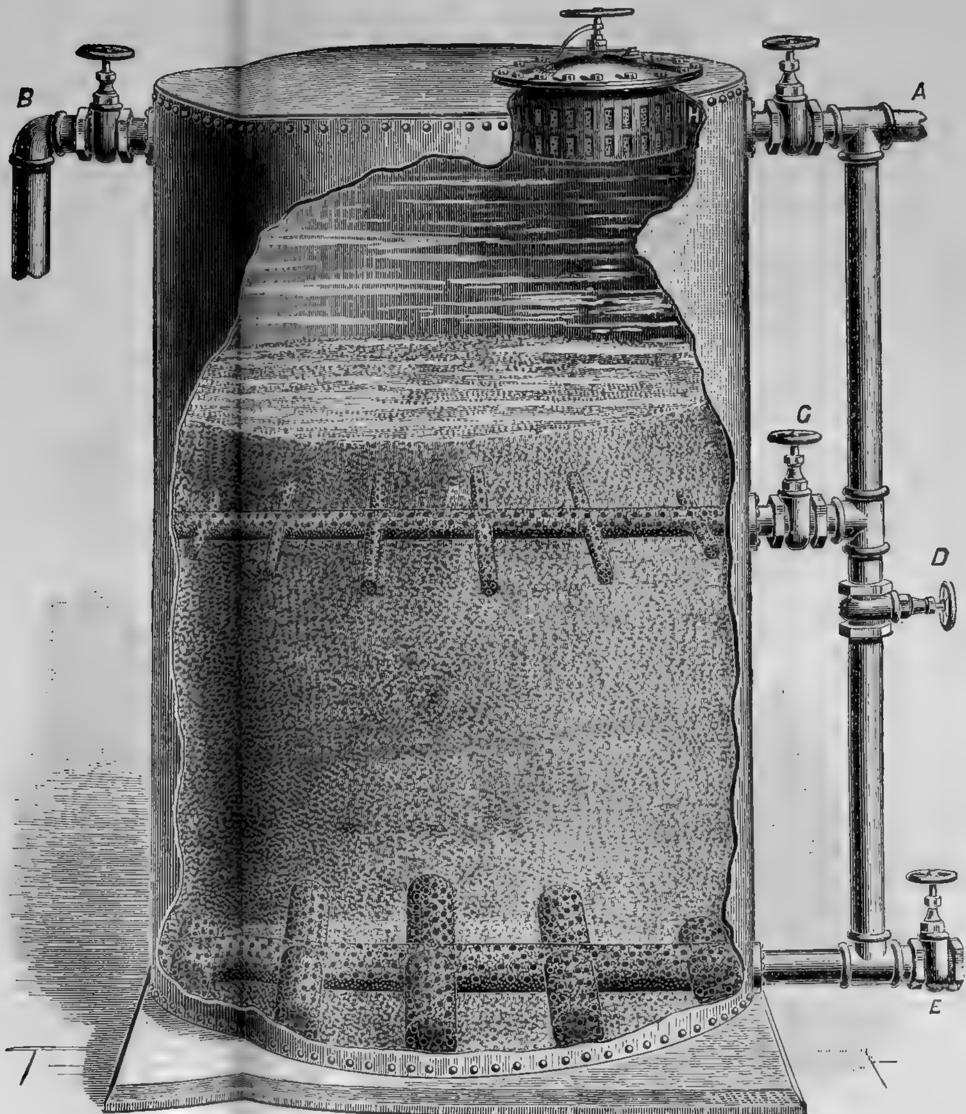
The oxygen gas dissolved in one litre was 5.17 cubic centimetres, the carbon dioxide 5.27 cubic centimetres, and the sum of the dissolved gases 25.90 cubic centimetres. It will be seen at once that the change of *such a dark yellow fluid to a colorless sweet* water was essential to rendering it potable.

MECHANICAL FILTRATION.

Up to the present time no material has been found which is practically available for filtration on a large scale except fine sand. Sponge, coke, animal and wood charcoal, porous brick, carbide of iron, spongy iron, and many other materials have been tried, but with the result as above stated. When metallic iron is used, excellent results are obtained through its chemical action as a carrier of oxygen to the organic matters, which are thereby oxidized and destroyed, but the water even then must be subsequently filtered through sand.

Until quite recently it has been supposed that the main benefit of sand filtration is in the removal of suspended mud and dirt, the amount of organic impurities thereby removed being small. But since Pasteur discovered that the micro-organisms, which are now held to be the specific germs of disease, may be completely arrested by filtration through a thin porous plate, a great revolution of opinion has been effected. In his report for the month of May last, Dr. Frankland states that the unfiltered Thames water yielded by the method of gelatine-peptone culture, 4,800 colonies of microbes per cubic centimetre of water. *After passage through sand filters* at Chelsea, it yielded only 59 colonies, and through those of West Middlesex only 19 colonies. This is indeed astonishing, and the more so when the remarkably pure water in the deep chalk wells of Kent yielded 8 colonies, and the same water by the time it reached its point of supply had increased in its number of micro-organisms, until 101 colonies were obtained in the culture liquid.

At the present time, *American engineers regard it as impracticable* to introduce the English system of sand-filters, on account of the great expense of operating them. This has been variously estimated at from $2.50 to $5.00 per day for each million gallons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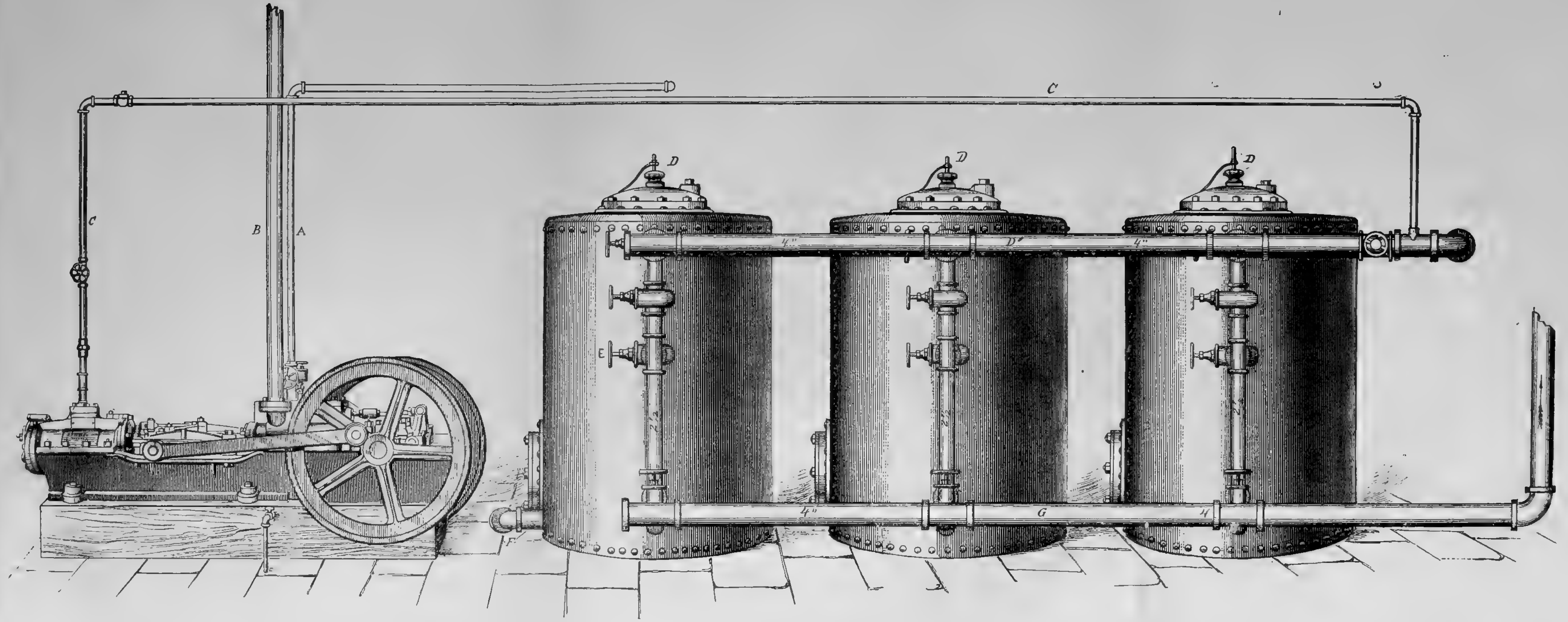
filtered, exclusive of first cost and interest. Such being the case, I need not go into a statement of the reasons why the few which have been actually brought into use in this country have been so little successful. The conviction appears to be generally entertained that American ingenuity has discovered a method by which mechanical arrangements have taken the place of the cumbrous English system, and done away with the manual labor required in cleansing. Many contrivances have been brought forward, but they are crude, or have complicated systems of pipes for reversals of the current, or are wasteful in the use of filtered water for cleansing. Recently, however, an extremely simple device has been proposed, which is yielding excellent results. As is well known, the efficient part of a filter-bed is the top layer of sand, which need not be more than two feet in thickness. At Poughkeepsie, on the Hudson River, (not in successful operation) this two feet of sand rests on four feet of gravel and stone which are provided *merely to support the sand and to afford channels* for the filtered water to drain away. This gravel and stone are replaced in the mechanical filter used in the American system of water purification, by perforated double pipes. The construction of this filter, called the National Filter, can be readily understood from the accompanying wood-cuts.

The water enters the filter at A, passes down through the bed of sand, and out through the perforated double pipes at G in the bottom of the filter. These pipes permit the filtered water to flow out freely, but prevent the escape of any of the sand with it. This filter has another device which is different from the English system, and is an entirely novel one. It is intended to thoroughly cleanse the upper surface of the filter-bed by means of *surface washing*. The dirt and filth are deposited at the surface of the bed, and these are swept off by a reverse current sent through the valve C, and the washing pipe F, and escaping at the top of the filter through the waste-pipe B. In the English filter-bed, the dirt is lodged on the surface, very little being carried below. The operation of cleansing is therefore that of shoveling off as thin a layer at the top as can be taken off by a shovel, washing this top layer in tanks, carting it back, distributing it over the surface, and then starting the operation of filtration over again. In the National Filter, this tedious work of cleansing, which in England is all carried on by manual labor, is performed by a reverse current. In the course of five minutes' time, the surface is cleansed from the impurities lodged upon it during as many hours of filtering very dirty water. Since the filter is worked under pressure, a greater thickness of the sand is compelled to do duty as the filtering medium, and the longer the time the filter is operated without starting the reverse current, the greater the depth to which the dirt penetrates. As a general rule, however, the dirt is retained within the first six inches, unless the filter is run for longer than twenty-four hours without cleansing, and since the upper pipes for cleaning are placed a foot below the surface of the bed, the rapid washing of this foot of sand when the reverse current is sent through it cleanses the filter thoroughly. The tendency is for the water to gradually form channels through the entire body of the filter-bed. For this reason, the bed is mechanically made over again and, as it were, renewed, by calling into play the lower series of double perforated pipes. After first cleansing the *surface*, in the manner just described, by the surface pipes, the reverse current is made to pass through the lower pipes. Every portion of the bed is floated loose, and by the attrition of one particle of sand against another the impurities are scrubbed off, floated to the top, and carried off through the valve B. When the cleansing is complete, which is shown by the pipe B delivering bright, clear water, the reverse current is shut off, and the filtering material settles down once more into a new uniform filter-bed.

The arrangements for aërating and filtering are shown in the annexed cut. The three filters are each 10 feet in diameter, and each capable of filtering 350,000 gallons per diem. 425 bushels of filtering material are required for each filter. The water passes in through the pipe D, and the filtered water out through the pipe G. The air is driven in under the amount of pressure required, and in the quantity requisite to bring the percentage of dissolved oxygen to a maximum, through the pipe C. The air-compressor is represented at the left of the drawing, and may be made to deliver either a very large amount or a very small amount of air, as the water requires. The mechanical arrangements for adding the precipitants, which are required in some cases, are not shown. The precipitants are usually added before the introduction of the compressed air, though sometimes after. The nature and amount of the precipitant, and the quantity of air required, is determined in each case by the character of the water as revealed by analysis. If it is a water whose only impurity is suspended matters, the filters alone are requisite. If, in addition to this, it is foul-smelling and tasting, and has lost the proportion of oxygen normally present in sweet waters, the aërator is attached to the filter. If it is hard, or filled with very minute suspended particles, or dyed with peat extract, etc., the precipitant of lime or alum or both is added. It is subsequently aërated or not, as the character of the water demands, and then both precipitant and precipitate are removed by filtration.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MR. LUCIUS PITKIN spoke as follows:

In his closing remarks, Dr. Leeds has referred to filters intended for household filtration on a small scale. The importance of this branch of water purification may be better realized, when it is considered with what care the source of water supply for large cities is selected, as compared with the supply in the suburbs and country towns. Here purification on a large scale is impossible in the absence of a co-operation, which is hard to secure, and while doubtful water should be avoided, still cases are not uncommon where no recourse is possible except to supplies more or less suspicious.

Proceeding on the germ theory of disease (now almost proven in its entirety), two methods of improvement for household use are prominent.

The one by boiling the water kills the germs, the other by filtration seeks to remove them. The first method by driving out the dissolved air renders the water flat and insipid. The second method has in the past been the cause of nearly as much harm as good. It is only within the last few years that, with our increasing knowledge of the character of disease germs, adequate filtration devices have been introduced. A bit of sponge in a metal globe may entrap "rotifers" and "entomostraca," but disease germs with their minute dimensions may easily laugh it to scorn, or in its accumulated debris find a fit breeding ground. And here I would emphasize the necessity of frequent cleansing in all forms of filtration apparatus. The increased volume of flow of the clean surface over that clogged with organic debris will, apart from sanitary considerations, repay the slight trouble incident to the cleaning.

It has been my good fortune, during the past six months, to have made many and rigorous tests of the value of porous porcelain in arresting the passage of bacteria contained in water. The porcelain tubes with which my experiments have been conducted, were of about one-tenth of an inch in thickness. It will be sufficient here to indicate briefly the result arrived at in my latest experiments on a set of four tubes. Under a pressure of about four feet, and with a continuous flow of water day and night, all of the tubes were delivering germ-free water at the end of five days (120 hours). Tests at the end of ten days (240 hours) showed two of the tubes delivering water free from germs. At the end of fifteen days one was still perfect in its action, and so continued for twenty days. The water which was used in the trial was purposely fouled, containing about two thousand germs per cubic centimetre. The results obtained, then, with this material, are all that can be desired when cleaned say once in five days, if used under the conditions of the experiment. In the case of a substance like porous porcelain, it is a very easy matter simply to take it from its sheath, brush it off, and place it in boiling water for a couple of hours or, better still, in a hot oven. The porcelain is then in its original condition, as far as regards efficiency.

December 6, 1886.

REGULAR BUSINESS MEETING.

The President, DR. J. S. NEWBERRY, in the Chair.

Twenty-one persons present.

The report of the Council was received and adopted, which recommended the payment of certain bills and the election of ALBERT A. CARY as Resident Member, and D. S. KELLICOTT, of Buffalo, as Corresponding Member.

The question of the adoption of the resolution offered by the Secretary, October 4th, 1886, making certain changes and additions in the by-laws, was declared in order. The President read from a copy of the printed resolution, which had been sent to all the members. Items I., III., IV., and VI., as recorded in the TRANSACTIONS of October 4th, 1886, were unanimously adopted. Item V. was unanimously adopted, with a change of the word "Proceedings" to "Practice." Item II., increasing the amount of the fees and dues, was discussed and laid over one month; and a Committee, consisting of the President, the Secretary, and Messrs. Chittenden, Martin, and Trowbridge, was appointed to prepare and send to all the members a statement of the question, and of the need of a larger income, with a request for the individual opinion of the members.

Mr. H. T. Woodman announced the discovery of an elephant's tooth, probably *Elephas Americanus*, in the beds of silicified coral in Florida. The President described the character, range, etc., of *Elephas* and *Mastodon*.

Mr. F. J. H. Merrill read the following

NOTE ON THE GREEN POND MOUNTAIN GROUP OF NEW JERSEY.

The Green Pond Mountain series of rocks in northeastern New Jersey, which also extends through Orange County, New York, to the Hudson River and for some distance beyond, has heretofore been studied by geologists, since the time of Professor Henry D. Rogers, without positive determination of its age. Rogers believed the red conglomerate and sandstone which forms the base of the series, to be Triassic, and Mather surmised that it might be Oneida, while in the report of the Geological Survey of New Jersey for 1868, it was described as Potsdam. Recent investigations by the State Geological Survey have discovered evidence which fixes the horizon of the system.

Dr. N. L. Britton has found that a fossiliferous limestone, formerly described as Trenton, is Lower Helderberg, and the speaker has discovered Oriskany and Corniferous fossils in a coarse white sandstone and conglomerate; so that there is represented a continuous series of rocks from the red conglomerate, which is of Oneida age, and rests unconformably on the magnesian limestone in places, to certain blue slates and grits which contain fossils, probably of Hamilton age, and which in New York State have yielded *Psilophyton princeps*, Dawson, and other Devonian plants. The slates in the valley southwest of Greenwood Lake, which were formerly supposed to be of Hudson River age, are proved stratigraphically and palæontologically to belong to the Upper Devonian. (See Annual Report Geol. Survey of N. J., 1886).

Mr. L. E. Chittenden spoke as follows upon

THE USE OF METALS BY THE ABORIGINES OF GEORGIA AND FLORIDA.

At a recent meeting of the Academy, in some remarks upon the ornaments of mixed gold and silver, from Indian graves in Florida, presented by Mr. Kunz, I said that there was reason to believe that the gold and silver in possession of the Florida Indians had been taken from Spanish ships wrecked on that coast. A recent examination of the evidence on that subject has developed some facts which may interest the Academy.

For more than half a century after the discovery by Columbus of the western hemisphere, only the eastern coast of Florida was known, and that was supposed to be a part of the island of Cuba, as it is laid down on the celebrated wood-cut map by Holbein, in the "*Novus Orbis*" of Grynæus, as late as 1555. Among the vessels there lost, was a large part of a fleet of thirty ships, including that on which the infamous Bovadilla, the persecutor of Columbus, had embarked, and which was laden with gold and silver, despoiled from the Indians. Strict truth will possibly require some discount on this treasure, in the account of Peter Martyr, who says "there were several pieces of 300 pounde weighte, and one of three thousand three hundred and tenne pounde, of eight ounces or pesos, albeit there were mo then a thousande persons which came and handled that peece of golde."

In the "Histoire notable de la Floride," by Basanier, Paris, 1586, occurs a passage translated as follows: "There was found among the Indians a great quantity of gold and silver, which, as I learned from themselves, was from the ships which had been wrecked along the coast. They trade in it with one another. What confirms this statement is the fact, that along that part of the coast and the cape where the wrecks occur, there is more silver than there is farther north. They said constantly that in the Apallache mountains there were mines of copper which I think are really gold."

The closing observation of Basanier indicates that investigations should be extended farther. There is little profit in searching the meagre records of the three first expeditions to Florida. That of Ponce de Leon, in 1512, was in search of the fountain of perpetual youth—those of Vasquez de Ayllon in 1522 and

1524 were after slaves, when that Spanish wretch seized and carried to perish in the mines of Cuba two cargoes of Indians. That of Pamphilo de Narvaez was in 1527. Over the last we must pause for a moment to note the sad results of his inconceivable brutality and its swift punishment. He found the most peaceful, inoffensive, and civilized race of Indians since known north of the Isthmus. They lived in towns; their dwellings were comfortable, they cultivated the earth, wove, and dressed their females in garments of cotton and other fibrous plants, and were almost ignorant of the arts of war. The mother of one of their chiefs complained of the brutal treatment of an Indian girl, by a soldier. Narvaez caused her to be thrown to his dogs, which tore her to pieces. Her son, the chief, remonstrated, and Narvaez cut off his ears. The Indians collected in a body and swept this Spanish brute and his army out of existence. They slew two-thirds of them, burned their ships, and the remaining two hundred embarking in a frail vessel, which they constructed, were wrecked and drowned. Only five were known to have escaped. Cabeça de Vaca, a priest, the chronicler of the expedition and three companions, and Ortiz, a soldier. De Vaca and three companions, after probably eating a fourth, made a desperate fight for life, and actually crossed the continent to the Yacqui river in the Mexican state of Sonora, on the Gulf of California, whence they returned to Spain, ten years after the expedition of Narvaez had sailed for Florida.

De Soto was the first who made search in Florida for mines of the precious metals. He had returned with riches from New Spain; the only man in Pizarro's army that brought any reputation, save that of robber, from the conquest of Peru. He was fitting out his five ships when De Vaca returned to Spain in 1537. As the latter hoped himself to lead a similar expedition, he gave De Soto no information about the mines, and there was little in his "Relaçam," afterwards published, except rumors relating to the precious metals.

At this time the region south and west of the Alleghanies was inhabited by the great Natchez family of Indians. They had reached a civilization higher than the Five Nations. The dwellings of the common people were commodious, of several rooms each, their cellars filled with the products of their cultivation and other industries, those of the chiefs were larger and hung with prepared skins in the manner of tapestry. They worshipped a Great Spirit in their temples, believed in future rewards and punishments, and lived under the severe, though patriarchal government of their chiefs. It is a mistake to say, as historians do, that the advance of the Natchez in the arts of civilization was arrested by De Soto. Their relapse into barbarism dates from the first expedition of Ayllon, and received a fresh impulse from that of Narvaez. It was not strange that Ucita, whose ears had been cut off by Narvaez, should have sent back the messenger of De Soto, with the reply, "Bring me no more promises from these people; I want their heads!"

There was in De Soto's army one who became the chronicler of the expedition. His name has never been certainly known. He calls himself a "Knight of Elvas," and his account of the expedition was first published in Portuguese in 1557. It bears intrinsic evidence of its author's fidelity to truth, and many of its statements have since been confirmed. It is upon his account that the fact that the Natchez Indians mined, smelted, and wrought in gold and copper must chiefly rest.

The route of De Soto as described by the Knight of Elvas has been projected upon a chart by Mr. J. Carson Brevoort in a translation of the "Relaçam verdadiera" published by the Bradford Club in this city in 1866. Following that chart and my own translations of the Relaçam, compared with the French translation of 1685, that by Hakluyt, printed in 1609 and 1686, and that by Buckingham Smith for the Bradford Club, it appears that the expedition marched inland from the head of Apallache or Oclockonnee Bay, pursued an irregular route a little east of north, crossing the Altamaha, to the Savannah river, not far from the site of the present city of Augusta. Before leaving the coast, De Soto had fortunately secured one Ortiz, a survivor of the party of Narvaez, who had been a captive among the Natchez for ten years, and had acquired their language. In him he had a competent interpreter in his intercourse with the Indians.

While still within a few leagues of the coast, there was brought to De Soto "a young Indian who had been captured at Napetaca. He said that he was not of that country, but from another, very distant, toward the sunrise, and was captured just as he had arrived, a traveller at Napetaca,—that his country was called Yupaha, was governed by a woman, whose city was of surprising grandeur; that she drew tribute from all her neighbors; from some in commodities, from others in gold. Whereupon he described the manner in which the gold was taken out; how they smelted and refined it (*le faisoit fondre, et affiner*) as if he had seen it done a hundred times, or the devil had instructed him. So that those who were experts in the ways of working mines were certain that he could not have spoken so accurately had he not seen it; and the relation passed for a constant verity from the circumstances which confirmed it."

Proceeding on their journey, they passed Cutifachaqui on the Savannah, which they ascended, passing Chelaque to Xavala, where they reached the mountains, which deflected their course to the southwest, passing through the Indian provinces of Chiaha and Coça, to Tuscaluça in central Alabama. At many places they were told that across the mountains, to the northward, lay Chisca, rich in mines of gold. Thus at Chiaha, near the northeastern corner of Alabama, "the Chief Acoste came to offer his services. And when De Soto asked him if he knew any rich and fertile country, he said that farther north he would find the province of Chisca where they smelted (fondoit) copper, and another metal more lively and more perfect, that this metal seemed much more precious than copper, but because of its softness it was not used. This account conformed to what De Soto was told at Cutifachaqui, where we saw some small axes of copper which they said was mixed with gold."

De Soto made several attempts to reach these mines. Once a party set out to visit a chief, who the Indians said "was a neighbor of the chief of Chisca, where the metal was found which the Governor believed to be gold;" but failed to reach their destination. From Coça, De Soto "sent thirty cavaliers and fifty footmen towards the province of Caluça, to find a road thence to Chisca, where the Indians had said he would find mines of copper and of that metal which resembled gold. These soldiers marched seven days through a desert country, but returned dreadfully wearied, for they found nothing to eat but green cherries and corn stalks, in a miserable town of seven or eight houses."

The province of Chisca, as indicated by these extracts and as located by Mr. Brevoort, was nearly coincident with the gold fields of northern Georgia, but north of the most southerly range of the mountains. I have given the evidence so that every one can judge for himself whether these Indians practiced the smelting of metals. The relation of the Knight of Elvas, throughout, gives an impression of the advanced state of civilization among the Indians, so that here, if anywhere, the knowledge of the smelting of metals should have existed.

One fact throws a little doubt upon the correctness of De Soto's route, as projected by Mr. Brevoort. His projection carries the route almost directly through the city of Dahlonega and the northern counties of Georgia. Members of the Academy, better acquainted than myself with the locality, will be able to say whether these counties are not within the gold fields. If they are, it is highly improbable that the sharp eyes of such a party of Spaniards would have failed to detect the gold if they passed through them.

The omission of all mention of silver in this "Relation" tends to confirm the suggestion that the materials of ornaments containing that metal, might have been obtained from the sunken ships, especially if they came from localities near the coast.

There is no reason why the Natchez Indians should not have understood the smelting of metals of well as those of Mexico and Peru.

The heroism and fine qualities of De Soto may command our admiration, without diminishing our satisfaction over the following record of good old Father Las Casas, the noblest Spaniard of the whole Castile de l'oro. "The merciless tyrants have invaded these provinces since the year 1510. They all committed the same outrages, to put themselves by robbery and pillage into places of honor and profit, far above their quality. But God was pleased to punish them after a most signal manner, for they all came to a most miserable end. These brutes would have committed yet more villanies, had He not shortened their days. Most of these cruel villains perished miserably without the least contrition or repentance. Although God is infinitely gracious and merciful, there is reason enough to fear that they were condemned to eternal torments."

December 13, 1886.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Over one hundred persons present.

The PRESIDENT exhibited, in illustration of his paper on Earthquakes, read October 18th, a series of lantern views, from photographs recently taken at Charleston, Somerville, and other localities in South Carolina affected by the late earthquake.

December 20, 1886.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

One hundred and thirty-two persons present.

The PRESIDENT announced the death of Dr. Isaac Lea, a Corresponding Member, and described his life and work.

MR. ELMER L. CORTHELL delivered an address upon

THE ISTHMIAN SHIP RAILWAY.

(Illustrated with Map, and Lantern views.)

Adjournment until January 10th, 1887.

January 10, 1887.

REGULAR BUSINESS MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Twenty-three persons present.

The Report of the Council was received, which made the following recommendations:

1. That the pending amendment to the By-Laws, increasing the fees and dues to ten dollars be adopted; and that all the Publications of the Academy be distributed free to all the Resident Members and Fellows.

II. That the Academy authorize the Council and the Publication Committee to change the *Annals* from a regular or yearly publication with a fixed subscription price, to an irregular or occasional publication, at special prices to persons not members; and to keep the "*Transactions*" the regular periodical, with a subscription price.

Pending the adoption of these recommendations, the Secretary made a verbal report in behalf of the committee which was appointed at the meeting of December 6th, 1886, to send a circular to all the Resident Members asking for their individual opinions upon the question of increasing the fees and dues to ten dollars, which report was to this effect: Sixty replies had been received, of which number forty-five were decidedly in favor of the increase, and six expressed a willingness to make the increase. Nine replies were negative, or gave adverse opinions. The Secretary also stated that these replies had been laid before the Council in the making of the recommendations.

After some discussion, the recommendations were adopted unanimously.

DR. N. L. BRITTON read the following

NOTE ON THE GROWTH OF A VINEGAR PLANT IN FERMENTED GRAPE JUICE.

My attention was recently directed to certain remarkable growths effected by the Vinegar Plant under circumstances evidently peculiarly adapted to its development. In September, 1884, about a gallon of grape juice was obtained and allowed to undergo a certain amount of fermentation. It was bottled during the ensuing winter and the bottles placed on the upper shelf of a closet, where I found them on July 25th, 1886; they had been then standing undisturbed for about eighteen months.

The closet was dark, but was generally opened once a day. The temperature to which the bottles and their contents had been exposed varied from the freezing point to the highest indoor summer heat, probably about 85° F. Their contents had never been frozen, so far as known. On the above-mentioned date the liquid in several of the bottles was an extremely acid vinegar, and in these were the peculiar growths about to be described. I will give an account of the bottles successively.

Bottle No. 1.—This was an ordinary green glass wine-bottle of about a quart capacity, with a neck a little over an inch in external diameter, a base three inches in diameter, and having a nearly flat bottom. The cork was loose, admitting access of air. The surface of the liquid rose to within an inch of the cork. When first observed, a solid cylinder of tough, white, gelatinous material was standing upright in the bottle. Its diameter was 22 mm., its length 215 mm. Another similar cylinder stood alongside of this one, having the same diameter and a length of 50 mm. This had evidently become detached and fallen from the longer one at some time, and subsequently the growth of the latter had been continued.

During the time which has elapsed since July 25th, the larger cylinder has twice been broken off in the bottle in the course of moving it from place to place, and an additional length of gelatinous cylinder to the length of 85 mm. has been formed by growth downwards from the surface of the liquid. The total length of gelatinous cylinder made in this bottle during the two and one quarter years has thus been 400 mm., about 16 inches and its volume about 12 cubic inches. The cylinders are distinctly stratified by an alternation of translucent with opaque layers.

On the first day of examination the liquid was quite clear in all parts of the bottle except the very bottom, where, by gently shaking, considerable turbidity was noticed. As this bottle made a fine museum specimen and it would have been necessary to break the glass in order to extract the cylinders, it was left intact and further examinations conducted on the others.

Bottle No. 2.—A green glass pint bottle, sloping from the mouth downwards, with no distinct neck and a conical bottom. In this a gelatinous cylinder exactly resembling that in No. 1, had formed from the surface of the liquid to the bottom. Its diameter was 15 mm., length 240 mm. or about 9.6 inches; this was in a single piece, but was broken in getting it out. Its extreme lower portion was of somewhat looser consistence than the parts above. To the naked eye this was seen to be distinctly stratified throughout by an alternation of opaque and translucent layers varying from the thickness of writing-paper up to one or two millimeters.

The superincumbent vinegar was perfectly clear when first seen, and contained only a very few cells of some species of *Saccharomycetes* similar to those next described.

The turbid liquid contained numerous *Saccharomycetes* cells, some spherical and detached, others in pairs or groups of threes when they were oblong, about twice as long as broad and attached end to end. Some of these were budding; their granular contents were well defined under a 0.1 inch water immersion objective. There were also myriads of smaller, spherical cells, mainly in rows or chains of from three to eight, many of the latter number being observed. Some of these chains were enwrapped in a transparent substance, apparently gelatinous; others were observed to be loosely connected, forming colonies; many transparent masses of gelatinous material contained numerous chains of these smaller spherical cells, which appear from figures and description in Grove's "Bacteria and Yeast Fungi" to be the *Saccharomycetes mycoderma*, Reess, (*Mycoderma cerevisiæ*, Desmazieres). Associated were swarms of extremely minute microbes, their length about one half the diameter of the smaller spherical cells, their diameter probably about one-eighth their length, and in rapid vibratory motion. No other organisms were detected. The gelatinous cylinder was tough in texture, requiring considerable force to pull fragments from it, and could be lifted between the fingers with only a slight compression of its periphery. Fragments taken from near its top and from points one-half and three-fourths the way down showed a nearly amorphous structure, which I could at times imagine was irregularly cellular, but, if so, there is no definite shape to the cells. A fragment from the extreme base of the cylinder was, however, seen to be almost entirely composed of chains and detached individuals of the chains above noted, immersed in the jelly-like substance of the cylinder. It seemed as though this was built up by the multiplication of the *S. mycoderma* and the deliquescence of its cell walls.

The liquid contents of this bottle with the gelatinous cylinders were placed in a loosely corked preserve jar of three inches exterior diameter, the bottle being broken in extracting the cylinders.

On August 1st, one week after my first examination, this liquid was covered with a film of the gelatinous material 2 mm. in thickness.

On August 14th this film had increased to 6 mm.

On October 3d it had reached a thickness of 12 mm. and was completely covered with a vigorous growth of the mould, *Penicillium glaucum*, in spore condition. There were two spots of another mould of an orange color, and bearing globular sporogonia.

On November 1st the *Penicillium* hyphæ had almost entirely disappeared, and an enormous number of black spores were all that was left to represent it. Some of these spores still remain on the jelly, which seems to be gradually decomposing.

Bottle No. 3.—The liquid had been mainly poured off from this bottle and its contents disturbed before my attention was called to these phenomena; only a small turbid portion remained in the bottom. The character of this was precisely the same as that of the turbid liquid in No. 2, containing some of the larger *Saccharomycetes* cells, multitudes of chains of *S. mycoderma* cells, and myriads of vibrating microbes. The gelatinous matter in this bottle had apparently been less abundant than in the others and had dried and contracted considerably, so I could not tell what its original shape had been. The bottle was similar in shape to No. 1. When I examined the mass it was resting on one side of the conical base and was itself conical, 60 mm. high with a base diameter of 40 mm. It clung closely to the surface of the glass and was only detached with considerable force. Its surface was completely covered with a white, downy coating about 1 mm. in thickness, which, under the microscope, was seen to consist of transparent, irregularly branching threads, a true mycelium. The diameter of these hyphæ was about that of the larger *Saccharomycetes* cells. Borne laterally on these threads at long and irregular intervals were exactly spherical cells of about the thread's diameter, which had granular contents. This mycelium was only on the parts of the gelatinous mass exposed to the air. The bottle had been emptied of liquid six days before my notes were taken. I was unable to identify this mould from any descriptions or figures at my command.

Bottle No. 4.—This was similar in shape to No. 2, but was more tightly corked. A very small amount of gelatinous material had formed in its neck. The upper portion of this was covered with the same kind of mould found on the mass in Bottle No. 3, and the turbid fluid at its bottom contained cells of *S. mycoderma.*

There were several more bottles of fermented grape juice in the same closet, but they were tightly corked and contained no gelatinous matter.

MR. A. L. EWING exhibited a photograph of the shark (*Lamna cornubica*) recently shown at Fulton Market.

THE PRESIDENT exhibited an etched section of an iron meteorite from Toluca, Mexico. He spoke of the chemical and physical character of meteorites, saying that they had apparently crystallized by slow cooling under great pressure, and that it seemed probable they were fragments of disrupted bodies of great size, analogous to the asteroids or minor planets.

January 17, 1887.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Thirty-nine persons present.

MR. A. L. EWING exhibited a specimen of limonite "pipe-ore" from Centre Co., Pa., having one of the pipes lying at an angle of 45° with the others.

MR. B. B. CHAMBERLIN showed a specimen of pyrite changed into limonite, from Mott Haven, New York City.

MR. WILLIAM E. HIDDEN read a paper

ON AN IRON METEORITE THAT FELL AT MAZAPIL, MEXICO, DURING THE DISPLAY OF "BIELID" METEORS, NOVEMBER 27TH, 1885, WITH AN ACCOUNT OF ITS FALL, BY PROF. JOSÉ A. Y BONILLA, DIRECTOR OF THE ZACATECAS OBSERVATORY.

(Published in the ANNALS, Vol. IV.)

The meteorite was exhibited.

The subject of the paper, and meteors in general, were discussed at length by PROF. J. K. REES, PROF. W. P. TROWBRIDGE, the PRESIDENT, and the author of the paper. PRESIDENT NEWBERRY also exhibited some stone meteorites.

MR. GEORGE F. KUNZ stated that he had recently acquired an eighty-pound mass of

METEORIC IRON FROM CARROLL CO., KENTUCKY,

which was largely transparent olivine, and apparently identical with the small masses found by Prof. Putnam in the Little Miami mounds. Altogether four specimens of this character were known, which might possibly be fragments of the same meteor.

In the spring of 1883, Professor F. W. Putnam found on the altar of mound No. 3 of the Turner group of mounds in the Little Miami Valley, Ohio, several ear ornaments made of iron (see Fig. 1),[1] and several others overlaid with iron. With these were also found a number of separate pieces that were thought to be iron. They were covered with cinders, charcoal, pearls (two bushels were found in this group of mounds), and other material, cemented by an oxide of iron, showing that the pieces had been subjected to a high temperature. On removing the scale, Dr. Kennicutt found they were made of iron of meteoric origin.[2] One of the pieces weighed 28 and another 52 grams.

[1] I am indebted to Professor Putnam for the cuts from which figs. 1 and 4 are printed, as also for information kindly furnished me.

[2] 16–17 Report of Peabody Museum of Archæology, p. 382.

In the autumn of 1883, another mass was found on the altar of mound No. 4 of this same group, which weighed 767.5 grams (27¼ oz.). Dr. Kennicutt suggests that these were all parts of some larger meteoric mass. The results of the investigation were published in connection with the description of the Atacama meteorites, because in structure they approached more closely to the latter than to those of any other occurrence. In the Liberty group of mounds in the same valley, Professor Putnam found a celt five inches long, and in another of the Turner mounds, an ornament five inches long and three inches wide, made also of this same meteoric iron.

It was not until after the above masses had been found that

FIG. 1.—Earring made of Meteoric Iron.

the Carroll County meteorite was brought to my notice; after a careful comparison, I have reached the conclusion that the irons from the Ohio mounds and the Carroll County meteorite probably belong to one and the same meteoric fall. Either the former was broken from the main mass by the mound-builders themselves, or they were all fragments of the same fall, scattered as were the Estherville meteorites, or, as suggested by Dr. J. Lawrence Smith, were those of Coahuila, and also, by Huntington,[1] the Sevier, Cocke County, and Jenny's Creek irons.

[1] Am. Jour. Sci., III., xxxiii., p. 115.

The Carroll County meteorite was found in 1880, about three-fourths of a mile from Eagle Station, Carroll County, Kentucky. The distance to the Turner mounds, where Professor Putnam found the meteoric iron and the ornaments made of it, is about 60 miles. The mass, which weighs about 80 pounds,

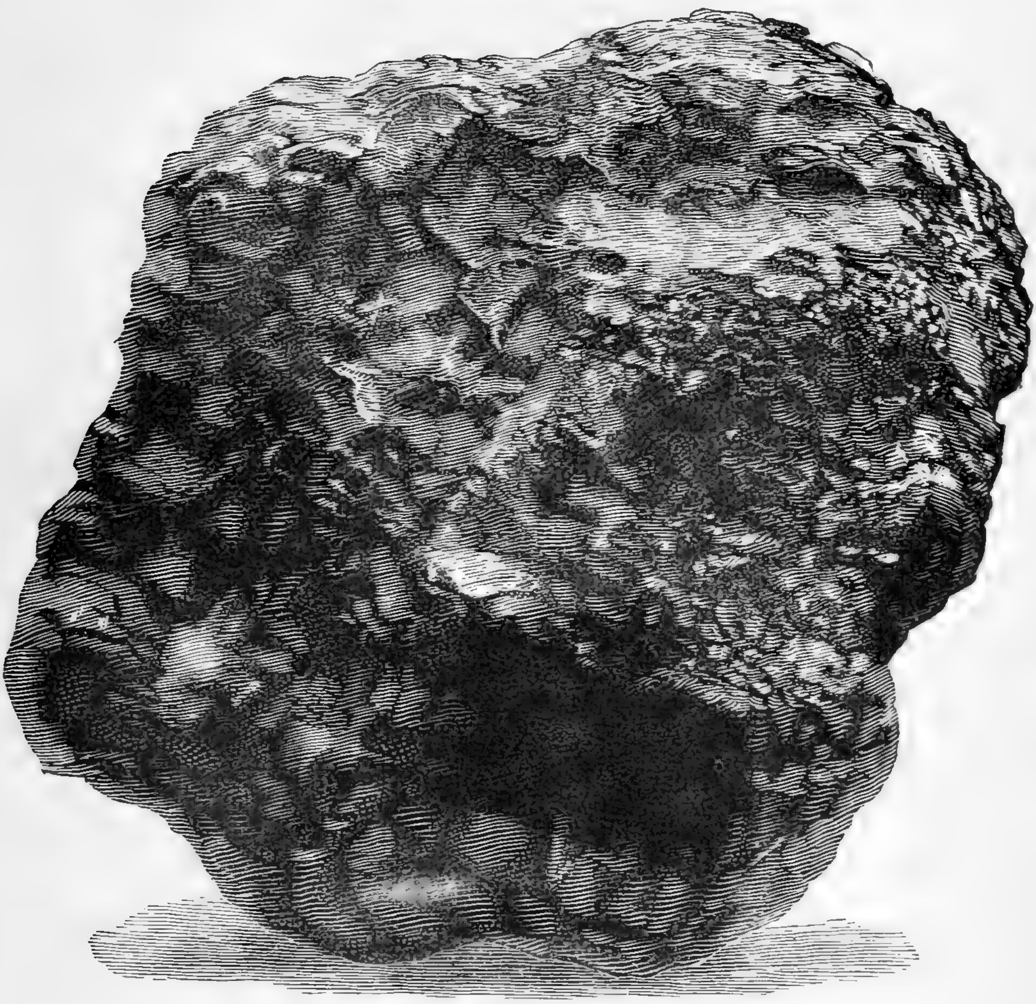

FIG. 2.—Carroll County Meteorite, upper side. ⅓ natural size.

or 36.5 kilos (figs. 2 and 3), is almost square, measuring 19^{cm} ($7\frac{1}{2}$ inches) in thickness, 22^{cm} (10 inches) in width and 29^{cm} (12 inches) in length. The surface is rusted in some places to a depth of 10 to 12^{mm}, and deep pits, some 2^{cm} across, are observed in spots where grains of olivine have probably dropped out. All of the original crust has disappeared. The mass is largely made up of fine yellow, transparent olivine, resembling closely that of the famous Pallas iron. This meteor-

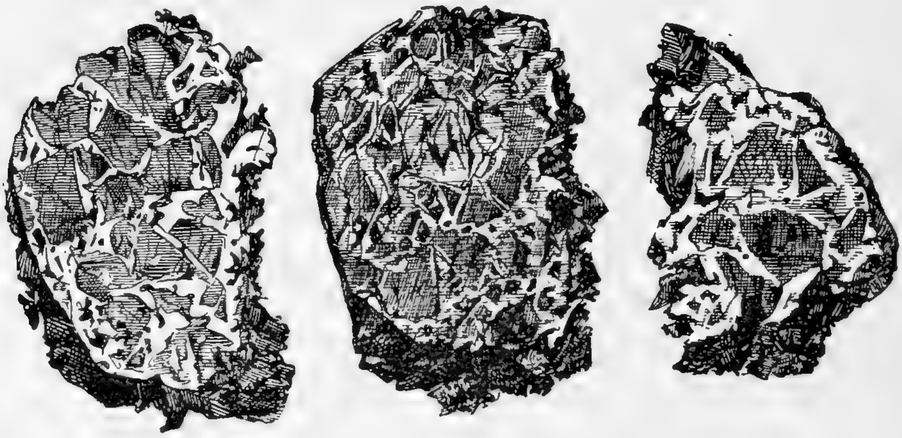

FIG. 3.—Sections of the Carroll County Meteorite. Natural size.

ite belongs to the siderolites or "syssidères" of Daubrée, and the Pallasite group.

Figure 3 shows three sections of the Carroll County mass, the light portions representing the iron and the dark portions the

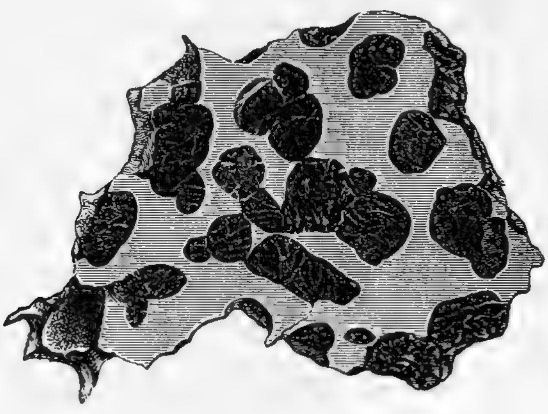

FIG. 4.—Section of the iron from the Turner Mounds

olivine. Figure 4 shows a similar section made by Dr. L. Kennicutt, of the Turner Mound mass. The specific gravities of the three sections figured are given below, with those of the Atacama and Turner's Mound meteorites.

No.	Carroll County.		Turner's Mound.	Atacama.
1	4.21	mean 4.41	4.72	4.35
2	4.379			
3	4.66			

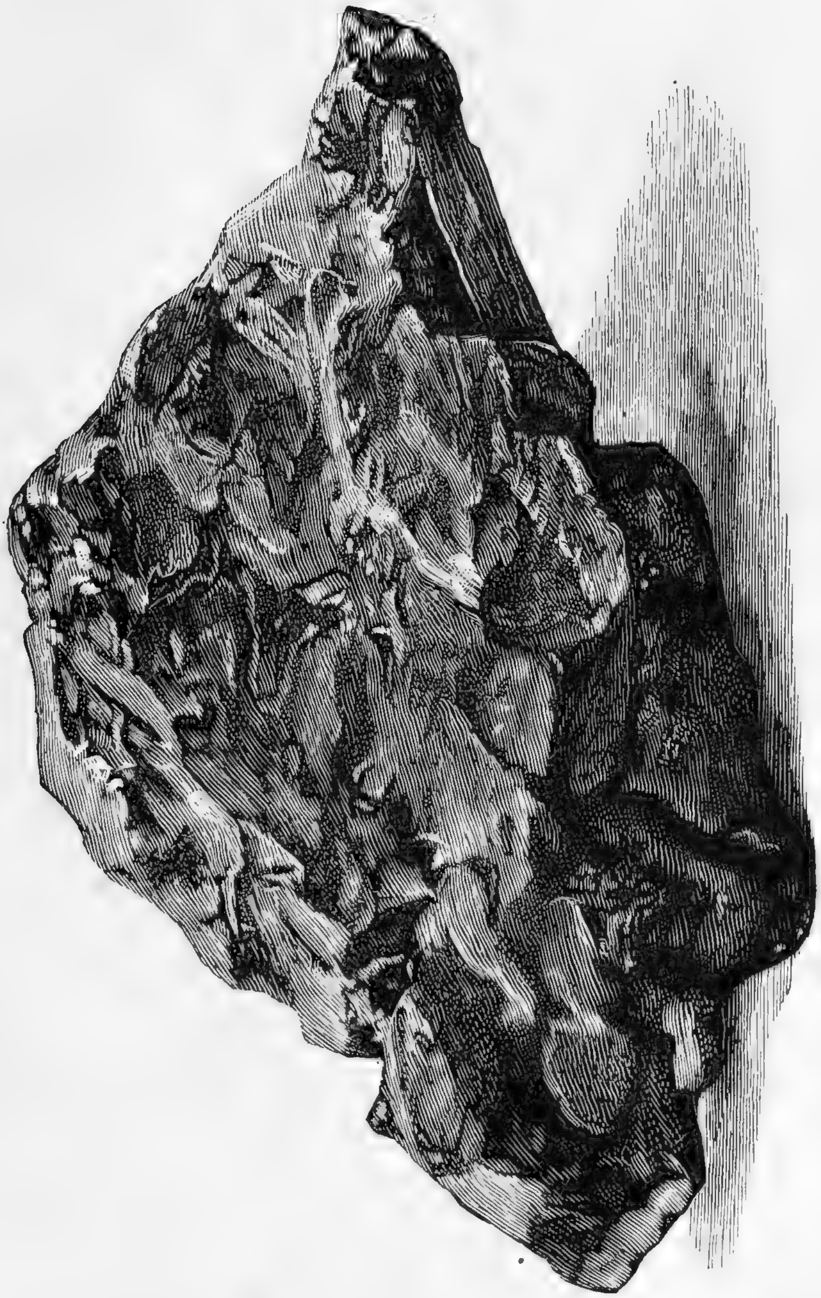

FIG. 5.—Catorze Meteorite. ⅓ natural size.

Taking the specific gravity of the iron at 7.6, and that of the olivine at 3.3, we find that all of these meteorites consist of about three parts of olivine to one part of iron. The iron in the Carroll County meteorite is scarcely more than sufficient to hold the mass together securely, as the olivine is in so much larger crystals than in the Atacama meteorite. On etching, small fine Widmanstätten markings are produced. By reflected light minute crystals of bronzite can easily be recognized, and analysis showed the presence of chromite in fine grains and a very small quantity of schreibersite.

MR. KUNZ also described

A NEW METEOR FROM CATORZE, MEXICO.

This mass, weighing 92 pounds, was found by a miner near Catorze, San Luis Potosi, Mexico, in 1885. It is 31.5^{cm} (12½

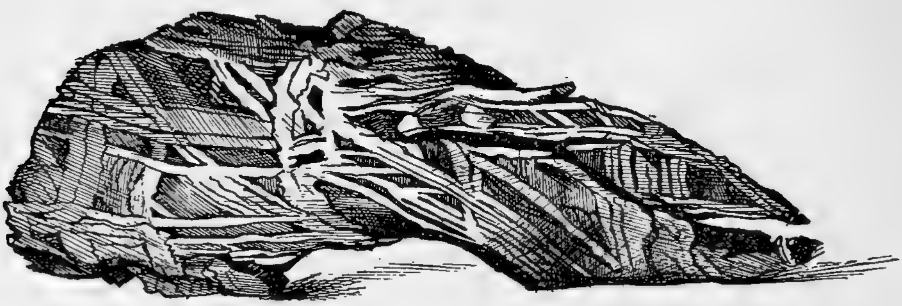

FIG. 6.—Catorze Meteorite, Widmanstätten Figures. Natural size.

inches) long, 34.5^{cm} (13¾ inches) wide, and 20^{cm} (8 inches) thick. It shows beautiful raised octahedral markings. On one side an opening 9^{cm} (3½ inches) long has been made, and a piece of a chisel of native copper left wedged in it. This piece, which is partially covered with oxide of copper, is 22^{mm} (⅞ inch) long on one side, 33^{mm} (1¼ inch) on the other, and 14^{mm} wide.

This iron is one of the Caillite group of Stanilas Meunier and shows the Widmanstätten lines very finely (see fig. 6).

It resembles the irons of Augusta County, Virginia, of Glorieta Mountain, and others of this group. No troilite was observed, the mass having been cut very little, and schreibersite is only sparingly present.

The specific gravity of the piece is 7.509. An analysis has been made by Prof. James B. Mackintosh, of Lehigh University.

January 24, 1887.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

A very large audience present in the East Lecture Room of the Library Building, Columbia College.

The first lecture of the Popular Lecture Course was given by PROF. WILLIAM LIBBEY, of Princeton College, on

RECENT EXPLORATIONS IN ALASKA.

(Illustrated with lantern views.)

January 31, 1887.

STATED MEETING.

The First Vice-President, PROF. O. P. HUBBARD, in the chair.

Thirty-four persons present.

MR. B. B. CHAMBERLIN exhibited two specimens of tourmaline from Washington Heights, one of them being black, in oligoclase, the other a spreading or radiating crystal.

The following paper was read by title:

A REVIEW OF THE CHÆTODONTIDÆ OF NORTH AMERICA, by CARL H. EIGENMANN and JENNIE E. HORNUNG.

(Published in the ANNALS, Vol. IV.)

PROF. W. P. TROWBRIDGE read a paper

ON SUB-SURFACE WATER-SUPPLY FOR CITIES AND TOWNS.

Two or three years ago, I prepared a paper for the *Sanitary Engineer*, describing the driven wells, and the method of connecting them with pumps, by which a large supply of pure water had been obtained for the city of Brooklyn from the gravel deposits on Long Island. The simplicity of the means adopted and the large and constant volume of water obtained were alluded to as constituting a new and successful experiment on a large scale in connection with the supply of water to towns.

Since the publication of the paper referred to, the Messrs. Andrews & Co., contractors, have established two additional "plants" along the line of the Brooklyn Aqueduct, increasing the supply for the city to eighteen millions of gallons daily from this source alone—a quantity equal to one-sixth of the supply to the city of New York at the present time.

This large volume of water is obtained from four hundred and sixty (460) 2-inch tubes (equivalent in area of cross section to a single tube or pipe 44 inches diameter) driven from forty to seventy feet into the gravel deposits. On a trial-test, these tubes have furnished twenty-seven millions of gallons in twenty-four hours. Eighteen millions is not, therefore, the maximum supplying capacity of these wells at this time.

It is not contended that there is anything novel in the idea of obtaining water for any purpose from the unconsolidated or loose detritus of the earth's surface; but the means and appliances by which such large quantities are drawn continuously and permanently from a few tubes driven into the ground are so effective and simple, and so much has been done to encourage further operations of the same kind, and to throw light upon the characteristics of these underground water-bearing deposits, that it may be said that new resources, in connection with the water supply of the largest towns, have been opened to the engineer—resources not *always* available, it is true, but in many cases highly practicable and economical.

The engineer who seeks a source from which may be obtained a proper supply of water for a town, must take into consideration a great variety of circumstances. Among these, the meteorological and geological conditions which prevail in the district are most important, since these influence the quantity as well as the quality of the water obtained. Of all the meteorological agencies, there are none which have more controlling influence on the physical geography of the globe and the adaptation of any part of its surface to the necessities of the human race, than those which relate to rainfall and the reflux of the condensed waters of the sea. The causes which determine the quantity of rain which falls in any region are various: ocean currents, aerial currents, monntain ranges, extended valleys and plains—all produce their effects; and, although the most varied extremes occur of regions where vegetation is luxuriant on the one hand, and where deserts exist without rainfall on the other, yet such is the constancy of nature in her great cycle of changes, that each place receives its appointed share almost unchanged from year to year.

The average rainfall of a region is, therefore, in most civilized countries, one of the best established of all meteorological phenomena.

It is not so, however, in regard to the return of the waters to the sea. The flow of surface streams may, it is true, be determined with approximate accuracy, and their courses are well defined; but the disposal by nature of that large part of the rain which does not appear in the rivers and brooks, as they accumulate in magnitude toward the sea, is involved in much obscurity. A portion of the condensed vapors is known to be absorbed by plants, and a portion is reëvaporated, but a still greater part, apparently, disappears beneath the earth's surface. By what precise channels this large volume of water ultimately reaches the ocean, how much of it enters the covered out-crops of porous strata and, finding its way deep into the earth's crust between underlying and overlying consolidated beds, is ultimately discharged underneath the waters of the ocean; how much enters faults and fissures, and again issues in springs of pure or mineral waters; how much is concerned in excavating underground courses through or among the softer or more soluble rocks, or follows channels already thus excavated, is not and cannot be known. But that no inconsiderable portion of this subterranean flow follows more shallow channels in the loose detritus upon the surface seems probable. In most countries where the rainfall is copious, moderate excavations at the surface reveal the presence of water. In our own country every farm has its well, whether it be situated on a hill or in a valley; and, while these wells occasionally become dry in very dry years, it is apparently, in most cases, because they have not been sunk deep enough to reach those water-bearing beds of gravel and sand from which a perpetual and continuous supply might be obtained. The farmer, in sinking a well, looks gratefully for the first indication of water, and as his needs are not excessive, the sinking of the well is stopped when the upper surface of the first ter-bearing stratum is reached. The methods and appliances at his command do not permit him to sink deep into watery ground.

The "driven well" goes deeper, and the tube is easily driven through soft ground to any desired depth; while the artesian boring proper pierces the solid strata still lower, if necessary, and draws its waters from sources more distant than those which supply the common or the driven well.

The proportion of the rainfall which passes off by the surface streams is so variable in different places that actual gauging of the streams is generally necessary to determine it. Over a large portion of our Northern States, this proportion is from 30 per cent to 90 per cent of the rainfall, depending upon the seasons, the surface topography, and the geological characteristics of a district. From 10 per cent to 70 per cent of the rainfall for the same localities disappears, being absorbed by plants, or re-evaporated from the surface, or sinking beneath it, and of this latter portion there is no doubt that, in many parts of our country, nearly all follow shallow sub-surface channels slowly to the sea-levels.

Artesian wells have become so common in every quarter of the globe as no longer to excite especial interest, beyond that which may be attached to the great depths of some and the large volume of flow from others. As a general rule, the hard or consolidated strata of the earth's crust have to be pierced, often at very great depths, to reach water-bearing strata which have been pointed out by precise geological knowledge, or which are sought for with much expense and uncertainty where such knowledge is wanting.

While the mechanical processes of boring these wells have reached such a degree of excellence and certainty that individuals or companies may now be found ready to undertake for a specified sum per foot the sinking of an artesian well to any reasonable depth, yet the great cost and the uncertainty of success of any one boring, as regards the volume of water which may be permanently obtained, have caused this method of search for water to be adopted for cities and towns only as a last resort.

If it be proper to classify the systems which have been referred to as the "artesian" and the "driven well" systems, it can be said of the latter that the methods of exploration and well-sinking which have been recently developed seem to offer incontestable advantages, and to promise results of the greatest value and importance. Facts have been established, in the explorations already made in different places, which seem to offer strong inducements for further and systematic researches, not only from an economic, but from a scientific point of view. Among the scientific questions presented, those which appear to be of special interest relate to the causes of some of the peculiar phenomena of deposition and arrangement presented in the interstratified beds of gravel, clay, and sand which are found to exist; and, if these are connected in any way with ancient river beds, the possibility of tracing out these beds with greater certainty.

A study of these surface deposits by the methods which have been introduced for the driven wells, and which are attended with little difficulty and expense, comparatively, seems to offer, at least, an attractive field for economic and scientific explorations.

Through the kindness of Mr. W. D. Andrews I have obtained sketches which illustrate the construction of one of the four "plants" on Long Island from which the supply above-mentioned is obtained, and also a sketch illustrating the process of boring or prospecting adopted; and another representing a section of the deposits of sand, gravel, and clay in the vicinity of one of these plants to the depth of 433 feet.

In these sketches, Fig. 5 represents a plan of the whole "plant." The system of driven tubes occupies a space about 800 feet long and 15 feet broad, parallel with the line of the Brooklyn aqueduct. The tubes are in two rows about 15 feet apart, while in each line the tubes are about 12 feet apart. Fig. 5 shows the relative position of the Brooklyn aqueduct M, the pump house O, and the driven wells in two rows DD, Fig. 4. Fig. 4 is an enlarged view of a portion of the plan. In this sketch it will be seen that each tube is connected with a large pipe A, lying midway between the two rows of driven tubes and connecting them with a central or common chamber H, from which the suction pipe J extends to the pump house. In this figure the connecting pipes C C and the junction B B are shown more clearly than in Fig. 5.

The pumps in the pump house O draw water from all the wells simultaneously and discharge it directly into the aqueduct through the pipe N. (Fig. 5.)

Fig. 1 represents a vertical section drawn through two driven wells, showing the extension of the tubes downward through several strata of sand and gravel to the lower stratum G, from which the supply is drawn. The ends of the tubes are pointed to facilitate their being pushed downwards, and are perforated for several feet in length near the ends, to permit the entrance of the water; the perforations being covered with a wire netting to prevent the introduction of large pieces of gravel.

Fig. 2 illustrates the apparatus for prospecting for water. A two-inch tube is driven down for a few feet at the surface, with fittings at the top which close the top, except that a spout shown in the figure is attached to discharge water, sand, gravel, and clay into a tub. These fittings permit of a smaller tube being inserted into the top of the larger, with a hollow handle connected with a flexible hose to a portable pump. A man, by grasping this hollow handle, can churn the inner tube up and down while water is being forced into it from the pump. The bottom of this inner tube is chisel-shaped, but there are two openings near the bottom, which permit the water pumped through the inner tube to enter the space between the inner and outer tubes near the bottom. The churning action cuts up the sand and gravel, and as it is mingled with the water forced in, both the water and sand or clay are forced to the surface upwards between the two tubes and discharged into the tub.

A barrel or portable tank supplies the water if necessary.

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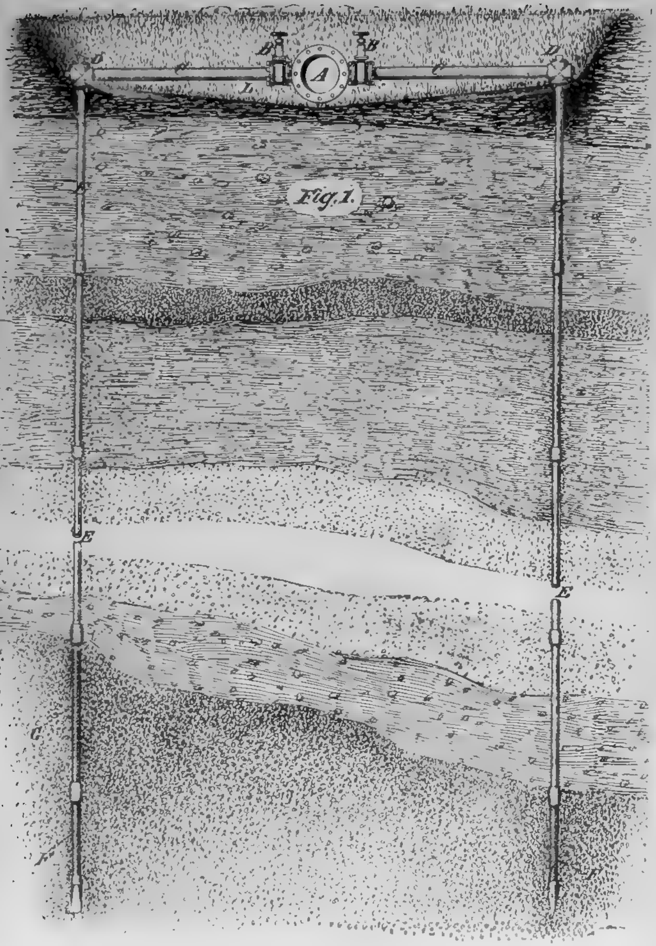
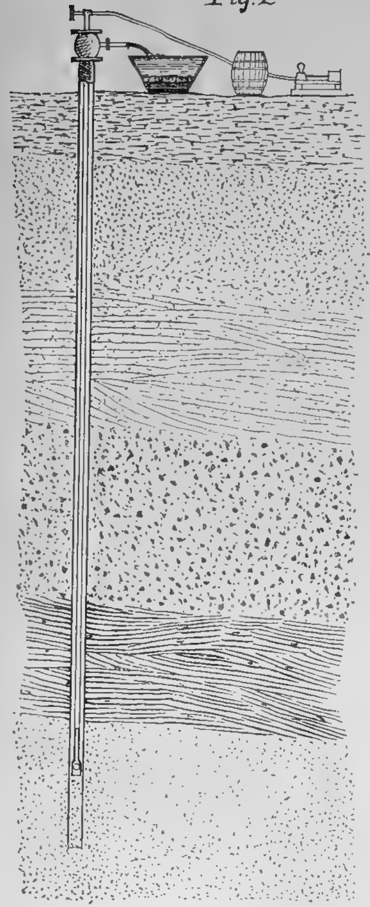
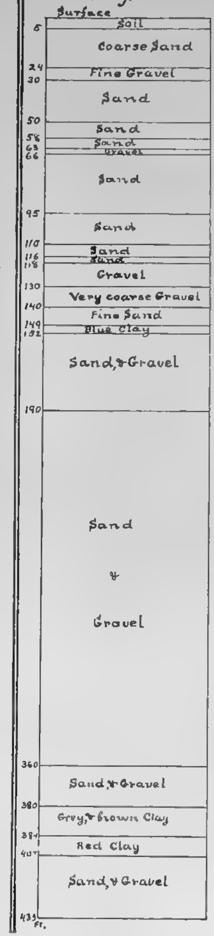


Fig. 2

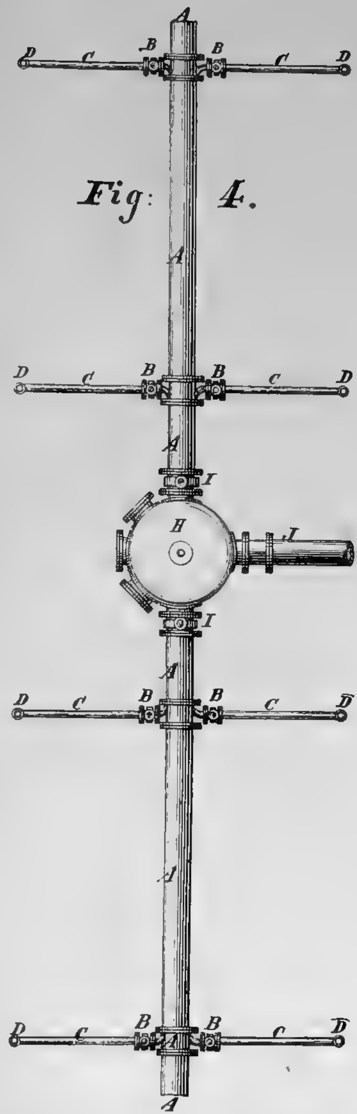


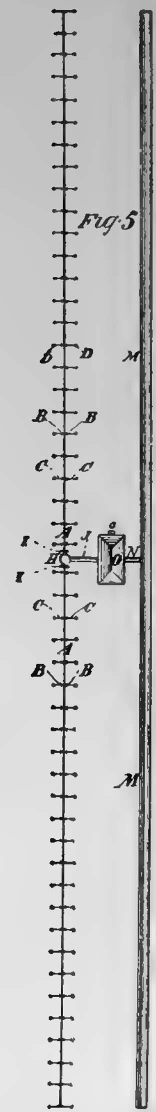
Sketch showing apparatus for prospecting for water.

Fig. 3



Section of deposits on Long Island in the vicinity of the driven wells.





The specimens discharged into the tub are collected and preserved, and thus a complete section of the strata may be obtained. The tubes may be extended by adding sections at the top as the boring extends downwards. Fig. 3 shows the section obtained near one of the plants on Long Island to the depth of 433 feet. Two of the gravel deposits passed through were composed of coarse rounded gravel, almost wholly free from any admixture of fine sand or clay, an evidence that there is a continued flow of water among the particles of gravel.

Mr. Henry E. Knox, Jr., formerly a student in the School of Mines, has been for many years engaged under the direction of the Messrs. Andrews in prospecting for water in various places, and I am indebted to him for the description of the prospecting device just described.

Mr. Knox found, between Albany and Troy, an extensive bed of gravel beneath a bed of fine clay, from 16 to 25 feet thick near the surface. The gravel bed is from 17 to 35 feet thick, about 700 feet wide and of indefinite length, it having been traced about half a mile longitudinally.

The gravel from this bed is entirely different from that on Long Island. It is composed of coarser grains or fragments of dark-colored rock, nearly all of uniform size, and less rounded than those from Long Island, showing evidence of that kind of attrition which comes from running water rather than wave action.

Mr. Knox found precisely the same gravel in his explorations near Utica; and under a bed of clay, 118 feet thick, near Albany, he found a bed of clean gravel, of nearly uniform size and uniform material, but composed of angular, water-worn pebbles as large as pigeons' eggs.

One of the most important questions connected with the system adopted on Long Island, and which has been repeated elsewhere on a smaller scale, was the permanency of the full supplying capacity of the wells.

It was urged by some distinguished engineers that the tubes must tap sheets or reservoirs of still water, and that a continued draught upon the system must speedily exhaust the reservoirs.

Experience has not confirmed this view. Mr. Knox informs me that, of the fifteen hundred or two thousand wells selected and driven by himself, not more than two or three have ceased to act, and that in nearly all the supply remains undiminished.

Experiments were made on Long Island to determine the line of depression of the water-level in the ground immediately adjacent to the plant of one hundred wells, while the pumps were drawing to their full capacity.

Test wells were sunk just outside of the plant on four sides, and a line of test wells extended out to a distance of 4,000 feet from the pump-house. Observations were made during three months. At the distance of 4,300 feet, the water-level was reduced about 6 inches. At a distance of 2,300 feet, about 2 feet 2 inches, and in the immediate proximity of the wells, within a distance of 300 feet, the depression was 4 feet 8 inches. When the pumps were stopped, all the levels were restored.

The rate of flow to wells sunk in sand or gravel depends, of course, upon the compactness of the material of the water-bearing stratum, the resistance to the flow being proportional to the narrowness of the minute channels through which the water must flow, and to the number of windings and turnings which a particle is forced to take throughout its course to the pumps. The velocity of a particle of water running into an ordinary filtering gallery along the margin of a stream is generally less than one foot an hour. The velocity of a particle flowing towards the pumps in the driven-well plant on Long Island, taken a little outside the rectangle formed by the hundred wells, is about the same—a velocity too small to be directly perceptible to the eye. This small velocity shows what great relative resistances are encountered.

The form of the water-surface will, therefore, depend almost entirely upon the coarseness or compactness of the materials through which the water passes, and is not to be taken as a measure of the degree of exhaustion of the source of supply.

In all the explorations thus far made, it has been found that the gravel-beds, available for water, are not continuous over indefinite areas, nor of uniform thickness, but certain beds and particular channels in certain beds appear to constitute the underground water-ways, rendering systematic explorations necessary.

The questions which naturally arise, concerning these deposits, are: What have been the causes of the peculiar arrangements of sand, gravel and clay? Are the gravel deposits the beds of ancient water courses, along which the finer sands and clays have been washed away by the stream? Can these old river beds, if they exist, be traced and identified throughout their courses?

In the exploration between Albany and Troy, the appearance of the gravel found seems to indicate a common origin with that of Utica, and it is the opinion of Mr. Knox that the same beds extend along the valley of the Mohawk between these points, but by a route not identical with the present course of that river.

The mode of exploration which has been described renders it more simple and less expensive than might be imagined, to conduct such researches, although not probably within the means of private explorers.

An instance has recently come to my knowledge which adds new interest to this subject, inasmuch as in this case water was procured in abundance from a sub-surface deposit in loose material in a region where the small rainfall and the absence of permanent surface streams has heretofore been considered a serious obstacle to any permanent settlement of the country.

Mr. Arthur Macy, a graduate of the School of Mines, having been appointed to take charge of the famous "Silver King" mine in southwestern Arizona, found that for the extensive milling operations indispensable in the treatment of the ore, an amount of water would be necessary for which no adequate supply appeared available. A valley of several miles in extent lay above the mines, and from the appearance of the country, he concluded that this valley, from which flowed a small torrent in the rainy season, must contain sub-surface water. He excavated two open wells, one 15 feet and the other 25 feet deep, at the outlet of the valley, and about 300 feet above his mills in vertical elevation and three miles distant from them.

A 3-inch pipe was carried from the mills up the valley to the wells, where it was connected to two siphons, one from each well; through these siphons, without the use of pumps, he obtains a continuous supply throughout the year of 200,000 gallons per day.

There is no doubt that Mr. Macy has thus discovered a practical method of obtaining water in Arizona, which may be repeated in many parts of that territory, and which will be found applicable in many other regions heretofore supposed to be practically deprived of water.

There is now, at least, abundant experience to encourage the search for and use of subterranean water for the most important uses of life, in the shallow and loosely compacted deposits which cover plains and valleys. Another significant example is found in the new water-supply for the villages on the east shore of Staten Island. A large part of this island is known to be covered with drift. That portion which is embraced between the principal ridge of serpentine rocks running through the middle of the island from north to south, and the dike of basaltic rock which skirts the western shore of the island, both of which have been described by Dr. Britton before the Academy,[1] is especially to be noted as bearing water; a very large part of the rainfall, doubtless, because the whole area of eight or ten square miles is peculiarly devoid of surface streams.

Along the southwestern shore of the island there are unmistakable indications that the underground flow reaches the surface only a few feet above high-water mark. Here the Crystal Water Co. have sunk large tubes about 40 feet into the drift. From these tubes the water destined for the villages along the eastern shore of the island is pumped to a reservoir, $3\frac{1}{2}$ miles distant, situated on the top of the dividing ridge referred to, whence it descends through pipes by gravity about $2\frac{1}{2}$ miles further to the eastern shore, furnishing a head of about 250 feet.

A few years ago Staten Island and Long Island were supposed to be almost destitute of water. when the prospective wants of their large and increasing population were considered. Now it may be said that in this respect, though isolated from the main land, they are better off in many respects than New York City. I recently examined, at the request of the Trustees of the village

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[1] The Geology of Richmond Co., N. Y., Annals N. Y. Ac. Sci., Vol. II.

of Edgewater, the facilities presented on Staten Island, and had no hesitation in advising that a contract might be safely made with the Crystal Water Co. for all the water which would probably be needed for a long term of years. Such a contract has since been made, and the water supply for the towns referred to may be considered assured.

Perhaps my own interest in this subject is derived partially from some of the earlier associations of my life. In the State of Michigan, where I passed my boyhood, there is a tract of country 20 or 30 miles broad, bordering on the river and lake St. Clair, the Detroit River, and Lake Erie, which is low and heavily wooded, and in wet seasons almost swampy. The settlers of this region had little difficulty in finding water a few feet below the surface, but there were few surface streams, and I have known the farmers to be obliged in very dry seasons to drive their stock several miles daily to water. A belt of country north of this, and stretching from Lake Huron in a southwest direction quite across the state to Lake Michigan, is covered with the most beautiful little lakes of pure and sparkling water, which never become stagnant and never dry up.

Farther north again, toward the northern part of the State, are found extensive pine barrens, where again there are but few rivers and streams; but I have seen wells driven there from 6 to 10 feet only to an abundant supply of water. The little lakes I have referred to are replenished from the exposed outcroppings of gravel beds, and while they are often linked together so as to constitute the sources of considerable streams, the water from most of these lakes seems to sink away slowly again and to flow underground in broad sheets toward the great lakes. Nearly everywhere in this State, water in abundance can be found by driven wells; and I am told that in the regions where the early settlers suffered so much from swamps and mud in winter, and drought in summer, surface drains and tube-wells have created an entirely new condition of things favorable to the farmer.

An objection has been frequently urged against the use of water from these shallow sub-surface deposits that there is danger from pollution or contamination of the water by sewage and surface drainage, the drainage from cemeteries, etc.

While it would obviously be undesirable to establish a driven well plant within the limits of a populous city, it may be said that the necessity for so doing is never likely to occur. Moreover, the purifying influence of the soil by infiltration is known to be very effective ; the well-known processes of sewage disposal by irrigation and downward filtration are based upon this property of the ordinary porous soils.

A microscopic analysis of the effluent water from the irrigation fields of Paris showed that the number of microbes in the sewage was reduced from 20,000 per cubic centimetre to 12 per cubic centimetre, and that the effluent water from the irrigation fields contained fewer microbes than the water supplied to Paris for domestic uses. (See Gray's report to the City Council of Providence.)

The water being drawn from considerable depths, usually, the purifying effect of the slow downward filtration from the surface would probably be much more complete than is produced by any artificial filtration.

It should be a source of public congratulation that, while our rivers and streams must become polluted by a growing population, nature furnishes another source of water-supply so abundant and widespread, so pure and so easily procurable.

Explorations and investigations having in view the more thorough study of this underground water-supply deserve, and should receive at the hands of the public, the most earnest appreciation and encouragement.

PROF. A. A. BRENEMAN spoke as follows :

Every plan for supplying water for domestic use to cities must be regarded from the standpoint of the chemist as well as from that of the engineer. Unfortunately for sanitary interests, it often happens that the chemist is called in only when some glaring defect in the operation of a system is met with which might have been prevented if his counsel had been sought at the beginning. Considerations of quantity and permanence of supply, so important in themselves, have too often been allowed to overshadow the question of the quality of the water to be used. As a result of this policy, we have to face the fact that not one-tenth of the large cities of this country are supplied with water that is really wholesome or good.

There is some excuse for this state of things in the fact that resort to the water of rivers and streams is generally had under pressure of danger from polluted wells or from failure of previous sources; and when the new system is decided upon, there is rarely time enough for a thorough inquiry into the character of the water to be taken.

It is characteristic of sanitary progress, however, that the tendency towards chemical investigation at the outset in such cases is a growing one.

The driven well, especially in its later development as the gang-well system, seems to offer a cheap and speedy way of supplying water in any desired quantity to a community. It has obvious advantages over an aqueduct or pipe-line bringing water from a distance. But there is a chemical question yet to be considered in regard to it. Unless the surface waters of the district in which wells are to be sunk are themselves unobjectionable, the method has little to recommend it to permanent application. The action of powerful pumps which draw from a limited area such enormous volumes of water as the system must supply will result eventually in drawing in all water, surface as well as subterranean, which the vicinity will yield. The increased depth of these wells as compared with surface wells is really very slight, when we consider the greatly increased draughts which are made upon them. It has been shown that there are considerable variations in the level of the subterranean waters, during the action of the pumps in a gang-well system, even at a distance from the pipes. Such changes of level must be proportionally greater near the wells. What is to prevent the gravitation of surface water to fill the vacuum thus created ?

The compact beds of clay so often appealed to to shut out all surface water are a fallacious dependence, unless they are absolutely water-tight over great areas and under enormous pressure. It is too much to expect that a layer of clay sufficiently thick or impervious to water will always be found or that prospectors will go sufficiently far afield to secure for their wells a region of which the surface is above suspicion. The danger to be feared especially is that the flow of water from all directions towards the wells will, under the high pressure created by the pumps, follow only the larger pores and crevices underground, and by continually enlarging these, create in time a system of channels leading directly to sources of pollution. Such action would annul the filtering power of the soil, upon which so much depends where subterranean waters are used.

The operation of the great system of gang-wells which now supplies about one-sixth of all the water used in Brooklyn illustrates these principles upon a large scale. Seven million gallons of water are daily drawn from a system of 100 wells, varying in depth from 45 to 100 feet and covering a line about 400 feet in length. Such a yield corresponds to a total rainfall of 32 inches a year upon 3,000 acres, or roughly represents the same annual rainfall upon all of the land within a radius of 1¼ miles from the pumping station. Owing to the sudden demand for this water, the soil waters must be continually drawn downward in the vicinity of the pumps, and the nearer regions must be more effectually drained than the more remote. The predicted consequences are abundantly realized. Shallow wells in the neighborhood are wholly or nearly dry since the pumping station has been opened. A swamp formerly existing about the station has been dried up. The subsoil of the Jewish cemetery 370 yards distant, which offers frequent opportunities for observation, is said by the sexton to be much drier than heretofore. The existence of filthy barnyards and open house drains close to the wells, and richly manured fields all around them, are suggestive features of the case.

Chemical analyses of the water from these wells show an abundance of nitrates, the sure indicators of organic decomposition.

The gang-well system may be, under proper precautions, of great benefit to communities seeking new supplies of water, but it is open to abuses in its applications which render it hardly less safe in the long run than the ordinary well. From a very large number of analyses of the water of small driven wells made by myself, I am convinced that the causes of deterioration in such wells rest also upon the principles already outlined.

Mr. Chittenden stated that litigation over patents had developed the fact that driven wells were first used practically by the Union armies during the war of the rebellion.

The subject was further discussed by Prof. J. J. Stevenson, Mr. Chittenden, Mr. Merrill, and the Chairman.

February 7, 1887.

Regular Business Meeting.

The President, Dr. J. S. Newberry, in the chair.

Sixteen persons present.

The Report of the Council recommended the acceptance of the resignation of Mr. John Townshend, which was adopted.

Mr. A. P. Bjerregaard read a paper :

REPORT UPON THE PINK DOLOMITE RECENTLY OBTAINED NEAR MORRISANIA, WITH ANALYSIS.

Discussion.

Prof. D. S. Martin thought that the mineral had some of the characteristics of calcite, but should be regarded as a variety of dolomite, the latter name properly being generic.

Dr. A. A. Julien said that there had been too much reliance upon chemical analysis alone; a microscopic examination of these dolomitic limestones shows a heterogeneous condition, grains of calcite being mingled in the mass. He thought that the mineral might be a mingled calcite and dolomite.

Mr. Bjerregaard said he had obtained little insoluble matter in dilute acid, less than five per cent.

Dr. Britton suggested that the color might be due to manganese.

The President spoke of the characters of true dolomite, and of the origin of the magnesian limestones, which he considered organic sediments and not chemical deposits.

The subject was further discussed by DR. BRITTON, MR. CHAMBERLIN and the author of the paper.

MR. ALBERT A. CARY exhibited an amethyst geode from Honduras, the crystals being of good color, and associated with crystals of calcite.

THE PRESIDENT stated that the new building to be occupied by the scientific and literary societies of Buffalo was being dedicated this evening ; and on motion of the Secretary it was voted to send a telegraphic message of congratulation to the Buffalo Society of Natural Sciences.

February 14, 1887.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Eighty-two persons present.

MR. WILLIAM E. HIDDEN stated that the chemical analysis of the "Bielid" meteorite, from Mazapil, Mexico, gave the following results :

Iron,	91.26
Nickel,	7.84
Cobalt,	0.65
Phosphorus,	0.30

Masses of graphite and of troilite were also found in the meteorite.

MR. L. E. CHITTENDEN directed attention to the published accounts of earthquakes in Japan and in the Sandwich Islands which, according to the reports, must have occurred simultaneously.

PRESIDENT NEWBERRY spoke of the result of observations on the diurnal nutation of the earth, by M. Folie, communicated to the French Academy of Sciences, at the session of January 3d, and reported in *Nature* of January 13th, 1887.

This phenomenon establishes beyond a doubt the fluid state of the interior of the earth, and a relatively thin crust.

DR. JOHN S. WHITE read a paper on

THE LANDSKIBET, OR VIKING SHIP, DISCOVERED NEAR GOKSTAD, NORWAY, IN 1880.

(Illustrated with lantern views.)

Remarks were made by MR. McDONALD, MR. CHITTENDEN, and the PRESIDENT.

February 21, 1887.

STATED MEETING.

MR. L. E. CHITTENDEN in the chair.

A large audience present in the East Lecture Room of the Library Building, Columbia College.

The second lecture of the Popular Lecture Course was delivered by PROF. JOHN K. REES on

THE GREAT TELESCOPES OF THE WORLD; THEIR CONSTRUCTION, POWERS AND LIMITATIONS.

(Illustrated with lantern views.)

Like all great inventions, the telescope may be considered the product of many minds. The inventor was one who worked out the proper combination of lenses, or mirrors with lenses. Long before the invention of the telescope, spectacle glasses or lenses had been made. In the 8th century A.D., magnifying spectacles for old people were commonly used. Seneca, who lived in the first century, tells us that, in his time, it was well known that when writing was viewed through a globe full of water the letters looked larger and blacker. This appearance must have attracted the attention of many persons before the time of Seneca. The natural result of such a discovery would be the invention of glasses to produce magnification. It is not strange, then, that we find the use of a simple magnifying lens extending so far back that we are unable to fix the date for its discovery. But, down to the beginning of the 17th century, no one seems to have thought of combining two lenses together, one in front of the other, so as to render distant objects visible.

There appears to be some uncertainty as to the name of the original inventor of the telescope. Undoubtedly, Galileo was the first to publish to the world the manner of making the instrument, and, furthermore, he was probably an independent inventor; but it is well known that he was not the original inventor. In the Archives of The Hague, quoted by Arago, we read that a spectacle-maker of Middleburg, named John Lippershey, addressed a petition to the States-General on October 2d, 1606, in which he asked leave to take out a patent which should constitute him the only maker of an instrument capable of rendering distant objects visible, or which should confer upon him an annual pension, on the condition of not manufacturing the instrument for other nations. On the 4th of October, 1608, the States-General appointed a deputy from each province to experiment on the new instrument, which was about one foot and a half in length. On the 6th of October, the commission declared the instrument to be useful to the nation, but demanded that it should be made for two eyes instead of for one. On the 9th of December, Lippershey announced that he had solved the problem. A favorable report was made on the 11th, and the binocular instrument was declared a success. "Saturnus tells us that an unknown man of genius called on Lippershey and ordered from him a number of convex and concave lenses. At the time agreed upon the man returned and chose two lenses, one convex and the other concave, and placing them one before his eye and the other at some distance from it, drew them backwards and forwards without giving any explanation of his manœuvres, paid the optician and left the place. As soon as he was gone Lippershey began to imitate the experiments of the stranger, and soon found that distant objects were brought apparently nearer when the lenses were placed in certain positions. He next fastened them to the ends of a tube, and lost no time in presenting the new instrument to Prince Maurice of Nassau."

According to another version, Lippershey's children were playing with the lenses, when one of them, happening to place a convex lens in front of a concave lens, was greatly surprised to see the vane of the clock-tower of the Middleburg Church apparently brought nearer. Lippershey's attention being called to the fact, he tried it, and, working out the idea, he invented the first telescope.

Metius, of Amsterdam, the discoverer of the ratio $\frac{355}{113}$ (the relation between the circumference and the diameter of a circle) claimed to be the inventor. Jansen and Baptista Porta and others disputed for the honor.

Inasmuch as the first telescopes were at once seen to be of great value in wars, it was attempted to keep the invention a secret. Galileo heard, through letters, that an instrument had been invented which rendered distant objects visible, but he obtained no account of the construction. He, however, on this hint, made a telescope after several trials. The highest magnifying power which Galileo used was nearly 30 diameters. He was the first to direct the telescope heavenward. He saw the spots on the sun, the moons of Jupiter, the mountains in our moon, the handles of Saturn, the phases of Venus, and made other interesting discoveries.

Kepler suggested for the single biconcave lens near the eye, used by Galileo and others, a double convex lens, which gave a larger field. This combination is called the "Astronomical eye-piece." It inverts the objects looked at.

It is foreign to my purpose to enter into the details of the construction of a telescope. You all know that the power of a telescope to magnify an object looked at depends upon the focal lengths of both object-glass and eye-piece. It is the ratio of the first to the second. If, then, our object-glass forms an image of the moon at a distance of 100 inches from the centre of the glass, and we view that image with an eye-lens whose focal length is one-quarter of an inch, we obtain an image in the field of view which is magnified 400 diameters. We can, therefore, increase our magnifying power either by making the focal length of the object-glass greater, or that of the eye-lens less, or by doing both. With a given object-glass we can, theoretically, make our magnifying power as great as we choose. If, in the case cited, we use an eye-lens with a focal length of say $\frac{1}{100}$th of an inch, we obtain a magnifying power of 100 × 100, or 10,000 diameters. "But in attempting to do this a difficulty arises with which astronomers have always had to contend, and which has its origin in the imperfection of the image formed by the object-glass. No lens will bring all the rays of light to absolutely the same focus. When light passes through a prism the various colors are refracted unequally, red being refracted the least, and violet the most.

"It is the same when light is refracted by a lens, and the consequence is that the red rays will be brought to the farthest focus and the violet rays to the nearest, while the intermediate colors will be scattered between. As the light is all not brought to the same focus, it is impossible to get any accurate image of a star or other object, at which the telescope is pointed. The eye sees only a confused mixture of images of various colors. When a sufficiently low magnifying power is used, the confusion will be slight, the edges of the object being indistinct and made up of colored fringes. When the magnifying power is increased, the object will indeed look larger, but these confused fringes will look larger in the same proportion, so that the observer will see no more than before. This separation of light in a telescope is called chromatic aberration."

The early astronomers found no way to get rid of this difficulty. They discovered, however, that they could diminish the trouble by increasing the focal length of the telescope, and thus making the image larger. An object-glass, say, of 5 inches diameter, with focal length of 60 feet, would give no more confused image than the same object-glass with a focal length of 6 feet. The image formed by the first would be ten times as large as that formed by the second, so that a low power of eye-lens could be used, and hence the confused fringes produced the less disturbing effect with a given eye-lens, the greater the focal length of the object-glass. In this way Hughens, Cassini, Hevelius, Blanchini and other astronomers of the 17th century were able to obtain quite high magnifying powers. These astronomers made telescopes of 100 to 150 feet in focal length, and one man finished an object-glass whose focal length was 600 feet.

Cassini mounted the objective on the top of a long pole free to move, while the eye-piece was moved along near the ground until the object-glass and eye-lens were brought into line with the star to be observed. The tube of the telescope was dispensed with. Hevelius connected his object-glass and eye-piece by a long pole. Newton, in his treatise on Optics, declared that the improvement of the refracting telescope was "desperate," and he turned his attention to reflecting telescopes. But an English optician, named Dolland, about the middle of the 18th century, discovered a remedy. He found that by a combination of lenses of crown and of flint glass he could obtain an almost colorless image at the focus. This, indeed, was a grand victory, and at once enabled the opticians to construct telescopes of less length.

They could now put more of the magnifying power in the eye-piece, and have a telescope of such a length as could be comfortably handled. Telescopes, made of such a combination of lenses as we have alluded to, are called "achromatic." As larger and more perfect achromatic telescopes were made, a new source of aberration was discovered, no practical method of correcting which is yet known. It arises from the fact that flint glass, as compared with crown, spreads out the blue end of the spectrum more than the red end. The consequence is that two lenses cannot be made so as to entirely get rid of the color. "In a small instrument the defect is hardly noticeable, the only drawback being that a bright star or other object is seen surrounded by a blue or violet ring formed by the indigo rays thrown out by the flint glass. If the eye-piece is pushed in so that the star is seen, not as a point, but as a small disc, the centre of this disc will be green or yellow while the border will be reddish purple. But, in the immense refractors of 2 feet aperture and upwards, this 'secondary aberration,' as it is called, constitutes the most serious optical defect." Some think that no art can cure this defect. Many methods have been tried, all without much practical value. The defect may be lessened in the same way that the astronomers of the 17th century lessened the effect of "chromatic aberration,"—viz., by lengthening the telescope. But the lenses of the 17th century were very small and light, compared with the large lenses now made. And it would be very difficult to mount rigidly a telescope 100 feet long, carrying one of the large modern lenses. Newcomb considers that, in the great refractors of recent times, the limit of optical power for such instruments has been very nearly attained.

Many of the telescopes of the older astronomers had object-glasses (of crown glass only) of from $\frac{1}{2}$ an inch to 1 inch in diameter. Some were larger. After Dolland made his discovery, the great difficulty experienced in obtaining discs of flint glass of the required degree of purity prevented the making of any large telescopes till the beginning of this century, when Guinand discovered a process of making large discs of glass free from air-bubbles and striæ, and of equal density throughout. Most of my audience understand that the object-glass of a refracting telescope is the "vital part, the construction of which involves the greatest difficulty." Given the object-glass, and the rest of the telescope can be quite easily made. And in the making of the object-glass there are two perfectly distinct processes. First, there are the beautifully clear discs of crown and of flint glass to be obtained. This is the work of the glassmaker. And then these discs have to be ground and polished, so as to form perfect lenses which will give uncolored images and bring all the rays of light to one focus. This is the task of the optician. Both require extraordinary skill. Few men have it.

About the beginning of this century the "English Board of Longitude" offered a considerable reward for bringing the art of making flint glass for optical purposes to the requisite perfection; but it led to no important discoveries. The Academy of Sciences of Paris offered prizes in vain for this object, and it remained for a man, not distinguished by education nor a glassmaker by trade, M. Guinand, of Switzerland, to have the honor of arriving at the solution of the difficulties.

Pierre Louis Guinand was one of those geniuses who seem to have great intuition and immense perseverance. He is said to have had no knowledge of optics, yet when quite young he constructed a small telescope equal to the best of his time. He soon turned his attention to producing glass discs of the requisite purity for making large telescopes. "He obtained some flint glass from England, but this was not always perfectly pure. He melted it anew, but did not obtain satisfactory glass." He then erected an establishment in which he constructed with his own hands a very large furnace, and commenced the manufacture of glass; and finally succeeded in obtaining pieces large enough for telescopes. He afterwards discovered a method of softening pieces of perfectly pure glass for the purpose of giving them the form of a disc. In 1805 he was employed by Utzschneider to assist in making object-glasses at the celebrated optical estabishment near Munich. Here he worked with Fraunhofer, but in a subordinate capacity. He had sold his secret with his service. After remaining here some nine years he returned home, drawing a pension from the Munich establishment so long as he did not reveal the secret or himself make object-glasses.

He could not long resist the temptation, and soon gave up the pension to undertake the manufacture of larger discs than any he had previously made. In 1823 he produced a disc 18 inches in diameter. In 1824 he exhibited at the exposition in Paris a grand achromatic object-glass which excited the admiration of the king, and Guinand was invited to come to Paris to live. He, however, was in feeble health and old. He died in 1825 at the advanced age of nearly 80 years. Many think that Fraunhofer owed to Guinand much of his fame gained in making large object-glasses.

After the death of Guinand, his widow and one of his sons set up works in Switzerland. The other son was introduced to Bontemps of Paris. They succeeded in producing good flint glass in discs of from 12 to 14 inches in diameter. In 1848 Bontemps accepted an invitation to unite with Messrs. Chance Bros. & Co., of Birmingham, England, in their efforts to improve the quality of glass.

They have succeeded in producing some very large discs, notably the ones for the Newall telescope of 25 inches, and also the discs for the great Washington telescope of 26 inches diameter. The establishment of Guinand at Paris is now conducted by Feil, a grandson of P. L. Guinand. Feil made the discs for the great Austrian refractor, 27 inches in diameter. He also made the discs for the Princeton telescope, and furnished the discs for the great Russian telescope of 30 inches diameter, and those of 36 inches for the Lick Observatory of California.

The process of making these large discs seems to be well understood by Messrs. Chance and Feil, so that the only difficulty in getting the large discs is the long delay. The Russian discs were received by the opticians (the Clarks), who do the polishing, in about two years after being ordered.

The flint disc for the Lick telescope was ready in about one year, and the crown was nearly ready in nine months after, but was broken in the handling. Newcomb thinks that the secret of the manufacture consists principally in the constant stirring of the molten glass during the process of making.

The reason why the glass-makers require so long a time to make the large discs may be understood from the following account:

"As optical glass is now made, the material is constantly stirred with an iron rod during all the time it is melting in the furnace, and after it has begun to cool, until it becomes so stiff that the stirring has to cease. It is then placed, pot and all, in the annealing furnace, where it is kept nearly at a melting heat for three weeks or more, according to the size of the pot. When the furnace has cooled off the glass is taken out, and the pot is broken from around it, leaving only the central mass of glass. Having such a mass, there is no trouble in breaking it up into pieces of all desirable purity, and sufficiently large for moderate-sized telescopes. But when a great telescope of two-feet aperture or upward is to be constructed, very delicate and laborious operations have to be undertaken. The outside of the glass has first to be chipped off because it is filled with impurities from the material of the pot itself. But this is not all. Veins of unequal density are always found extending through the interior of the mass, no way of avoiding them having yet been discovered. They are supposed to arise from the materials of the pot and stirring-rod, which become mixed in with the glass in consequence of the intense heat to which all are subjected. These veins must, so far as possible, be ground or chipped out with the greatest care. The glass is then melted again, pressed into a flat disc, and once more put into the annealing oven. In fact, the operation of annealing must be repeated every time the glass is melted." Annealing consumes two months each time for the large discs. "When cooled it is again examined for veins, of which great numbers are sure to be found. The problem now is to remove these by cutting and grinding without either breaking the glass in two or cutting a hole through it. If the parts of the glass are once separated they can never be joined without producing a bad scar at the point of junction. So long, however, as the surface is unbroken, the interior parts of the glass can be changed in form to any extent. Having ground out the veins as far as possible, the glass is to be again melted and moulded into proper shape. In this mould great care must be taken to have no folding of the surface. Imagining the latter to be a sort of skin inclosing the melted glass inside, it must be raised up wherever the glass is thinnest, and the latter allowed to slowly run together beneath it.

"If the disc is of flint, all the veins must be ground out on the first or second trial, because after two or three mouldings the glass will lose its transparency. A crown disc may, however, be melted a number of times without serious injury. In many cases—perhaps the majority—the artisan finds that after all his months of labor he cannot perfectly clear his glass of the noxious veins, and he has to break it up into smaller pieces. When he finally succeeds, the disc has the form of a thin grindstone two feet or upward in diameter, according to the size of the telescope to be made, and from two to three inches in thickness. The glass is then ready for the optician.

"The first process to be performed by the optician is to grind the glass into the shape of a lens with perfectly spherical surfaces. The convex surface must be ground in a saucer-shaped tool of corresponding form. It is impossible to make a tool perfectly spherical in the first place, but success may be secured on the geometrical principle that two surfaces cannot fit each other in all positions unless both are perfectly spherical. The tool of the optician is a very simple affair, being nothing more than a plate of iron somewhat larger, perhaps a fourth, than the lens to be ground to the corresponding curvature. In order to insure its changing to fit the glass, it is covered on the interior with a coating of pitch from an eighth to a quarter of an inch thick. This material is admirably adapted to the purpose because it gives way certainly, though very slowly, to the pressure of the glass. In order that it may have room to change its form, grooves are cut through it in both directions, so as to leave it in the form of squares, like those on a chess-board.

"It is then sprinkled over with rouge, moistened with water, and gently warmed. The roughly ground lens is then placed upon it, and moved from side to side. The direction of the motion is slightly changed with every stroke, so that after a dozen or so of strokes the lines of motion will lie in every direction on the tool. This change of direction is most readily and easily effected by the operator slowly walking around as he polishes, at the same time the lens is to be slowly turned around either in the opposite direction or more rapidly yet in the same direction, so that the strokes of the polisher shall cross the lens in all directions. This double motion insures every part of the lens coming into contact with every part of the polisher, and moving over it in every direction. Then whatever parts either of the lens or of the polisher may be too high to form a spherical surface will be gradually worn down, thus securing the perfect sphericity of both.

"When the polishing is done by machinery, which is the custom in Europe, with large lenses, the polisher is slid back and forth over the lens by means of a crank attached to a revolving wheel. The polisher is at the same time slowly revolved around a pivot at its centre, which pivot the crank works into, and the glass below it is slowly turned in the opposite direction. Thus the same effect is produced as in the other system. Those who practise this method claim that by thus using machinery the conditions of a uniform polish for every part of the surface can be more perfectly fulfilled than by a hand motion. The results, however, do not support this view. No European optician will claim to do better work than the American firm of Alvan Clark & Sons in producing uniformly good object-glasses, and this firm always does the work by hand, moving the glass over the polisher and not the polisher over the glass."

Little imperfections are sure to exist after the first polishing. It is in the nice correction of these that the great skill of the optician is shown and much time is consumed.

The American firm of Alvan Clark & Sons enjoys the reputation of being the best opticians in the world for polishing large lenses.

When the Russian government decided to construct a telescope that would surpass in size the great Washington telescope of 26 inches diameter of object-glass, Otto Struve, the director of the Imperial Observatory, was commissioned to make an examination of the optical workshops of the world to discover where the best object-glass makers could be found. After he had made a thorough examination in Europe and in this country, he gave the contract to the firm of Alvan Clark & Sons. This great object-glass 30 inches in diameter is now completed. When the Russian glass was contracted for, the trustees of the Lick Observatory in California ordered an object-glass of 36 inches aperture—so that we still have in the United States the largest refracting telescope in the world.

I have dwelt upon the object-glass of a great refracting telescope because of its vital importance. We will have some explanations to make in regard to mountings, etc., when at the close of the lecture we throw on the screen several pictures to illustrate our subject.

As we have previously stated, Isaac Newton, in the latter part of the 17th century, believed that there was no remedy for the defects in the refracting telescopes as then made, and he turned his attention to reflecting telescopes. Now it is well known that when parallel rays of light fall on a concave mirror they will all be reflected back to a focus, there forming an image of the object from which the rays emanate. The form of this concave mirror must be such that a section of it cut by a plane parallel to the length of the telescope will be a parabola. The image formed will be made up of *all* the rays—there will be no such thing as chromatic aberration. Thus if a mirror could be made and would continue of the true parabolic shape, the great and desperate difficulty in the way of improving the telescopes might be removed.

In the time of Newton, the reflecting telescopes, however, did not excel the long refracting telescopes. Even after Dolland' discovery, the great difficulty met with in obtaining pure glass made the earlier short achromatic telescopes not much better than the long instruments. But in the latter part of the 18th century a genius arose who solved the problem of the construction of large mirrors. History tells us that "William Herschel, in 1766, was a church organist and teacher of music, of high repute in Bath. He spent what little leisure he had in the study of mathematics, astronomy and optics. By accident a Gregorian reflector two feet long fell into his hands, and turning it to the heavens, he was so enraptured with the views presented to him that he sent to London to see if he could not purchase one of greater power. The price named was far above his means. He resolved, then, to make one for himself. After many experiments with metallic alloys, to learn which would reflect most light, and many efforts to find the best way of polishing his mirror, and giving it a parabolic form, he produced a five-foot long (Newtonian) reflector, which revealed to him a number of interesting celestial phenomena, though, of course, nothing that was not already known."

He determined, then, to make the largest telescope that could be made, and after many failures, he produced a telescope having a mirror two feet in diameter and 20 feet long. At this time, 1781, he discovered the planet Uranus. His fame coming to the ears of the king, George III., that monarch gave him a pension of £220, that he might devote his life to the study of the heavens. He now accomplished his greatest work by making a reflector four feet in diameter and forty feet long. With this he discovered two new moons of Saturn.

It was not until 1842 that another great step was taken in the direction of increasing the power of the reflecting telescopes. Then the Earl of Rosse, of Parsonstown, Ireland, constructed (using steam machinery for grinding and polishing) a great mirror, six feet in diameter, the tube being fifty-four feet in length. The telescope has not done as much work as was expected, owing to the bad climate of the region where it is placed. It has been said that there are only a few hours in the year when the telescope can be used with its greatest efficiency.

Since 1842 a considerable number of large reflecting telescopes have been made. But as a general rule (though silvered glass mirrors have been substituted for those of metallic alloy), the reflectors have not given as much satisfaction as was to be expected. The large ones are more difficult to handle; the mirror tarnishes readily, and has to be frequently resilvered, and the alternations of heat and cold and of flexure produce a distortion of the curve which makes the mirror focus badly. These difficulties are so troublesome that refractors are usually preferred.

The following table gives the location, character and aperture of the great telescopes of the world.

Size of Principal Telescopes in the World.

Refractors.

Owner and Location.	Constructed by.	Aperture.	Remarks.
Lick Observatory, Cal.,	A. Clark & Sons,	36 in.	
Pulkova, Russia,	A. Clark & Sons,	30 "	Finished in May, 1833.
Yale College,	A. Clark & Sons,	28 "	Constructing.
Littrow, Vienna,	Grubb,	27 "	
University of Virginia,	A. Clark & Sons,	26 "	
Washington Naval Observatory,	A. Clark & Sons,	26 "	
Gateshead, England,	Cooke,	25 "	
Princeton, N. J.,	A. Clark & Sons,	23 "	
Buckingham, London, E'd,	Buckingham,	21 "	
University of Chicago,	A. Clark & Sons,	18.5 "	
Strasbourg,	Merz,	18 "	
Private Observatory, Buffalo,	Fitz.	18 "	
Warner Observatory, Rochester,	Clark & Sons,	16 "	
Washburne Observatory, Madison, Wis.,	A. Clark & Sons,	15.50 "	

Owner and Location.	Constructed by.	Aperture.	Remarks.
Harvard College,	Merz,	14.95 "	
Pulkova, Russia,	Merz,	14.93 "	
Lord Lindsay, Dun Echt,	Grubb,	15 "	
Royal Society, near Lond.,	Grubb,	15 "	
Downsede College, Bath,		14.5 "	Destroyed by fire in 1867.
Markree Castle,		14 "	
Oom, Lisbon,	Merz,	14 Fr. in.	
C. H. F. Peters, Clinton,	Spencer,	13.5 in.	
Boss, Albany,	Fitz.	13 "	
Columbia College Observ'y,	Rutherfurd & Fitz,	13 "	Photographic lens attachable. Presented to Columbia College by Mr. Rutherfurd in Dec. 1883.
Allegheny Observatory, Pa.	Fitz,	13 "	
Ann Arbor, Mich.,	Fitz,	12.5 "	
Christie, Greenwich,	Merz & Simms,	12.25 "	
Vassar College,	Fitz, reworked by Clark,	12.5 "	
Pritchard, Oxford,	Grubb,	12.25 "	
Glasgow, U. S.,	A. Clark & Sons,	12.25 "	
Paris,	Secretan & Eichens,	12 Fr. in.	
Littrow, Vienna,	A. Clark & Sons,	12 in.	
Adams, Cambridge,	Cauchoix,	12 "	
White, Brooklyn, N. Y.,	Fitz,	12 "	
Ball, Dublin,	Cauchoix,	12 " (?)	
H. Draper, Jr. New York,	A. Clark & Sons,	11 "	
Main, Oxford,	Cauchoix,	12 " (?)	
Pritchard, Oxford,	Grubb,	12 "	
Cincinnati,	Merz,	11.5 "	
Bothkamp, Germany,	Schroeder,	11.7 "	
Cordova, S. A.,	Fitz,	11.2 "	
Munich, Germany,	Merz,	11 "	
Copenhagen, Denmark,	Merz,	11 "	
Middletown, Conn.,	Clark & Sons,	11 "	

And many others.

Reflectors.

Owner and Location.	Constructed by.	Aperture.	Remarks.
Lord Rosse, Birr Castle,	Rosse,	6 feet.	
William Herschel, Slough,	W. Herschel,	4 "	Out of use.
Lassell, Liverpool, etc.,	Lassell,	4 "	Since destroyed.
Ellery, Melbourne,	Grubb,	4 "	
Paris,	Martin, Eichens.	4 "	Silvered glass.
Lord Rosse, Birr Castle,	Rosse,	36 in.	Silvered glass.
Common, England,		36 "	
Tisserand, Toulouse,	Foucault,	32.4 "	
Stephan, Marseilles,	Foucault, Eichens,	31.5 "	
H. Draper, nr. N. Y.	H. Draper,	28 "	Silvered glass.
Lassell, Maidenhead,	Lassell,	24 "	Metal.
W. & H. Herschel, Slough, and C. G. H.,	W. & J. Herschel,	18 "	Several mirrors.
H. Draper, nr. N. Y,	H. Draper,	15 "	
M'Lean, Tunbridge Wells,	With & Browning,	15 "	
Pritchard, Oxford,	De La Rue,	13 "	
Worthington & Baxendell, Manchester,	With & Browning, (?)	13 "	
And many others.			

NOTE.—The object-glass of the Lick equatorial is to cost,	$52,000 00
Photographic lens of crown glass......................	13,000 00
Mounting of telescope.................................	42,000 00
Dome and machinery........................	56,800 00
Total.......................	$163,800 00

Mr. A. Swazey, of Cleveland, furnishes the following data in regard to the great Lick telescope:

Focal length 56 feet.

Length of polar axis 12 feet.

Diameter of polar axis 12 inches, with a cylindrical hole 5 inches in diameter.

Declination axis: length, 12 feet; diameter, 10 inches, with 5-inch hole.

Largest circles 3 feet in diameter.

The tube of steel will weigh about 3 tons. The tube and all the movable parts (polar axis, etc.) will weigh 12 tons. The "head" will weigh 3 tons, and the pier 10 tons, making a total of 25 tons.

The lenses with their cell weigh about 700 pounds.

It has been stated that the photographic lens cracked in three pieces while the Clarks were polishing it.

February 28, 1887.

SEVENTY-FIRST ANNUAL MEETING.

The Second Vice-President, PROF. W. E. TROWBRIDGE, in the chair.

Twenty persons present, in the regular meeting-room of the Society, in Hamilton Hall, Columbia College.

The following notice was read by request:

ELIZABETH THOMPSON SCIENCE FUND.

"This fund, which has been established by Mrs. Elizabeth Thompson, of Stamford, Connecticut, 'for the advancement and prosecution of scientific research in its broadest sense,' now amounts to $25,000. As the income is already available, the trustees desire to receive applications for appropriations in aid of scientific work. This endowment is not for the benefit of any one department of science, but it is the intention of the trustees to give the preference to those investigations, *not already otherwise provided for*, which have for their object the advancement of human knowledge, or the benefit of mankind in general, rather than to researches directed to the solution of questions of merely local importance.

"Applications for assistance from this fund should be accompanied by a full statement of the nature of the investigation, of the conditions under which it is to be prosecuted, and of the manner in which the appropriation asked for is to be expended. The applications should be forwarded to the Secretary of the Board of Trustees, Dr. C. S. Minot, 25 Mt. Vernon street, Boston, Mass., U. S. A.

"The first grant will probably be made early in January, 1886.

(Signed) H. P. BOWDITCH, *President.*
WM. MINOT, JR., *Treasurer.*
FRANCIS A. WALKER,
EDW. C. PICKERING,
CHARLES SEDGWICK MINOT, *Secretary.*"

The Report of the Recording Secretary, PROF. H. L. FAIRCHILD, for the past year is summarized as follows :

The Council held nine meetings, and the Academy held thirty-five meetings, including nine business meetings and three popular lectures.

Six regular meetings had over one hundred persons present. Only one meeting had so small an attendance as eight. The average attendance (not including the popular lectures) was fifty. (The average attendance the preceding year was thirty-eight.)

The list of resident members numbers three hundred and one. During the year, seventeen persons have been elected, of whom thirteen have qualified. Eleven resignations have been accepted, and three members have died.

The number of formal or announced communications is thirty-one. (The number the preceding year was twenty-six.) They may be classed as follows : Mineralogy, 7 ; Geology, 3 ; Archæology, Astronomy, Bacteriology, Engineering, Hygiene, Meteorology, Seismology, 2 each ; and one each upon Botany, Chemistry, Ethnology, Geography, Palæontology, Physics, and the "History of the Society."

The informal communications are numerous and wide in range ; the larger number upon topics in Ethnology, Geology, Mineralogy, Meteorology, Seismology, and Zoology.

The Librarian, Dr. A. A. JULIEN, reported an increase in the library for the past year of 1,062 numbers, making a total of 9,335. These arranged in volumes, make the library as follows : bound volumes, 4,482 ; unbound volumes, 2,197 ; total number of volumes, 6,679.

During September, the library was transferred from the American Museum of Natural History to the Herbarium Room in the Library Building of Columbia College, where it is accessible every day of the year, except Sundays, from eight o'clock A.M. to ten P.M. The College authorities agree to bind and care for the books equally with their own. The transfer was made under the authority delegated to the President and Recording Secretary, June 9th, 1884. Notice of termination of the contract with the Museum was given August 14th, 1885. The moving of the books was under the personal direction of the Secretary, Dr. Britton, and Mr. Merrill.

In the autumn a circular was distributed, proposing an exchange of publications with about three hundred scientific societies and institutions not on our list of exchanges. The present number of our list is two hundred and seventy-eight, which will soon be largely increased in response to the circular. Eighty replies have already been received, and only about seven per cent of them are not affirmative.

The Report of the Treasurer, DR. JOHN H. HINTON, was read by the Secretary, which showed a small balance in the treasury.

The election of officers for the coming year resulted as follows :

President, J. S. NEWBERRY.

First Vice-President, O. P. HUBBARD.

Second Vice-President, W. P. TROWBRIDGE.

Corresponding Secretary, A. A. JULIEN.

Recording Secretary, H. L. FAIRCHILD.

Treasurer, HENRY DUDLEY.

Librarian, N. L. BRITTON.

Councillors, J. A. ALLEN, A. R. LEEDS, J. J. STEVENSON, P. H. DUDLEY, D. S. MARTIN, C. VAN BRUNT.

Curators, B. B. CHAMBERLIN, S. LOWELL ELLIOT, G. F. KUNZ, F. J. H. MERRILL, C. E. PELLEW.

Finance Committee, J. H. HINTON, *Chairman*, W. H. RUDKIN, L. E. CHITTENDEN.

The following resolutions, presented by Mr. Chittenden, were unanimously adopted :

Resolved, That the members of the Academy have heard with deep regret of the lamentable accident which deprives them of the President at the Annual Business Meeting, and which has called him to the bedside of his son, and

Resolved, That the Secretary be directed to transmit by telegraph to President Newberry the unanimous expression of their deep sympathy with him in the great trial through which he is passing, their fervent hope for the recovery of his son, and the hope that he may be spared for a long life of usefulness, of which his father has furnished such an excellent example.

The following papers were read by title :

DESCRIPTION OF A NEW SPECIES OF THRUSH, (MARGAROPS ALBIVENTRIS) FROM THE ISLAND OF GRENADA, W. I., BY GEORGE N. LAWRENCE.

(Published in the ANNALS, Vol. IV.)

MONOGRAPH OF THE NORTH AMERICAN IULIDÆ, BY CHARLES H. BOLLMAN.

(Published in the ANNALS, Vol. IV.)

MR. GEORGE F. KUNZ exhibited a pectolite hammer from Pt. Barrow, Alaska, made of a fragment of a pectolite boulder. In color it is a light grayish-green, resembling jade. It had not been rubbed or polished except at the breaking edge and on the side where the handle is attached. The material is very compact and tough, and is similar to that which was supposed to be jade until it was identified by Prof. Clarke's analysis. A small groove has been made at the point of greatest resistance to receive a thong which binds the handle to the head. The handle is of reindeer bone, 15 cent. long, and is secured to the head by means of spliced reindeer sinews, which pass ten times round the head and through a perforation in the handle, thus binding the two parts together with wonderful firmness. The sinews were evidently wet when the work was done. Although made by a savage, this hammer is as light, symmetrical, and strong for the purpose (crushing bones), as any skilled artisan could possibly make out of whatever material. It would be difficult to conceive a hammer in which the force of concussion would be more evenly distributed through the head, and although the fastening is light it could be still lighter.

MR. KUNZ also exhibited specimens of, and remarked as follows upon

HYDROPHANE (MAGIC STONE) FROM COLORADO.

A white, opaque variety of hydrophane has recently been brought from some Colorado locality, which is quite remarkable for its power of absorbing water. It is in rounded lumps, 5 mm. to 25 mm. in diameter, with a white chalky or glazed coating somewhat resembling the cachalong from Washington Co., Georgia.

When water is allowed to drop slowly on it, it first becomes very white and chalky, and then gradually becomes perfectly transparent. This property is developed so strikingly that the finder has proposed the name "*Magic Stone*" for it and suggested its use in rings, lockets, charms, or other objects of jewelry to conceal photographs, hair, etc., which the wearer wishes to reveal only as his caprice dictates. The specific gravity and weight of several specimens were taken, with the following results:

	Weight dry. (grammes)	Weight wet. (grammes)	Water absorbed. (grammes)	Weight in water. (grammes)	Specific gravity.
Slabs 2 m.m. thick.	.880	1.342	.588	.463	2.110
	.644	.934	.416	.338	2.091
	.730	1.109	.379	.382	2.097
Natural lump with glazed coating.	1.874		1.059	.864	2.097

It will be seen that the mineral absorbs more than an equal volume of water.

MR. KUNZ also exhibited hollow quartz crystals; and very large and perfectly transparent crystals of rhodochrosite from Colorado.

MR. P. H. DUDLEY exhibited plants which he had obtained ten days previously at Panama, one of which when young resembled the banana, and was called by the natives "wild plantain."

March 7, 1887.

REGULAR BUSINESS MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Thirty persons present.

The Report of the COUNCIL recommended the payment of certain bills, and the acceptance of the resignations of the following persons: Birdseye Blakeman, A. H. Elliott, Mrs. J. A. Gallagher, Dr. Alex. Haddon, Thomas Holland, Jos. M. Knap, Rev. E. F. Moldenke, Dr. W. B. Neftel, Chas. E. Strong, Alexander Warner.

The report was adopted, and the resignations accepted.

The following paper was read by title:

NOTES ON THE SURFACE GEOLOGY OF S. W. VIRGINIA.
By PROF. J. J. STEVENSON.

PROF. H. L. FAIRCHILD read a paper upon

TRANSFORMATIONS OF THE SKIN IN THE ANIMAL KINGDOM.

(Illustrated with lantern views.)

March 14, 1887.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Twenty-six persons present.

An invitation was read from the Trustees of Columbia College asking the Academy to participate by delegate in the Centennial celebration of the College, April 13th, 1887.

DR. N. L. BRITTON presented the shell of *Anodon excurvatus* from Southampton, L. I., it being new to the locality.

MR. B. B. CHAMBERLIN exhibited geodes, containing amethyst and calcite, from trap rock of Nova Scotia.

MR. A. P. BJERREGAARD exhibited smoky quartz from Morrisania.

PRESIDENT NEWBERRY stated that he had received from Prof. Dwight of Vassar College some trilobites, collected near Poughkeepsie, which were characteristic of the middle Cambrian, and which indicated a geological horizon probably equivalent to the "St. John's" of New Brunswick.

PROF. W. P. TROWBRIDGE read a paper upon

LAWS OF FATIGUE AND REST IN ANIMAL MECHANICS, AS APPLIED TO BOAT-RACING.

The question has been frequently discussed among those who take a general interest in college sports, whether the excessive training for long-distance boat-races, and the violent and long-continued muscular and nervous exertions incident to these contests, do not in reality result in unnecessary and hurtful exhaustion during a race, and frequently in permanent injury to the contestants. It is quite certain that boat-races with four-mile courses are extreme tests of physical endurance, as well as of strength and skill; and it is well to ask whether a certain kind of collegiate supremacy, an exciting holiday for assembled crowds of students and their friends, the momentary exultation over a college victory, are not too dearly bought when the price paid is the health and perhaps the life's usefulness of a student.

As long, however, as one college challenges another, whether it be to a boat-race, a ball-match, or a foot-race, we may expect that the challenge will be accepted; the faculties being generally not only willing but ready backers, certainly the most enthusiastic applauders—after a victory. But since all sports or friendly contests must take place under established rules, it is a very proper subject for discussion whether the distance to be rowed in our inter-collegiate boat races may not be changed to three miles, without the slightest risk of rendering these contests less exciting or diminishing the value of the victory, while at the same time the long and extremely rigorous training which is now necessary might then be diminished somewhat, and the exhausting effect on the rowers during the week of the races be avoided. It is a matter of experience, I believe, that a race is practically decided at the end of the third mile, the occasions on which the crew that leads at the end of the third mile is finally beaten being very rare. This means that in everything that brings victory, strength, skill, coolness, and endurance, a three-mile course is all that is necessary. The fourth mile adds almost complete exhaustion, without changing the result, but it is the fourth mile that demands so much more rigorous training and previous work.

A lesson might be taken from the rules of horse-racing, where such complete over-fatigue on the part of the horse is not tolerated, and would indeed be looked upon by spectators as a sort of cruelty to animals not unlikely to bring about perhaps the official interference of Mr. Bergh. The laws of fatigue and refreshment, and of total exhaustion, applicable to muscular exertion, are special examples of a universal law as immutable and infallible as any other law of nature. One of the most interesting of all the developments of animal mechanics, is found in the discovery that the law which governs the expenditure of energy in artificial motors is not only analogous but identical with that which applies to animal or muscular energy. This identity is most clearly shown in comparing the consumption of a given amount of coal in driving a vessel through the water through the medium of a steam engine, with the consumption or exhaustion of a given amount of muscular energy in propelling a boat. It is well known that the resistance to the motion of a boat in the water is proportional to the square of the velocity; and as the work performed (or coal consumed) in a unit of time—one hour, for example—is proportional to the resistance multiplied by the velocity or speed per hour, it follows that the consumption of fuel is proportional to the cube of the velocity. It is also known that a given quantity of fuel is capable of doing only a a fixed amount of work, whatever be the rate of combustion or speed with which the vessel is driven. The number of hours required, therefore, for the consumption of equal quantities of fuel in propelling the same vessel through the water at different velocities, will be proportional inversely to the cubes of the velocities, while the space passed over will be inversely proportional to the squares of the velocities. Suppose a steam-vessel with a given amount of coal on board, to start on a passage of one hundred miles, the speed to be five miles per hour. The time required to make the trip will be twenty hours, and the coal is supposed to be just sufficient for this voyage with this velocity. Suppose again the same vessel to undertake the same trip with the same amount of coal, but with a velocity of ten miles per hour. The result will be that the coal will all be consumed in two and one-half hours, one-eighth of the time, and the boat will only make twenty-five miles of the distance; it must then become helpless and unable to go further unless more fuel is supplied.

This is an important law, which, if it be found applicable to the expenditure of muscular energy, should be heeded by every one: It is that the time of exhaustion is inversely as the cube of the speed with which work is performed; when resistances overcome are proportional to the square of the velocity. In ordinary daily work, however, the law takes a somewhat different form. In walking, for instance, the resistance is not proportional to the square of the speed, but to the speed or velocity simply; the exhaustion being that of raising the body about one and two-tenths inches at each step against the resistance of gravity and inertia, the latter being proportional to the velocity with which the body is lifted. In walking, therefore, the time of exhaustion is inversely proportional to the square of the velocity, and the space passed over inversely to the velocity.

The law that the time of exhaustion is inversely as the cube of the velocity is, however, strictly applicable to the boat-race, since the resistance of the boat is proportional to the square of the velocity; and as the test of victory is the speed, it follows that the price of victory is a certain degree of exhaustion. How great that exhaustion shall be, depends on the length of course. Unfortunately, it is not the fatigue of the muscles of the legs, arms, and back that are most concerned, but those of the respiratory and circulatory organs, the lungs and the heart, are involved. It is well known that the action of a muscle in contracting is accompanied by a destruction of tissue, a true combustion in one sense, carbonic acid, water, and other products being formed, and that the refreshment of the muscle consists in the rejection of these products, and a building up of tissue through the blood, which flows to the muscle from the heart. This refreshment is essential to continued action. Muscular work therefore involves both fatigue and refreshment as well as strength or muscular force. It has been ascertained by careful estimates that the average laborer in various callings performs work equivalent to about 350 foot-tons in ten hours; *i. e.*, work equivalent to raising 350 tons one foot high in ten hours. But the day-laborer finds many intervals of rest during his work; each exertion is usually followed by a short interval of rest, sufficient for the refreshment of the muscles, and he might thus continue his exertions almost indefinitely were it not that the peculiar and essential kind of rest which is found in sleep demands its share of his time. Moreover, in ordinary labor, all of the muscles of the body are seldom in action at once, the diversity of effort permitting certain muscles to rest temporarily while others are engaged.

The boat-race involves the action of all the muscles, those of the legs, arms, and shoulders, as well as of the back; and hence the demands on the heart and lungs are the greatest possible. The work which a rower performs in each minute of a four-mile race is easily calculated. The distance—21,120 feet—is traversed in about 21 minutes. The speed is therefore practically about 1,000 feet per minute. At this speed the resistance to the boat in the water is about 75 pounds. This resistance has been determined experimentally as well as theoretically in England, the average result being 75 pounds. The work per minute for eight men is therefore 75,000 foot-pounds, or 9,375 foot-pounds (4.2 foot-tons) for each man per minute.

At the rate of 350 foot-tons in ten hours, the day laborer performs work at the rate of only $\frac{6}{10}$ of a foot-ton per minute. The rower in the boat race therefore performs work each minute equivalent to the work of seven strong laborers, or at the rate of nearly one-third of a theoretical horse-power each minute during the race.

The question now recurs: for how long should these extraordinary efforts be sustained? Four miles in distance and twenty-one minutes in time, mark extreme limits of endurance, according to all experience in boat-racing. And if races are practically decided at the end of the third mile, or whether they are so decided or not, the fourth mile is a test, not of skill and muscular strength, but of the hearts and lungs of the crews.

This is rather serious business. Is it quite rational to make the ultimate endurance of these vital organs in a dozen young men a matter of sport and amusement? The muscles of the heart and lungs are among those whose action is quite voluntary, although they are called involuntary muscles. They are the ready and obedient servants who need no prompting from the will, but who, sleeping and waking, guard and sustain animal life. But the laws of fatigue and refreshment for these muscles are the same as for others. Long-continued excessive violent action must impair their efficiency.

It is hardly to be expected that any boat crew will initiate a movement to reduce the length of course from four miles to three; to use an appropriate expression, they "would die first." Such a movement might be looked upon as a confession of weakness. But when the suggestion comes from an outsider, it is made to all alike, and may at least be discussed with possible profit.

Refreshment of Muscles.

An interesting inquiry connected with this subject is, at what rate refreshment of muscular action takes place. From experiments made by Dr. Haughton, of Trinity College, Dublin, to whose investigations in animal mechanics we are indebted for the law of fatigue, it seems probable that the actual time required for complete refreshment is many times greater than the time necessary for complete exhaustion. The slight intervals of rest during periods of ordinary exertion are not, therefore, in themselves sufficient, and prolonged repose during some period of each day becomes necessary.

The above laws of fatigue and refreshment refer especially to muscular action, and include both the voluntary and involuntary muscles of the animal system.

If we may by analogy or inference assume that corresponding laws govern the action of the nerves and brain in man, the conclusions arrived at in regard to over-exertion in the boat-race have much wider and more comprehensive bearings when applied to the daily labors of the great multitude of men and women, where the fatigue and exhaustion incident to their struggles for the support of themselves and their families are those of the brain and nerves, not of the muscles.

Assuming that the total exhaustion of a given amount of nerve and brain energy is inversely proportional to the square or the cube of the rapidity with which the nerves and brain are urged into action by the will, and that the time required for refreshment is many times greater than that required for total exhaustion, we can appreciate at once the fatal effects of what is called over-work.

In no country in the world probably do we find such utter disregard of the rational uses of the brain and nerves as in our own. Partly from necessity, and partly from habits and customs of living, work is accomplished here with a speed and nervousness that constantly threatens exhaustion and permanent injury to health. The necessary time and means for the refreshment of these important functions are grudgingly given, and, indeed, are generally looked upon as periods of improvident idleness, a kind of self-indulgence which demands explanation, and which is likely to be the subject of apologetic remarks or ill-natured criticism.

Most of us can remember the time when if a lawyer, or doctor, or clergyman, or teacher, or banker, or any other of the hard brain-workers, desired to find relaxation after a week or month of toil, with his rod or gun, he felt that he must steal away through back yards, or enter a closed carriage to get out of town without being seen, lest he might be considered as encouraging idleness in others.

When it is fully recognized that injury from over-work does not come from patient plodding, constant industry with proper means and intervals of rest, but from attempts to do too much in too little time—from too rapid or too prolonged expenditure of the powers of the brain and nerves, and from a total disregard of the law of refreshment and rest, we shall find that success, health, and enjoyment of life will be better assured.

These laws and rules of rational labor are infringed voluntarily, though perhaps ignorantly, by multitudes who seek to attain wealth or distinction, or who devote themselves too assiduously to their various vocations. Not only does severe strain long continued produce over-fatigue, but ordinary work continuously repeated is often quite as trying in its effects. A distinguished public man once told me the hardest work he had to do was to sign his name repeatedly for hours together, as he was often obliged to do. The merchant, the tradesman and tradeswoman, the lady who has the care of a family and the servant who repeats day after day the same routine of work, inevitably experience a certain kind of fatigue for which there is no relief but a longer period of repose than can be found during the day or week, and a complete change from the surroundings that accompany their duties. It is this which makes the country so welcome a retreat to the hard workers of the cities; the country landscapes, the different modes of passing the hours of the day, the novelties encountered in daily walks, the temporary relief from responsible exertion, are quite as efficient agencies as the fresh air, which is too often credited with all the benefits. Such rest and refreshment, when it can be procured, is as much a duty of life as are the fatigues and anxieties incident to useful labor.

But there are large numbers who are denied these periods of enjoyment and necessary recreation. This fact brings us face to face with one of the great social problems of to-day—the condition of the laboring masses: not the day-laborers, as they are called, only, but the thousands who often work with their brains while the laborer works, and still work on when he sleeps; the men and women everywhere who toil under the direction of others and hold their places by a tenure too often and too generally upon rigid rules which tolerate no day of rest except the Sabbath, and sometimes not even that. While we hold it to be presumptuous on the part of a few societies composed of men laborers, to consider manual labor the only kind of work which is entitled to recognition, and to exclude toiling thousands in every community from the ranks of labor because they only work with their brains and nerves, yet there are grievances for all which should be remedied.

One of these evils, incident to the concentration of capital in business at the present day, is that employees are over-worked. There would be less complaint in regard to pay, if men and women could have a reasonable time for rest and refreshment—for the recreation which alone makes work anything more than a dreary, continued draught upon the vital energies without hope of relief and without enjoyment.

Insurance companies, merchants, railroad corporations, and other organizations, are too apt to look upon men and women as mere machines, to be used, and thrown aside when they are worn out. A weekly half-holiday has been granted within a few years, willingly by some, grudgingly by others, but the firms or corporations that give more than a week in summer to their hard-worked employees are exceptions to the general rule.

The working man, the working woman, the cashier, the clerk, all need proper periods of rest, as much as the director of a company, the proprietor of a manufactory, the president of a bank or of an insurance company. If these matters were better regulated we should hear less of the complaints of labor. Until they are better regulated, there can be no harmony of interest between the employer and employee. No one can be excused for not wishing to work, and no one can be blamed for complaining if he be over-worked.

Though all cannot perform the same parts in the work of social life, all should have their full rights and shares in social benefits, if they are faithful workers. Among those rights, none is more sacred and unalienable than the right to a fair proportion of time for rest and recreation after fatiguing labor. When this is granted, what matters it whether one works with his brain, another with his hands?

> "Life's work is long,
> Life's day is short;
> But if each day we toil aright,
> Sweet is the sound of evening song
> That ushers in the night."

THE PRESIDENT subsequently spoke upon the subject of the paper.

March 21, 1887.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

A large audience present in the East Lecture Room of the Library Building, Columbia College.

The third lecture of the popular lecture course was delivered by GEN. HENRY L. ABBOTT on

SEA-COAST DEFENSE.

(Illustrated with lantern views.)

March 28, 1887.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Thirty persons present.

The following paper was read by title:

THE GENERA AND SPECIES OF NORTH-AMERICAN CARBONIFEROUS TRILOBITES, by LIEUT. A. W. VOGDES.

(Published in the Annals, vol. IV.)

MR. GEORGE F. KUNZ read an informal paper on

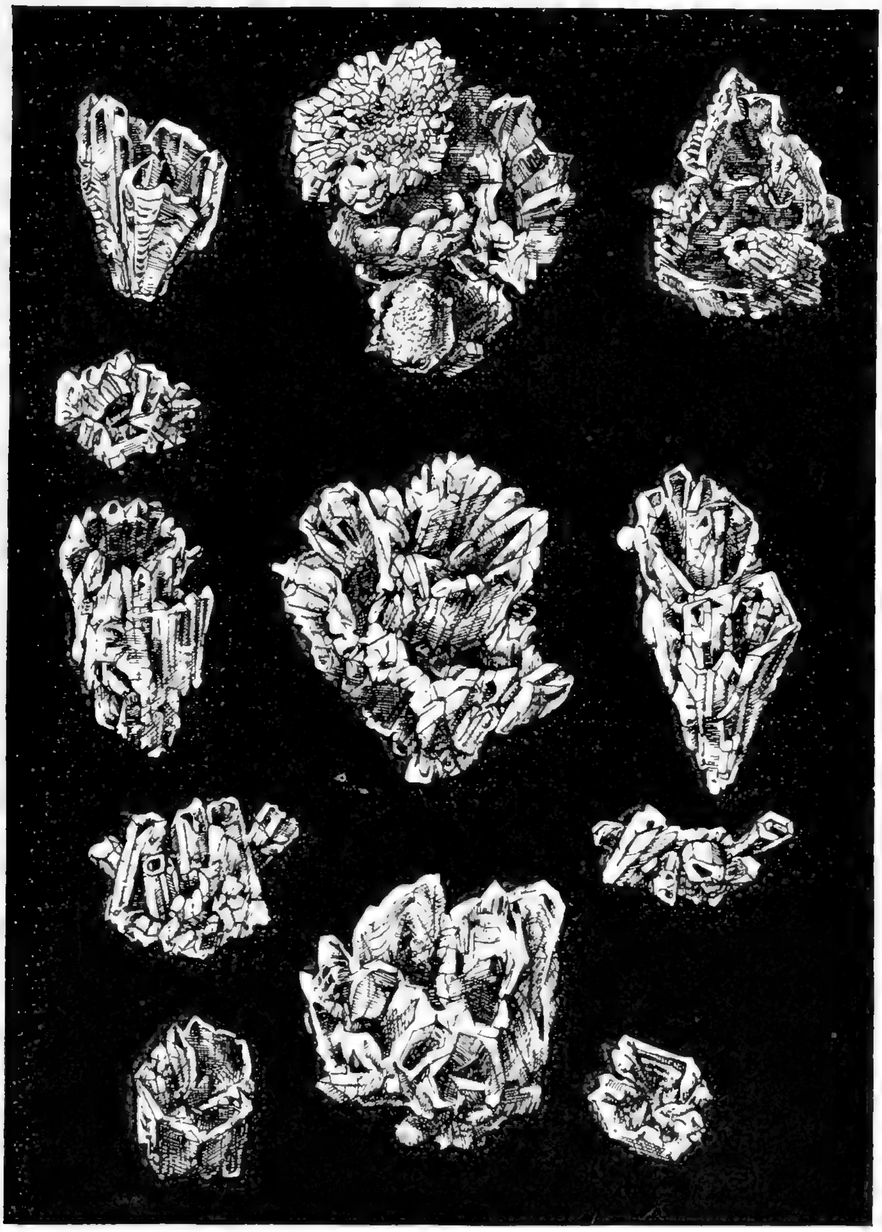
CRYSTALS OF HOLLOW QUARTZ, FROM ARIZONA.

(Illustrated with specimens and drawings.)

These crystals are found about three miles southwest of the town of Pinal, in Pinal Co., Arizona, occurring in a sandstone rock, which has been traced for about one mile. It is found to be penetrated in many places by spherules of obsidian, one-eighth to three inches across, which cover the ground like a shower of large hailstones.

These quartzes are of exceptional interest from the fact that they are mere walls surrounding hollow spaces much larger than the area of the wall itself (see Figures 1, 5, and 8). In some instances the crystals seem to have formed from some radial point, and numbers of the detached crystals show this very strikingly, especially Figures 1, 5, and 7. At the point of attachment on a number of crystals there appear small nuclei of chalcedony, and in some instances they radiate from this chalcedonic centre so as to form veritable quartz flowers, as in Figure 2. Quite often they are single individuals hollowed out, leaving only the smallest edges of what ought to be a pyramid, and the interior of the crystal being unfilled or hollow to the base in a few instances.

This extends entirely through the crystals. They are not cavernous like the Paretta, Italy, and Burke Co. quartz. As



hollow quartz their characteristics are sufficiently marked to isolate them from those found at any other locality.

It is very evident that these were the result of crystallization from a solution, and the chalcedony, being rounded and coated white, has every appearance of stalagmitic growth, and fades imperceptibly into quartz. In some few instances the quartz crystals terminate with chalcedony coating on them. The sides of the prismatic faces *i* are striated and have all the unevenness of having been made up of crystalline plates. The hollow crystals themselves are usually made up of six flat individuals so systematically arranged as to leave the centre hollow, the whole being often one distinct crystal. Many of the crystals are terminated with the pyramid face R only; I when present is usually very small and only slightly developed. Some, however, have both R and I. In general appearance they resemble the amethyst of Schemnitz, Hungary.

The figures were all carefully drawn and are of the natural size. In this connection it may be mentioned that from near Crouch's Mill, Gaultney's township, Alexander Co., North Carolina, the writer obtained a beautiful group of quartz radiating from one of these chalcedonic nuclei, and forming a complete flower that measured seven centimetres across. None of these crystals, however, were hollow. To Mr. J. G. Heistand I am indebted for information concerning the locality.

PRESIDENT J. S. NEWBERRY read a paper on

THE FAUNA AND FLORA OF THE TRIAS OF NEW JERSEY AND THE CONNECTICUT VALLEY.

(Abstract.)

The Triassic rocks of New Jersey and the Connecticut Valley were laid down in estuaries that in Triassic times indented the east coast of North America. Being surrounded by land and having no great depth of water, these basins were for the most part filled with the wash from the surrounding shores, gravel, sand, and clay. In the New Jersey basin the water was never clear and deep enough for limestone to form, but in the Connecticut valley, locally a few feet of limestone are contained in the Triassic rocks, a record of an interval when the water was deeper and more pure.

Tides probably swept up and down these estuaries, sorting and transporting the sediments and giving alternations of clay

and sand, now sandstone and shale. The inflow and outflow of the water, and its brackish character, were unfavorable to the development of animal or vegetable life, and as a consequence we find the Triassic strata remarkably barren of fossil remains. This absence of organic matter, and the exposure of the sediments to the air, resulted in the peroxidation of the iron they contain, and therefore the prevailing color of both sandstones and shales is red or reddish brown.

By the ebb and flow of high tides the shores of these estuaries were alternately laid bare and again covered by a sheet of sediment carried by an overflow of the water. The shores thus alternately covered and exposed seem to have been the feeding grounds of a host of terrestrial, air-breathing animals which have left their tracks in great numbers on many layers in the series. About one hundred different kinds of tracks have been distinguished, varying in size from one inch to nearly two feet in length. Most of the impressions are those made by three-toed bipeds and closely resemble the tracks of birds; but some of them are four and even five toed. They are now generally regarded as the tracks of reptiles and amphibians, which inhabited this region in great numbers, but left almost no other record of their existence than these autographs. A few bones and portions of two skeletons are all the remains yet found of the animals themselves.

Alternating with the barren red sandstones and shales of the Triassic series, are some layers of dove-colored shale which contain much diffused organic matter, a few impressions of plants, and large numbers of the remains of fishes. The plants are cycads, conifers and ferns, mostly of the same species with those found in the coal basins of Virginia and North Carolina and described by Prof. Fontaine in a monograph on "The Older Mesozoic Flora of Virginia," published by the U. S. Geological Survey. These plant remains are generally fragmentary and are evidently twigs and leaves, representing the vegetation which covered the shores of the estuaries. No broad-leaved plants (angiosperms) grew here or anywhere on the earth in the Triassic age, but the forests which covered the uplands consisted of sago-palms and conifers; some of the latter resembled *Juniperus*, *Thuja,* and *Araucaria,* but all were different from living genera. Along the marshy shores grew gigantic equiseta and ferns. Remains of a few sea-weeds have been found, but it is evident that the turbid and turbulent water was not congenial to marine vegetation. The following is a list of the plants which have been identified in the Trias of New Jersey and the Connecticut Valley:

Bajera Munsteriana, Sap.
Brachyphyllum gracile, Newb.
" *foliosum,* "
Cheirolepis Munsteri, Schenk, sp
Clathropteris platyphylla, Brong.
Dendrophycus Triassicus, Newb.
Dioönites longifolius, Em., sp.
Equisetum Rogersi, Schimp.
Loperia simplex, Newb.
Otozamites latior, Sap.
" *brevifolius,* Fr. Br.
Palissya diffusa, Em. sp.
Schizoneura planicostata, Rogers, sp.

Of these all but two have been found in the Trias of Virginia and North Carolina, and prove what was before generally believed, that the age of the rocks under consideration is essentially the same from Massachusetts to North Carolina. Prof. Fontaine has shown that the plants of the Richmond Basin have greater affinity with those of the Rhætic beds of Europe than with those of any other horizon, and has inferred from this fact that the southern extension of our Triassic rocks hold the same position in the geological scale. I am able to give some additional facts which confirm and emphasize this conclusion. At Durham, Connecticut, are found fronds of cycads which are quite undistinguishable from those so common in the Rhætic cf Germany and France, viz., *Otozamites latior,* Sap., and *Otozamites brevifolius,* Fr. Br. With these is a fern which cannot be distinguishes from *Clathropteris platyphylla,* Brong. Hence we may be certain that at least such portions of our Triassic rocks as have yielded plants represent the upper division of the Trias of Europe.

The fishes of our Triassic rocks are all ganoids and belong to six genera, viz., *Diplurus*, Newb., *Ischypterus*, Egt., *Catopterus*, Redf., *Ptycholepis*, Ag., *Dictyopyge*, Egt., and *Acentrophorus*, Traq. Of these *Dipterus* was a large Coelacanth attaining a length of three feet and closely allied to *Holophagus*, Egt., of the English Lias. *Ptycholepis*, *Acentrophorus* and *Dictyopyge* are each represented but by a single species; while of *Catopterus* there are five and of *Ischypterus* eighteen. All the species are distinct from any known in the Old World, but a species of *Ptycholepis* allied to ours, though distinct, is found in the Lias of Boll, Wurtemburg, and a species of *Dictyopyge* has been described from the Keuper of Germany. *Catopterus* seems to be distinct from any genus of fossil fishes found in the Old World, but *Ischypterus* is very near to *Semionotus*, Ag., which is represented by species in both the Lias and Trias of Europe. These genera are indeed so nearly allied that it is somewhat doubtful whether they should be separated. *Acentrophorus*, Traq., is very near to *Ischypterus;* apparently differing from it only by the absence of the spiny scales on the dorsal line. Of this we have only one species, found at Chicopee Falls, Massachusetts.

The following is a list of the fishes found in our Triassic rocks. Fragments obtained in the Richmond Coal Basin indicate the presence there of another and as yet undescribed genus and a large species of *Dictyopyge* different from *D. macrura*, Egt.

Diplurus longicaudatus, Newb.
Ptycholepis Marshii, "
Acentrophorus Chicopensis, "
Dictyopyge macrura, Redf., sp.
Catopterus Redfieldii, Egt.
" *gracilis*, J. H. R.
" *anguiliformis*, W. C. R.
" *parvulus*, "
" *ornatus*, Newb.
Ischypterus Agassizii, W. C. R.
" *ovatus*, "
" *parvus*, "
" *macropterus*, "
" *Marshii*, "

Ischypterus latus, J. H. R.
" *fultus*, Ag.
" *tenuiceps*, Ag.
" *micropterus*, Newb.
" *gigas*, "
" *Braunii*, "
" *lineatus*, "
" *robustus*, "
" *modestus*, "
" *alatus*, "
" *lenticularis*, "
" *minutus*, "
" *elegans*, "

The above facts are quoted from a report "On the Fossil Fishes and Fossil Plants of the Triassic Rocks of New Jersey and the Connecticut Valley," which has been prepared for the U. S. Geological Survey and is now in the hands of the printer.

April 4, 1887.

Regular Business Meeting.

The President, Dr. J. S. Newberry, in the chair.

Seventy-one persons present.

The Report of the Council made the following recommendations:

I. The payment of certain bills.

II. The appropriation of twenty dollars for the purchase of catalogue books for the Library.

III. The election of Vice-Pres. O. P. Hubbard as delegate to represent the Academy at the approaching Centennial Celebration of Columbia College.

IV. The acceptance of the resignation of Mr. J. H. Jackson.

V. The election of the following persons as Resident Members:

Mr. Lucius H. Bigelow,
Mr. Alfred C. Cheney,
Mr. Edward Holbrook,
Mr. Jacob K. Lockman,
Mr. Richard G. G. Moldenke,
Mr. John I. Northrup,
Mr. Isaac L. Rogers,
Henry H. Rusby, M.D.

VI. That the initiation fee be remitted in the case of Mr. Moldenke.

VII. That the Academy appoint a committee of five to confer with other societies of New York and vicinity regarding the formation of a Local Committee to arrange for the meeting of the *American Association for the Advancement of Science.*

The recommendations were severally adopted, and in pursuance of the last one the President was authorized to appoint the Conference Committee.

Mr. Bjerregaard exhibited laumontite from veins in the rocks at Ninety-fifth Street.

Henry H. Rusby, M.D., read a paper :

NOTES OF RECENT TRAVEL ON A JOURNEY FROM LA PAZ TO PARA, THROUGH THE BOLIVIAN ANDES, AND THE VALLEYS OF THE BENI AND MADEIRA RIVERS.

April 11, 1887.

Stated Meeting.

The President, Dr. J. S. Newberry, in the chair.

Twenty-five persons present.

The President announced that he had appointed as the Conference Committee ordered at the last meeting the following members :

Daniel S. Martin, Chairman.
Joel A. Allen,
Nathaniel L. Britton,
Herman L. Fairchild,
John J. Stevenson.

DR. J. J. FRIEDRICH exhibited a variety of minerals, and read

NOTES ON LOCAL MINERALOGY.

Kalinite, a potassa alum with distinct styptic alum taste, occurs as an ingredient of a soft mica schist, which is also rich in fine scales of molybdenite, in a well-kown molybdenite locality, in First Avenue, between Forty-third and Forty-fourth Streets. Some specimens show well-preserved incrustations. Molybdite is also found there.

In an excavation in Forty-third Street, between Third and Second Avenues, I found several specimens of fine crystals of calcite, the faces of which are coated with minute cubes of iron pyrite, producing a beautiful iridescent effect. These specimens contain also crystals of galenite, smoky quartz, and a peculiar yellow crystalline calcite. Galenite has formerly been found, as I was told by contractors, in the tunnelling of the eastern outlet of Forty-second Street. In the same quarry, which abounds in giant gneiss and smoky quartz, I found a fine beryl with a peculiar banded appearance.

Black serpentine occurs in contact with albite and calcite in Ninety-sixth Street, between Lexington and Third Avenues. From the same locality I have some specimens of amianthus.

The excavation in One Hundredth Street, between Third and Lexington Avenues, so rich in magnetite, has in its upper schists, which are characterized by pyroxenites and prochlorite, abundant traces of ilmenite and rutile.

I have from this locality some specimens, containing reddish translucent crystals, which do not resemble rutile, but seem rather to be a magnesium sphene or greenovite.

DR. CHARLES B. WARRING read a paper

ON CERTAIN LAWS OF GYRATING BODIES.

Secular Changes in Nutation their Result.

A gyrating body is one revolving on an axis passing through its centre of gravity, and acted upon by a force—for convenience called herein the second force—tending to make it revolve on another axis at right angles to the first.

The object of the present paper is to demonstrate, experimentally, certain laws or results—not to give their rationale.[1]

Apparatus used.—A rather heavy gyroscope, to one side of whose frame was attached, in line with the axis of the wheel, an arm twelve inches long. By adjusting a weight on this arm, the instrument can be balanced, or either end made the heavier. A hook at the opposite side of the frame permits of readily attaching a weight, or a little pail into which weights can be put. The whole is supported on a fine point a very little above the centre of gravity, and resting in a saucer-like depression, both being of very hard and highly polished steel. This arrangement gives great delicacy and freedom of precessional and nutational movement. The instrument weighs, complete, about six pounds.

I.—A gyrating body, not frictionless, yields to the "second force," *i. e.*, tilts in the direction of that force.

Proof.—I attach a weight to the free end of my balanced gyroscope, and that end falls. Or, if the weight is attached to the opposite end, the gyroscope rises. The experiment may be varied in all possible ways, with the same result.

II.—The tilting becomes more rapid as the "second force" is increased, and *vice versa.*

Proof.—Attach weights of different sizes, and note the time required to tilt, say 40°. It will be seen that the time diminishes as the weight increases.

III.—A frictionless gyroscope will not remain in a horizontal position forever. *Proved in two ways.*

It has been shown that a gyroscope, not frictionless, tilts, or

[1] For what seems to me such, see my monograph on Gyrating Bodies; also for description and drawings of both the instruments used in the experiments.

falls, at a rate varying as some direct function of the downward-pull, or weight, and, inversely, as some direct function of the rate of rotation. Or, calling h the time of horizontality; w, some direct function of the weight; v, a direct function of the velocity of rotation; we have $h \propto \frac{v}{w} - f$, where $f =$ the effect of friction. The only possible effect of f is to decrease h. Hence, when $f = 0$, we still have $h \propto \frac{v}{w}$. Now v and w are independent variables, and direct functions of velocity and down-pull. Hence, h can become infinite only when $v = \infty$, or $w = 0$. The first is impossible; the second is merely saying that a body will stay up infinitely long if no force acts upon it to send it down.

Second Proof.—(1) I remove the friction at the point of suppor by causing it to revolve in the same sense, and a trifle faster than the gyrational or precessional movement. (2) I replace the energy lost by friction at ends of the axle, and by the friction of the air.

The first is easily accomplished by suspending the gyroscope by a twisted cord, whose torsion acts in the same direction as the gyration.

The second is accomplished by an electric motor driven by a small battery.[1] For this purpose a form of Bohnenberger is used, the point of support being in a vertical line passing through the centre of gravity of the wheel. A small horse-shoe electro-magnet is attached to the ring of the instrument, and is rapidly driven by four cells of a Smee's battery. The connections are through very large open cups of mercury in which the connecting wires revolve. The whole is supported by a fine cord about six feet long, the torsion of which is made alternately to aid and to hinder the horizontal rotation. Starting from rest, the wheel quickly reaches a speed at which the loss and gain of energy are equal; and, consequently, the rate of motion on the axis is uniform. It will continue uniform so long as the battery is constant; and, as the experiment occupies but a few seconds, or a few minutes, according to the weight applied, even a bi-

[1] Mr. Geo. M. Hopkins was the first to apply electricity to a gyroscope.

chromate battery, which is said to be constant for only fifteen or twenty minutes, will answer our purpose.

If, while v is uniform, we attach larger or smaller weights, it will be found that here, also, $h \propto \frac{v}{w}$; or, as v is constant, $h \propto \frac{1}{w}$.

Hence, I conclude that a frictionless gyrating body does yield to the "second force."

IV.—If the "second force" be gradually lessened while the instrument is moving horizontally and falling, the latter (the falling) will cease, and the instrument gradually rise to a horizontal position. The horizontal movement will not change its sign, but will gradually grow less, and become zero when the "second force" becomes zero.

Proof.—Let the weight (or "second force") be a cup of shot. When in motion, open (by burning off a thread) a valve in the bottom of the cup; as the shot runs out, the instrument begins to rise. It will go considerably above its starting position.

V.—When in operation, the gyroscope is apparently destitute of momentum.

Proof.—Attach by a thread a weight sufficient to cause rapid horizontal movement, then when in rapid motion burn off the thread: the instrument stops suddenly.

From these we deduce the following laws:

1st. A gyrating body tilts in the direction of the "second force," whether this is uniform or accelerated.

2d. It tilts in the opposite direction if the force is a diminishing one.

3d. When the "second force" ceases, the precessional movement ceases, not gradually, but at the same time.

4th. No tilting, no gyration; or, in other words, no nutation, no precession.

Nutation.

The earth is a gyrating body, and consequently subject to the laws of such bodies.

The "second force" in its case, is the result of the moon's and sun's attraction on the equatorial protuberance, and its effect varies inversely as the cube of their distance, and directly as the sine of their declination.

It requires about nineteen years for the moon to go through a cycle of such changes. There is an increase of its effective pull for about nine and a half years, and a decrease for as many more. The former, by the first law, causes tilting towards the ecliptic; and the latter, by the second law, causes tilting from the ecliptic. This is nutation in latitude; that in longitude is effected in the same way.

The same reasoning applies to solar nutation, but its cycle is only a year.

There is a secular variation in the eccentricity of the earth's orbit, and this generates a secular change in that of the moon. Hence there must be a secular change in nutation. This I pointed out more than two years ago in a paper before Vassar Brothers Institute, of Poughkeepsie.

It is an interesting fact that last summer it was announced in *Nature,* and also, I believe, in *Science,* that M. Folie had discovered a secular change in nutation, and that approximately its period is 30,000 years. It is confirmatory of the view taken in this paper of the physical cause of such variation, that what may be called the present cycle in the earth's orbital eccentricity occupies about the same time. Some past cycles have been much greater. Hence, the secular change in nutation is itself subject to changes; all, however, obedient to one grand law, viz.:

Increase of the "second force" increases the depth of the nutation, while decrease of that force increases its height.

The above laws and their application to nutation are, I believe, new, and, as at present informed, I claim them as such.

Whether they account for all the nutation is a question outside of my present purpose. That change of distance is a real cause seems to me beyond doubt.

NOTE.—A series of experiments on all forms of gyrating bodies performed in my laboratory give the same testimony. A large number of these, with drawings "from life," are published in my Studies on Gyrating Bodies. See Proceedings of Vassar Brothers Institute, 1885. The "Studies," 204 pp., can be had of the writer.

The chief interest in these laws is their bearing upon established beliefs as to these bodies, and the clew which they give, if not to all nutation, at least to that secular change spoken of above.

Dr. Warring presented photographs of the tracings or autograph of a top, with written descriptions.

April 18, 1887.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Eleven persons present.

DR. J. J. FRIEDRICH exhibited serpentine from Fifty-seventh Street and First Avenue.

The PRESIDENT read a list of accessions to the Library.

DR. ALEXIS A. JULIEN read a paper :

THE TRANSFORMATIONS OF IRON DISULPHIDE.

(Illustrated with specimens.)

(Published in the Annals, Vol. IV.)

April 25, 1887.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

A large audience present in the East Lecture Room of the Library Building, Columbia College.

The fourth lecture of the Popular Lecture Course was delivered by DR. CHARLES S. MINOT, on

THE EVOLUTION OF THE HEAD.

(Illustrated with lantern views.)

May 2, 1887.

REGULAR BUSINESS MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Sixty-two persons present.

The Report of the COUNCIL recommended the payment of certain bills, and the election of the following persons as RESIDENT MEMBERS:

MR. W. F. ALLEN,
HON. ADDISON BROWN,
MR. S. VICTOR CONSTANT,
MR. ARNOLD GUYOT DANA,
MR. L. H. JACOBY.

The recommendations of the COUNCIL were adopted and the candidates were elected.

The Secretary made an informal report in behalf of the Conference Committee ordered April 4th, 1887.

The following circular-letter had been printed and sent to scientific, educational, and public institutions in and about New York:

"*The New York Academy of Sciences.*

"*Madison Avenue and 49th Street.*

"The American Association for the Advancement of Science has decided to hold its XXXVIth meeting in New York City during the week beginning August 10th, 1887. It, therefore, becomes the duty and privilege of the scientific and educational institutions of the city and vicinity to provide for the meeting in a manner which shall be creditable alike to themselves and to the metropolis.

"The Academy of Sciences having been asked to take the initiative in the matter, the undersigned have been appointed by the Academy a Committee of Conference to secure concert of action among the several institutions. As the time is brief, we take the liberty of suggesting a meeting of representatives at the Hotel Brunswick, at 8 o'clock, on the evening of Friday, April 29th.

"Will the.................................please appoint delegates to meet at this time and place? And in case the date is too soon for such formal appointment, will not the President or other officers of the institution attend as informal representatives?

"The special work before this conference will be the consideration of ways and means, and the formation of permanent committees which, united, shall constitute a Local Committee for the meeting of the Association.

"This great national gathering of scientists will be an important event in the history of our city, and should mark an epoch in the development of scientific interest in the community. It is highly desirable, therefore, that the Association should find a cordial welcome, and should receive a kind and degree of interest and hospitality worthy of the great metropolis.

"Yours very respectfully,

DANIEL S. MARTIN, *Chairman.*
J. A. ALLEN,
N. L. BRITTON,
H. LE ROY FAIRCHILD,
JNO. J. STEVENSON.

NEW YORK, April 12th, 1887."

In response to this invitation, a meeting of representatives had been held, and the initial steps in organization had been taken.

The PRESIDENT, PROF. J. S. NEWBERRY, described

CŒLOSTEUS, A NEW GENUS OF FISHES FROM THE LOWER CARBONIFEROUS LIMESTONE OF ILLINOIS.

(Abstract.)

Prof. Newberry exhibited jaws, teeth, and bones of this large fish, recently discovered by Mr. William McAdams in the Mountain Limestone at Alton, Illinois. The lower jaw is about one foot in length, an inch and a half in width at the anterior extremity, and widening to four inches behind. It is marked on the upper margin by a series of broad shallow pits for the insertion of comparatively few but large teeth. The teeth are conical, acute, and striated at the base, where they have a convoluted structure like those of *Dendrodus.* A large bone, probably a coracoid, is two inches by one and a quarter in diameter in the centre, expanded at either extremity and must have been originally about one foot in length. Like the jaws, this consists of a thin shell of bone surrounding a large area which was undoubtedly occupied by cartilage. This structure is peculiar and suggested the name *Cœlosteus* (hollow bone) given to the genus. Dr. Newberry said this fish was apparently allied to *Dendrodus* and *Rhizodus,* which had mandibles somewhat similar in form, set with few large teeth implanted in broad, shallow sockets. In *Rhizodus,* however, the dentary bone was segmented, while in *Cœlosteus* it was entire. The specific name given to the new fish was *ferox,* with reference to its formidable dentition.

DR. HENRY H. RUSBY read a paper

FURTHER NOTES OF A SCIENTIFIC JOURNEY ACROSS SOUTH AMERICA, THROUGH THE VALLEYS OF THE BENI AND MADEIRA RIVERS.

May 9, 1887.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the Chair.

Twenty-three persons present.

A list of accessions to the Library was read by the PRESIDENT.

In reply to questions by MR. CHITTENDEN, the PRESIDENT discussed the "Taconic System" of Emmons, and affirmed the truthfulness, in general, of that author's generalization.

The following paper was read by title:

DESCRIPTIONS OF NEW SPECIES OF BIRDS OF THE FAMILIES SYLVIIDÆ, TROGLODYTIDÆ AND TYRANNIDÆ. By GEORGE N. LAWRENCE.

(Published in the Annals, Vol.—–)

MR. GEORGE F. KUNZ read the following papers:

(A.) ON JADE AND JADEITE.

In illustration of this paper a large number of objects were exhibited. *A gigantic jadeite votive adze, from Oaxaca, Mexico,* is described as follows:

This jadeite adze of Mexican origin is, as far as the writer has been able to ascertain, the largest yet found, and is notable not only for its great size, but also for its peculiar character and the excellence of the working in so hard a material. It is said to have been found about twenty years ago in Oaxaca, Mexico. It measures 272 mm. ($10\frac{13}{16}$ inches) in length, 153 mm. (6 inches) in width, and 118 mm. ($4\frac{5}{8}$ inches) in thickness, and it weighs 229.3 oz. Troy. Across the ears 153 mm. (6 inches), across the lower axe end 82 mm. ($3\frac{1}{4}$ inches), height of head to neck 158 mm. ($6\frac{1}{4}$ inches), height from chin to foot 115 mm. ($4\frac{1}{2}$ inches), and the legs 50 mm. (2 inches). The piece removed at the back is 160 mm. (5 inches) long and 50 mm. (2 inches) wide. The color is a light grayish green, with streaks of an almost emerald green on the back. In style of ornamentation it very closely resembles a gigantic adze of granite (57 cm. long and 34 cm. wide) mentioned by A. Chavero in the *Mexico d. través d. Los Siglas,* 1886, p. 64, and has almost an identical counterpart in the avanturine quartz adze now forming part of the Christy collection at the British Museum, and formerly in the possession of Mr. Percy Doyle, of the English Diplomatic Service; differing from these two objects, however, in having no ornamentation on the forehead, and having in addition four dull markings on each ear, and under each eye, and one near each hand, which seemingly could have served no other purpose than to hold thin plates or films of gold, which the polished surfaces would not do. Of the gold used here no trace can at present be seen.

From all appearances, this adze is the result of the shaping of a boulder, since weathered surfaces would only be found on a fragment that had been exposed. The lapidarian work on this piece is probably equal to anything that has ever been found, and the polish is as fine as that produced by modern man.

Of additional interest is the fact, that, although this adze is undoubtedly one of the finest objects which these Aztecs or Mayas possessed, yet they desired to "extend" the material, as it may be termed, as has been described by Dr. J. J. Valentini before the American Antiquarian Society, as to the origin of the Leyden plate, April 27th, 1868, p. 11, and more recently by Prof. F. W. Putnam in his paper before the American Antiquarian Society, new series, vol. 5, April, 1886, on the Central American celts, showing how they had been cut into two and even four pieces.

There have been two fully successful and one partly successful attempts to remove pieces from this object, evidently for the purpose of making other objects (the supply of material being exhausted), and possibly from the wish to bestow on new branches of the same tribe portions of a material which they held as sacred, or to bury the pieces with deceased chiefs. Enough has been cut from the back of the object to equal one-eighth of the entire weight, and the instrument used in cutting it has produced a rounded cut on each opposite side from where the cutting was done, lending credence to the theory that some abrasive was used, such as sand or sapphire, by means of a string held in the hands or stretched across a bow. In the *American Journal of Science* for July, 1882, the writer has described a sapphire pebble found in a brook in Oaxaca, almost equal to that from Ceylon. If they knew of the existence of this sapphire, we can more readily understand how they worked so large a mass of tough and hard material. The material is jadeite, its hardness being 7, in the Mohs' scale.

So far as the writer has been able to ascertain, no similar object of equal magnitude and archæological interest exists. The Humboldt celt, the Leyden plate, the Vienna adze, and the one in the Ethnological Museum at Dresden, which weighs only seven pounds, and is entirely devoid of ornamentation, can scarcely compare with it.

MR. KUNZ exhibited a green jade wedge from New Zealand, evidently used for splitting wood, weighing 7 lbs. and measuring 31 cm. by 9 cm. by 5 cm. in thickness. It had evidently seen considerable wear, and was made from a fragment taken from the exterior of a boulder, as one corner of the chisel edge is broken off on account of its impaired toughness, and the stone here is yellowish-brown, a color to which jade usually weathers in New Zealand. It shows considerable polish on both sides from usage. The sides only were rudely shaped.

MR. KUNZ also exhibited :

Two jade celts from the guano islands ;

Four " " " New Zealand ;

A rude pebble hollowed-out for a snuff-bottle, from China ;

A nephrite from Jordansmühl, Silesia ;

A series of carved jades from China ;

A polished jade from India ;

A series of serpentine chloritic rocks, green basalts, and a series of imitations of jades and jadeite, from Burmah ; casts of the most famous aboriginal jade objects in the European museums, as well as a series of photographs and engravings fully illustrating the subject.

The topic was discussed by DR. PHILIP VALENTINI and the PRESIDENT.

(B) DESCRIPTION OF THE METEORITE WHICH FELL NEAR CABIN CREEK, JOHNSON CO., ARKANSAS, MARCH 27TH, 1886.

The meteorite which I exhibit this evening fell about six miles east of Cabin Creek, Johnson Co., Arkansas, in longitude 93° 17′ W. of Greenwich, latitude 35° 24′ North, within seventy-five yards of the house of Christopher C. Shandy. Mrs. Shandy states that about three o'clock in the afternoon of the 27th of March, 1886, while in her house, she heard a very loud report, which caused the dishes in the closet to rattle and which she described as louder than any thunder she had ever heard. At first she thought it was caused by a bomb-shell, and ran out of the house in time to see the limbs fall from the tops of a tall pine tree, which, she says, stands about 75 yards from her dwelling. She did not investigate the matter until her husband came home about six o'clock in the evening, when in company with John R. Norton, their hired man, they went out to find the cause of the noise that had so startled Mrs. Shandy. They discovered that a large hole had been made in the ground by some falling object, and that the fresh earth had been thrown up to a height of thirty feet on the surrounding saplings and trees. They dug down, and a steam or exhalation arose, which on a dark night might perhaps have produced a phosphorescence similar to that described in the case of the Mazapil iron. The iron had buried itself in the ground to the depth of three feet, and the earth around it to the thickness of one inch seemed to be burned.

The ground was still warm when the iron was taken out, and the iron itself was as hot as the men could well handle. The weather had been quite cloudy all day, but no rain fell until night. These facts are from the affidavits of Mr. and Mrs. Shandy and John R. Norton. Mr. Shandy at first supposed that their find was platinum, then silver, and he finally learned what it really was and sold it. Mrs. India Ford, Dr. W. J. Bleck, Mr. S. A. Wright, Constable, and Mr. L. Wright, Chief of Police, also heard the report caused by the fall.

The noise was heard 75 miles away and was likened to a loud report followed by a hissing sound as if hot metal had come in contact with water. It caused a general alarm among the people, and teams of horses twenty-five miles distant, becoming frightened, broke loose and ran away, and in Webb City, Franklin Co., on the south side of the Arkansas river, a number of bells kept on sale in a store, are said to have been caused to tinkle. Cabin Creek is on the north side of the Arkansas River.

Mr. B. Caraway, who visited the spot for me, informs me that the pine tree through which the meteorite fell is 107 feet high, and that the distance from the foot of the tree to the centre of the hole made by the mass is 22 feet 3 inches. The limbs on the west side of the tree are broken, and the meteorite lay in the hole with the flat side down. The hole was 75 yards from the house.

Professor H. A. Newton, who has kindly interested himself in this matter, says that the data furnished indicate that the mass must have fallen nearly from the zenith. This was the direction of the end of its path, the earlier portion being more inclined to the vertical, as the path must be affected by gravity and the resistance of the air. The earlier direction must have been from the N.E. and more nearly from the East than the North.

This mass is almost an exact counterpart of the Hraschina (Agram), Croatia, iron, the first of the recorded falls. The Agram iron fell in two fragments, one weighing about 40^k and the other about 9^k, the combined weight being about equal to that of the Johnson County iron.

The mass is in general quite flat and very irregular, resembling strongly a mass of molten metal thrown on the ground and then pitted. The illustration of the Agram[1] mass figured by Von Schreibers could be mistaken for the upper side of this, were it not that this is larger. It measures 17½ inches (44^{cm}) by 15½ inches (39^{m}) while the Agram measures 15½ by 12 inches. A high ridge, 5 inches high at the highest point (12.5^{cm}), runs through the centre. One-half of the mass is not over 3 inches (7.5^{cm}) thick, part of it is only 2 inches (5^{cm}), and around the edge it is only one inch or less. It is only exceeded in size among the irons seen to fall by the Nejed, Central Arabia, now in the British Museum, which fell in the spring of 1865, and weighs 59.420 kilos. The weight is 107½ lbs. (48.75 kilos), and is intact with the exception of three small points, weighing not more than two ounces in all, which are broken off.

The two sides are wholly dissimilar. In fact, one would scarcely suppose that they belonged to the same mass. The upper side is ridged and deeply dented, while the lower side is flat and covered with shallow, but very large pittings. On top the color is in many places almost tin-white without any coating whatever, and the pittings are very deep and usually quite long, like finger depressions, made in potter's clay. These depressions measure from 2^{cm} to 4^{cm} and from 1^{cm} to 4^{cm}. This side is remarkable for striæ showing the flow and burning and all running from the centre toward the edge, identical with those in

[1] "Beiträge zur Geschichte und Kenntniss Meteorischer Stein- und Metallmassen," by Dr. Carl von Schreibers, Wien, 1820, folio, plate viii.

the Rowton, Nedagolla and Mazapil irons, but on a larger scale. Some of them are thinner than a hair and yet twice as high (like a high knife-edge), and they are from one to four inches long. In one space of 5^{cm} twenty are arranged side by side, and on one small part which is black, there are 50 lines in one inch of space (25^{mm}), all running in the same direction. Near all the pointed edges the fused metal has flowed and cooled so as to hang like falling water. The striæ and marks of flowing are around the edges of the upper surface. On the under side pittings are very shallow but much broader, one depression, apparently made up of four pittings, being 20^{cm} long and 9.5^{cm} wide. The whole side is coated with a black crust, 1^{mm} thick and having minute round bead-like markings. On one of the indentations of the lower edge the crust has a strikingly fused appearance as if a flame had been blown on it from the other side. In reality this edge is undoubtedly the place where a greater amount of burning took place when the body was passing through the air. Seven small, bead-like lumps, from 5^{mm} to 10^{mm} in size, which are visible on this side, are drops of metal that were entirely melted and flowed and cooled so that they resemble drops of a thick liquid. There are also to be seen what appear to be cracks, 15 in number and nearly as thin as a hair. One of these is 10^{cm} long and extends from the highly fused edge above-mentioned toward the centre. The others are from 3^{cm} to 5^{cm} long. These are so evenly arranged that they are without doubt "Reichenbach lamellen" in which the inner troilite has been burnt out. If such is the case they are as abundant as in the Staunton, Va., meteoric iron.

On the upper side ten nodules of troilite are exposed, measuring from 33^{mm} in diameter to 55^{m} long and 25^{mm} wide. On the lower side there are 12 such nodules exposed, 13^{mm} in diameter, while the largest measures 19^{mm} by 39^{mm}. On the upper side these nodules are coated in spots with a black crust similar to that found on the mass, but on the lower side the crust extends completely around the side of the nodules, showing the fusion very plainly. The troilite is very bright and fresh, like a newly broken mineral, and on the upper side one of the nodules shows deep striation, suggesting that the entire nodule is one crystal and the exposed part is only one side of it. In some cases where the nodules were broken they were found to be iridescent. This is one of the octahedral irons showing the Widmanstätten figures beautifully on etching, and is one of the Caillite group of Stanislas Meunier and of the *mittlere lamellen* of Brezina. The lamellæ are 1^{mm} wide and the markings more closely approach the Rowton [1] and Mazapil irons. The specific gravity of the small piece figured is 7.773. Troilite, as before stated, is very abundant in the mass. Schreibersite and carbon have also been found between the laminæ. Chloride is present only in slight quantity, as scarcely any deliquescence has been observed.

The following is a comparative table of analyses of meteoric irons most nearly approaching this in composition:

	Cabin Creek. (Whitfield.)	Estherville. (Smith.)	Mazapil. (Mackintosh.)	Rowton. (Flight.)	Dickson Co. (Smith.)
Iron	91.87	92.00	91.26	91.25	91.15
Nickel	6.60	7.10	7.845	8.582	8.05
Cobalt	trace	0.69	0.653	0.371	0.72
Phosphorus	0.41	0.112	0.30	.....	0.06
C, S, etc.	0.54				
	99.42	99.902	100.038	100.203	99.98

From the fact that the ridged side is so free from crust and the flat side so thickly coated; that the ridged side is covered with striæ and marks of flowing, and the other has so few marks of this kind; and from the fact that at the edges, especially at the indentation, the back looks as though a flame had come from the other side—from all these facts the writer concludes that after entering our space the iron traveled with the ridged surface forward, the iron burning so rapidly as to be torn off, leaving part of the surface bright. The flame thus passed over the sides, and the indented edge being downward, the flame was driven upward as the iron advanced. On the flat side, not being so much exposed, the iron was not so completely consumed, hence a crust and large but shallow pittings. These conditions

[1] "Meteoriten Sammlung des k. k. mineralogisches Hofcabinet in Wien." 8vo, Wien, 1885, plate 2, figure 2.

would perhaps have been entirely different had the mass been round or thicker, for it evidently moved as straight as possible without rotating at all. That it was found in the hole with the flat side down was due perhaps to the fact that, having lost its impetus, it turned and then fell almost in a straight line.

As the iron only penetrated to a depth of three feet (90^{cm}) the earth where it struck must have been very compact and the force of the body itself nearly spent. The large Agram iron penetrated 14 to 15 feet ($425–450^{cm}$) in a freshly ploughed field, which shows that in the case of that meteorite there must have been considerable force left, the small mass falling very near it. The Mazapil mass, one-tenth of the weight, penetrated only 12 inches (30^{cm}).

Remarks were made by PROF. D. S. MARTIN.

May 16, 1887.

STATED MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Fifty persons present.

The PRESIDENT exhibited a copy of the "HISTORY OF THE NEW YORK ACADEMY OF SCIENCES, *formerly the Lyceum of Natural History*," published by the RECORDING SECRETARY, and remarked upon the character and historical value of the work.

The book contains the following

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ILLUSTRATIONS.

Portraits.

John S. Newberry, John B. Beck, James E. De Kay, Charles A. Joy, Samuel L. Mitchill, Joseph Delafield, John Torrey, William Cooper, Robert H. Brownne, William C. Redfield, Benjamin N. Martin, Asa Gray, Charles M. Wheatley, Thomas Bland, John C. Jay, John H. Redfield, Robert Dinwiddie, Thomas Egleston, Alexis A. Julien, John H. Hinton, H. Carrington Bolton, Albert R. Leeds, Daniel S. Martin, Oliver P. Hubbard, Louis Elsberg, William P. Trowbridge, Herman L. Fairchild.

Buildings.

College of Physicians and Surgeons in Barclay Street, New York Institution, New York Dispensary, the Lyceum Building, Stuyvesant Institute, University Medical College in Fourteenth Street, Hamilton Hall.

Dr. Henry H. Rusby read a paper:

CONCLUDING OBSERVATIONS IN A SCIENTIFIC JOURNEY ACROSS SOUTH AMERICA, FROM THE ANDES TO THE MOUTH OF THE AMAZON.

May 23, 1887.

Stated Meeting.

First Vice-President, Prof. Oliver P. Hubbard, in the chair.

A large audience present in the East Lecture Room of the Library Building, Columbia College.

The fifth lecture of the Popular Lecture Course was delivered by Prof. W. P. Trowbridge.

THE DEVELOPMENT OF BRIDGE-CONSTRUCTION, WITH NOTICES OF SOME REMARKABLE HISTORIC BRIDGES.

(Illustrated with the magic lantern.)

In works of engineering generally, unlike those connected with the fine arts, there is little to be learned from the ancients. We are surrounded on all sides by structures of a purely engineering character, which could only have been devised and executed in modern times, and for which antique models do not exist. There are certain elements, however, of these structures which belong to all ages, since they are but the practical applications of simple mechanical laws in which boldness of conception and design, simplicity and taste in construction, and perfect adaptability to their uses and objects, exhibit the intellectual condition of the people by whom such structures have been erected.

It may be said that properly constructed lines of land travel are both causes and effects of civilization. The common road and the railway, pushing out beyond the boundaries of populous districts or penetrating uninhabited wildernesses, are sure to be followed by an advancing tide of emigration, while the introduction and maintenance of thoroughfares, more complete and permanent in their construction than was at first practicable, is an indication of increasing thrift, culture, and refinement on the part of the people.

The famous engineer, Telford, who constructed many hundred miles of good turnpike roads in England and Scotland under special acts of Parliament, expressed the opinion or belief that these roads had advanced the communities of the districts through which they passed, one hundred years in civilization.

The construction of a line of land travel involves, of course, numerous bridges, rude and cheap in primitive times, but exhibiting elements of a more permanent character and more pleasing architectural features as a country advances in wealth and education. There are few architectural structures which more truly indicate intellectual cultivation and general prosperity than the bridges found along the lines of intercommunication.

It is certainly true in our own day that a district in which streams are crossed only by fording is either sparsely populated, or else occupied by ignorant, unthrifty, and improvident communities. The energy, the talent, the means of surmounting material obstacles, are in such cases wholly or partially wanting, while, on the other hand, where wealth is accumulated and science and the arts are fostered, the bridge, in beauty of design and workmanship, is often the most significant expression, not only of the skill and genius of a people, but of their refinement and taste.

It is unfortunate in this latter respect that the necessities of railway traffic in modern times have caused the introduction of forms and modes of construction in iron, scattered everywhere throughout civilized countries, which mar the most delightful landscapes, and which contain no lines of grace perceptible to any one, except the engineer who may claim to find beauty in every structure which fulfils its object. He only knows how much of intellectual labor the uncouth skeletons which carry our railway trains safely across the widest chasms, have cost in the efforts that have been required to design and adapt them to their uses.

An English writer on the subject of bridges in discussing, forty years ago, the designs of American timber bridges, although compelled to give them the pre-eminence, applied to them the remarkable criticism (because they were boxed in or covered on the sides and top to preserve them from decay), that they "looked like coffins for sea-serpents."

If this curious criticism be in any way applicable, it might be said now that the coffin has been removed and the skeleton, transmuted into iron, exposed fully to view.

It would appear to be not only difficult, but, in the eyes of many, a violation of constructive art, to attempt to give the same pleasing appearances to most modern systems of iron bridges that are easily and naturally embodied in bridges of stone; and although the present is the age of iron, yet it is to be hoped that the stone bridge, once the pride of the great engineers of history, may not be given up and forgotten, but that it may be reintroduced, whenever circumstances may allow, in order that it may again add beauty to our landscapes, even in rural districts and outside of the limits of ornamented parks and pleasure-grounds, to which it has in modern times been mostly confined.

It should not, however, I think, be considered impossible to add to the skeleton structures in wrought iron, which are now met with at every turn, and which are constantly being multiplied, simple architectural adjuncts to relieve their uncouth appearances. In one instance, at least, this has been done in this country with marked effect, though the conditions under which the structure was built were certainly unusually favorable in this respect. I allude to the Girard Avenue bridge in Philadelphia, designed and built by the Phœnix Bridge Company, a wrought-iron bridge, which has called forth from many a traveller from foreign lands expressions of delight on account of the architectural elegance of its design.

The history of the development of the art of bridge construction is marked, to a certain extent, by periods or eras coincident either with the introduction of new materials in the arts, or with the necessities which have arisen for compassing greater spans under conditions of heavier traffic. The suspension bridge, of very ancient origin, has held its place, though to a limited extent, until our own time, when its place is likely to be usurped, to a great degree, by the cantilever. Built in primitive times, with cables of organic material, the introduction of wrought iron and of iron wire furnished facilities of construction and elements of durability and strength which the older suspension bridges did not possess, and the great bridge between this city and Brooklyn may be regarded as the culmination of this system, and perhaps the most remarkable example which the world is destined to see; there being inherent defects of the system, which render it inapplicable to rapidly moving heavy loads, which will always be a sort of bar to its general use.

The reverse of the suspension bridge, the arch, of all systems has held the most universal sway, until the long spans met with in the routes of railway communication, and the difficulties of establishing numerous piers in swift currents and on treacherous foundations, brought about, first, the long-span timber bridge, and subsequently, the modern structures in wrought iron, which have become so common in our times. The history of the arch in bridge construction extends from a period further back than the beginning of the Christian era to the present day; but the days when great engineers like Perronet, Nimmo, Telford, Rennie, and others, could acquire fame by building chaste and beautiful arch bridges of stone masonry seem, unfortunately, to have passed.

One of the largest and most picturesque structures of this kind in the world, unsurpassed in many respects by the most famous arches of history, constitutes a part of the Potomac Aqueduct, near the city of Washington. This magnificent structure, called the Cabin John Bridge, erected by General M. C. Meigs, of the U. S. Army, will probably remain the most conspicuous memorial in this country of a system which, for highways and railways, is gradually being replaced by iron.

Cast-iron arch bridges were first introduced a little over one hundred years ago in England, and for a time met with marked public favor. The facility with which cast iron lends itself to the introduction of minor decorations in forms and mouldings enabled bridge architects to present a great variety of pleasing designs, and numerous bridges were constructed about the beginning of this century which attracted much attention. It has been claimed that Thomas Paine, whose name has been preserved in history only through his atheistical writings and doctrines, was the inventor of the cast-iron arch bridge. This claim is, however, not well founded, inasmuch as this kind of bridge was already in use in England before Paine sailed from America with the object of carrying his plans abroad, where he thought they might be favorably considered.

The cast-iron bridge had, however, but a brief historical record. The want of sufficient elasticity, the imperfection of castings, and the liability to rupture under certain strains or blows, have caused cast-iron to be thrown out of the catalogue of available materials for the principal elements of bridges of any considerable importance.

Of timber bridges it may also be said that they have had their day and have fulfilled their temporary uses. When railways were first introduced, about the end of the first quarter of the present century, the necessity of providing bridges along their routes, of longer span and cheaper construction than could be furnished in stone, led to a more critical study in the use of timber for bridges than had ever before been bestowed on the subject. Previous to this, however, many noted bridges had been built, which were masterpieces of work in timber, and which have preserved to history a few names which will always be remembered in connection with the noble art of carpentry—an art now, for various reasons, in its decline. Among these names that of Ulric Gruebenmann, who built the famous bridge over the Rhine at Schaffhausen toward the end of the last century, and the name of Timothy Palmer, of Newburyport, Mass., will always be prominent. The timber highway bridges of the latter in this country were models of scientific, practical, and mechanical workmanship. The Schaffhausen bridge stood alone as a great work, in which the inherent principle of construction was the arch, combined with the elements of the common roof, but it brought into use no new principle, and had no elements which might cause it to be reproduced or copied.

Another name destined to a more substantial and enduring fame in connection with timber bridges is that of Ithiel Towne, for many years before his death an architect of New Haven, Conn. Two or three miles out from New Haven there is a covered bridge spanning a narrow part of Lake Whitney, which, in connection with the subject which we are discussing, has an interesting history. This bridge, which is called the Towne Lattice Bridge, although presenting in itself no artistic feature, being entirely covered in, and being, in fact, the first of the bridges which on this account was sneered at by the eminent English writer referred, to as looking like "a coffin for a sea-serpent," is nevertheless the central feature of a limited but charming little landscape, and to the people of New Haven who know its history is the chief object of interest in this particular spot. Few persons, however, are aware of the fact that the mechanical design of this bridge was the first departure from the principle of the arch and the suspension principle ever attempted; and that it is, although constructed entirely of timber, without a nail or a spike except those used in the board covering, the prototype of nearly all modern constructions in iron which have of late years become so numerous, and which are classified as braced girders. This bridge was devised and erected by Ithiel Towne, about the year 1823, for the New Haven and Hartford Turnpike Company, across the Mill River. It is 100 feet long, fourteen feet wide, and twelve feet high, and is built on the principle of straight top and bottom chords, connected by diagonal bracing; a principle invented by Mr. Towne and never before introduced into bridge construction.

About the year 1840, Mr. Eli Whitney, of New Haven, who was then constructing the dam and reservoir on Mill River, which now supplies New Haven with water, removed this bridge bodily on skids from the point where it was first erected to the place it now occupies, about half a mile distant—a difficult feat of engineering, but accomplished without removing or displacing a single timber of the bridge. The bridge is thus probably the oldest timber bridge of any considerable span in this or any other country, having fortunately escaped the fate of nearly all large timber bridges—destruction by fire.

The principal parts have never been renewed, and, thanks to the board covering, these parts are still sound and serviceable.

I have dwelt at some length on the history of this particular bridge, because the interesting feature of its construction was the employment of an entirely new principle in bridge construction which, by mere change from timber to wrought iron and steel, has been followed ever since. Details have changed, the modifications giving rise to various types as they are known at the present day, but the fundamental principle has been almost universally adopted in all countries, and remains unaltered.

The tubular bridge, a later design, of which the famous Menai Bridge, erected by Stevenson and Fairbain across the Menai Straits, is the most conspicuous example, has had no important development, skeleton structures being now universally preferred.

The latest advance in what some would perfer to call the "evolution" of the bridge, is the cantilever system. Though designs were made, and the system strongly urged upon the engineering profession of this country nearly twenty years ago, for spans exceeding the possible limits of the straight girder, yet it was not until Mr. C. C. Schneider designed, and the Central Bridge Works, of Buffalo, constructed, under his supervision, the Niagara Cantilever Bridge, that the merits of this system for very long spans became fully appreciated.

The system has spread with great rapidity since the Niagara Cantilever Bridge was completed, the Forth Bridge, now being erected in Scotland on this principle and destined for railway traffic, having the extraordinary span of seventeen hundred feet, a greater length than that of the New York Suspension Bridge.

A cursory glance at the development of the art of bridge construction thus reveals a series of interesting facts:

First—That masonry arch-bridges, from their simplicity, elegance, permanence, and strength, have in all ages been the most favored forms of construction for highways, and that the use of iron and steel has in no way changed this popular favor, except where the employment of these materials is either favorable to economy or to the introduction of larger spans. For railway-bridges, other considerations favor also the use of iron and steel over the use of stone.

Second—The introduction of cast-iron arches, though favorable to architectural elegance of design, has not resulted in any permanent useful developments.

Third—Timber bridges have in all ages been regarded as temporary structures which were to be replaced sooner or later by others more permanent in character.

Fourth—The springing up and immense development of the railway systems of the world within the last sixty years, and the concurrent progress made in the metallurgy of iron and steel, have given rise to entirely new problems in bridge building and to a new branch of the engineering profession.

Fifth—The demands of railway traffic for direct lines which must surmount every obstacle either by tunnels or bridges, the heavy weights transported, and the great speed of trains required, have diverted, for a time, public interest from the highway; formerly, in the time of the old stage-coach, the source of many peculiar delights to the traveller.

We are now rattled over bridges and whirled through tunnels at a speed which precludes more than an unsatisfactory glimpse of the scenery which seems to flit by us; comfort, safety, and speed fill the measure of our expectations. But the change has caused our highways to be neglected, and even in the great thoroughfares which lead out from our cities and towns the iron bridge seems to have driven out the more beautiful and durable structures in stone, which ought here, at least, to occupy their proper places. There is no internal improvement more imperatively demanded in this country at the present time than systematic reconstruction and maintenance of our highways.

Viewed as intellectual and mechanical achievements, however, the great bridges of modern times are to be classed with steamships, locomotives, and pumping-engines, which could not have been suggested a hundred years ago by the most vivid imagination. They are triumphs of science rather than of art, and as such we should, perhaps, be content to look at them; deriving our interest from cold, unimpassioned reflections upon the thought, the genius, and the skill which have produced them, rather than from any such pleasing emotions as arise when we look upon some of the works of the same kind of the older bridge architects.

Famous Bridges.

The most ancient bridges of which we have any precise knowledge were built by the Romans, all those of a permanent character having been arched masonry bridges. It is certain, however, that such bridges were built in China many centuries ago, but of their history little is definitely known.

Of the Roman bridges, that erected by Trajan across the Danube is said to have been the most magnificent. It consisted of nineteen arches, each 170 feet span, the piers rising 120 feet above the foundations. The width of the bridge was 60 feet, and its total length 1,500 feet. This bridge was destroyed by the immediate successor of Trajan, Hadrian, for fear that it might afford an easy passage for the barbarians into the Empire. Some of the piers are still to be seen, however, near the town of Walkel, Hungary.

The next considerable work of this kind built by the Romans is the Pont du Garde, which is still standing.

It served the double purpose of a highway bridge over the Gardon and an aqueduct for supplying with water the town of Nismes in the south of France. The bridge is a triple arcade, the lower tier of arches having a total length of 660 feet, and supporting a second tier of eleven arches of 780 feet, and on these is supported a third tier 850 feet in length. This brings the structure up to the level of the aqueduct, which rests on the third tier of arches. This extraordinary structure is built of very large stones put together without cement and held together by iron clamps. The whole height is 190 feet above the river.

Another Roman bridge over the Tajo at Valenza, about 25 miles from Madrid, 679 feet in length, and consisting of only six arches, was built at the time of Trajan. It is now standing, but not used.

A single arch near the old town of Brionde, in France, having a span of 181 feet, and which is said to be still standing, is attributed to the Romans.

Another bridge, 2,400 feet in length, near Lyons, in the south of France, was also erected by the Romans.

Among the later Roman arched bridges may be mentioned the Devil's Bridge over the Serchio, Italy, which is, in some respects, the most remarkable in the whole history of stone bridges, being only twelve feet wide between the parapets, and spanning a stream in which the floods rise sometimes nearly to the crowns of the arches, and yet, while every other structure on the turbulent Serchio has been swept away, this bridge has withstood the floods of nearly nine centuries.

The bridge of Trezzo, built in 1380 by Bernabo Visconti, Duke of Milan, consisted of a single arch of granite of 251 feet span, the largest stone arch probably ever erected. It was destroyed by Carmagnola 120 years after its erection.

The aqueduct bridge of Alcantara, near Lisbon, begun 1713, and finished in 1732, consists of thirty-five arches of various dimensions, the largest having a span of 108 feet.

The bridge of Neuilly, which crosses the Seine, built between the years 1768 and 1780 by the famous Perronet, is considered one of the most beautiful of existing bridges. It consists of five equal arches of 128 feet span each, each arch being composed of eleven arcs of circles of different diameters, the resulting effect being a curve in appearance like an ellipse, but even more pleasing to the eye than an ellipse.

In England the oldest bridge remaining entire is the bridge of Croyland, in Lincolnshire. It was erected about the year 860.

The first bridge over the Thames was of wood, built in the reign of Ethelred II., about the year 1000.

The Old London Bridge was begun in 1176, under Henry II., and finished in 1209. The length was 940 feet, the height 44 feet, and the width between the parapets 47 feet. It was hardly much more than a wall of stone thrown across the river, a few openings being left for the passage of the waters of the Thames, half the water-way being taken up by the piers. It was extensively repaired and altered five hundred years after its erection, and in 1823, the obstruction which it offered to traffic on the river having become the subject of persistent and loud complaints, this bridge was removed and the New London Bridge erected in its place by Mr. John Rennie. The new bridge was placed near the site of the old bridge, and is formed of five semi-elliptical arches, the least of which is larger than any elliptical arch ever before erected.

The Westminster Bridge over the Thames was constructed by a Swiss Engineer, Mr. Labalye. It is 1,220 feet long, and consists of thirteen large and two small arches. It was opened to the public in 1750.

Blackfriars Bridge, also one of the London bridges, was built by Mr. L. Mylne, between the years 1760 and 1771. It is 999 feet long and consists of nine elliptical arches.

The Waterloo Bridge across the Thames, nearly midway between the Westminster and the Blackfriars bridges, is, perhaps, the most magnificent structure of its kind in Europe. It was built by Mr. Rennie, and is composed of nine elliptical arches, each having a span of 120 feet. Its length is 1,380 feet.

The first cast-iron arched bridge was built across the river Severn at Colebrookdale, England, by Mr. Darby, in 1779. Some years later Thomas Paine made preparations for erecting a similar bridge at the same place, according to plans which he had prepared in this country, and caused his bridge to be erected for exhibition in a meadow near Colebrookdale, but having no funds to erect the bridge across the Severn, it was removed from the meadow and parts of it used for a bridge over the Wear in 1793.

Vauxhall and Southwark bridges over the Thames were of cast iron. The latter, built by Mr. Rennie, was composed of three cast-iron circular arches, the central arch having a span of 250 feet. Ten years were occupied in its construction.

Iron suspension bridges were constructed in Europe as early as 1615, but this class of bridges had already existed in Asia, Africa, and America at much older dates. The Spaniards found a suspension bridge in Peru, built by the fifth Inca, the cables, four in number, being composed of vegetable fibre, and the floor made of rushes. This bridge was systematically repaired every six months and remained standing and in use up to a very recent date.

Telford constructed a suspension bridge across the Menai Straits, of 560 feet span, which at the time was regarded as a great achievement. All suspension bridges of the Old World are, however, insignificant in comparison with the great bridge, beautiful in design and appearance, as well as magnificent in its proportions, erected by Mr. Roebling across the East River between New York and Brooklyn.

In timber bridges, America has taken the lead of all other countries, the only structure in Europe comparable with the great timber bridges built in this country during the early part of this century being the Schaffhausen and Wittengen Bridges across the Rhine, built by Ulric Grubenmann. A stone bridge that had spanned the Rhine at Schaffhausen having fallen, a model of a wooden bridge to supply its place was presented by Grubenmann, and accepted. This extraordinary work was completed in 1758. The length of each span was 364 feet. It was destroyed by the French in 1799.

Another famous bridge of timber, called the Colossus of Fairmount, was erected over the Schuylkill, at Philadelphia, by Louis Wernwag, towards the close of the last century. It had the form of a very flat arch, having a span of 340 feet. Its slender, graceful appearance was much admired. Fannie Kemble, in her journal, compared it to a "scarf rounded by the wind and flung across the river." It was destroyed by fire in 1838.

Timothy Palmer, of Newburyport, Mass., built several notable bridges, one of which crossed the Schuylkill at Philadelphia. The construction was a combination of king-posts and bracing with the arch. Another was built across the Piscataqua River about seven miles above Portsmouth. Both these bridges received extended notices in both American and foreign journals.

Among the architects of notable timber bridges during the early part of the century appear the names of Burr, Towne, Long, and Howe—Long and Howe having followed Towne, and produced modifications of his truss to which their names have since become attached.

Towne's truss was such a remarkable and important improvement—the application, in fact, of a new mechanical principle in bridge building—that it was immediately extensively copied, the most important example being the bridge erected across the James River at Richmond, built by Mr. Moncure Robinson. The total length of this bridge was 2,900 feet. It was supported on eighteen granite piers at distances apart varying from 130 to 150 feet, the total cost being about $100,000. Other bridges on the same principle were built, one across the Susquehanna 2,200 feet, with span of 220 feet; another at Nashua, N. H.; at Newburyport, Springfield, Northampton, Philadelphia, Trenton; one near New York, another near Troy, and many others in the Southern and Middle States.

These bridges have nearly all disappeared, wrought iron having taken the place of timber, while the principle of Towne is still preserved in new constructions.

Of wrought-iron bridges it is hardly necessary to treat at this time, since they belong to our own period, and are the work of engineers of our own day.

May 30, 1887.

No meeting held.

June 6, 1887.

REGULAR BUSINESS MEETING.

The President, DR. J. S. NEWBERRY, in the chair.

Thirty-four persons present.

The report of the COUNCIL recommended the payment of certain bills, and the making of certain appropriations.

Verbal reports were made by several officers and committees.

Several minor items of miscellaneous business were acted upon.

MR. W. A. J. SIEBERG read a proposition from the *New York Mineralogical Club* asking to be received into the Academy as the mineralogical section. The proposition was favorably received and was referred to the COUNCIL.

It was voted that when the meeting adjourned, it should be to meet in August, at the call of the President and Secretary, during the session of the American Association for the Advancement of Science.

The PRESIDENT, PROF. J. S. NEWBERRY, exhibited

A NEW METEORITE FROM TENNESSEE.

(Abstract.)

This is an entire metallic meteorite, which he had received from Dr. A. R. Ledoux, to whom it had been sent from Knoxville, Tenn. It was found on the Cumberland Mountains. It had evidently been exposed to fire and was considerably weathered, for the coarse crystalline structure, such as produces Widmanstätten figures on etched surfaces, was very plainly revealed. No analysis has yet been made of this meteorite, but it undoubtedly contains 90 per cent or more of metallic iron. A more complete description will be given when it is analyzed and cut.

MR. GEORGE F. KUNZ exhibited and described

A METEORITE FROM POWDER MILL CREEK, TENNESSEE.

(Abstract.)

During March, 1887, Col. T. B. Sublet, United States engineer, formerly of Frankfort, Ky., and Mr. W. B. Lenoir, visited the farm of Elihu Humber at Powder Mill Creek, about eight miles west of Rockwood Furnace on the eastern slope of Crab Orchard Mt., latitude 35° 50′ north, longitude 84° 45′ west of Greenwich, in Cumberland Co., Tennessee (Rockwood being in Roan Co.). Mr. Humber showed them what he believed to be a piece of iron ore, and the two gentlemen decided to divide the mass. Col. Sublet took off over 2,000 grams, which were sent to me through the kindness of Mr. Moritz Fischer, of the Kentucky Geological Survey, who suspected its meteoric origin, and intended to forward the whole mass subsequently. I was informed that the weight of the mass was about 100 lbs., and that it measured 15 × 10 × 9 inches. It belongs to the syssideres group or lithosiderites and polysideres, of Daubrée, and logronites, of Stan. Meunier. It also resembles very closely the Hainholz, Westphalia, 1856,[1] and also the Newton Co., Arkansas iron,[2] now the Taney Co., Missouri. It is scarcely distinguishable from the latter by the eye, though in the latter the grains are larger and more readily defined.

The specific gravity of a piece was found to be 4.745.

On action with nitric acid, this iron develops Widmanstätten figures very similar to those of the Estherville, Io., iron.

Mr. J. Edward Whitfield, of the Geological Survey, had made a very full analysis of the iron, consequently another was not deemed necessary.

Chloride of iron (laurencite) is present in considerable quantities, and on a number of sections which had been cut and

[1] Pogg. Ann., 1857, vol. 100, p. 342.

[2] Am. Journ. Sci., Ser. 2, vol. 40, p. 213. Sec. Rep. Geol. of Ark., 1860, p. 408.

polished, it was perceptible within a short time. It collected in small beads on the piece itself, and will undoubtedly lead to a rapid disintegration unless the iron is coated with varnish or some other preservative. Even small fragments have already become seamed, suggesting that the fall is evidently very recent.

Microscopic sections were prepared, and in the ground-mass of metallic iron were seen clear crystals of anorthite and olivine. The former are quite pellucid, with inclusions of glass having fixed gas bubbles, and of many needle-shaped microlites and some of larger size. The former microlites are probably enstatite, while some black quadratic sections may be chromite or magnetite. The twin bandings of the anorthite are quite sharp and distinct. The olivine crystals have greenish, brownish veins of alteration (perhaps induced by the laurencite), with inclusions of glass, microlites, and an abundance of black grains of picotite. These grains are occasionally arranged symmetrically around the crystal as a border, outside of which is usually a grayish, partly opaque mass between the crystal and the metallic iron. This grayish mass is an alteration of the olivine, which in many cases has taken place in the entire crystal, and in others has left only a small centre of clear olivine.

To Dr. O. W. Huntington and Mr. J. H. Caswell the writer is indebted for suggestions, and to the latter for microscopical determinations.

The PRESIDENT described some features of the Iowa coal fields which he had observed on a recent visit.

Remarks were made by several members upon the preparations for the New York meeting, in August, of the *American Association for the Advancement of Science.*

August 15, 1887.

SPECIAL BUSINESS MEETING.

Meeting called by the COUNCIL, under order of the meeting June 6th, 1887, for the purpose of giving welcome to the *American Association for the Advancement of Science.*

The President, Dr. J. S. Newberry, in the chair.

The audience filled the large Hall of the Library of Columbia College.

The Report of the Council recommended:

(1) The appropriation of a sum, not exceeding one thousand dollars, to defray the cost of the meeting, with the reception and collation, held in honor of the *American Association for the Advancement of Science.*

(2) The election of the following persons as Corresponding Members:

Prof. Henry Drummond, of Glasgow, Scotland.

Sir John Thurston, Gov.-Genl. of the Fiji Islands.

Mr. Thomas Webber, of Kellyville, Ireland.

Cavre. Sebastiano Fenzi, of Florence, Italy.

La Princesse Héléne Koltzoff Massalsky, of Florence, Italy.

The recommendations were adopted, and the candidates elected.

Prof. D. S. Martin spoke as follows upon

A MONUMENT TO J. J. AUDUBON.

There is a matter which it seems eminently fitting to bring before the Academy for consideration, and I trust for action in some form; and that is in regard to the grave of our great ornithologist, John J. Audubon, and the proposal to erect a suitable monument to his memory. Audubon is buried in an old family vault in Trinity Cemetery, at the southwest corner of the grounds, 153d street and North River. The spot is remote and inconspicuous. Furthermore, some street openings are likely to run close to the vault, and interfere with it. Under these circumstances, the trustees of the cemetery have very kindly offered the representatives of the family a plot of ground in a choice position, at the head of what is to be known as Audubon avenue. The proposal has been made that the naturalists of the country, who owe so much to the early and enthusiastic labors of Mr. Audubon, should unite in a subscription to provide a handsome and suitable monument to mark this spot. It is peculiarly fitting that the New York Academy of Sciences should bear a part in this movement, one which is so suitable in itself, and which appeals so strongly to both scientific and local pride in one of the greatest naturalists of our country.

The PRESIDENT, PROF. J. S. NEWBERRY, read the following paper:

DESCRIPTION OF A NEW SPECIES OF TITANICHTHYS.

(Illustrated with diagrams and drawings.)

(Abstract.)

Some years ago, Mr. Jay Terrell found in the Cleveland shale—base of the Carboniferous system—at Sheffield, O., the cranium of a very large fish allied to *Dinichthys*. Drawings of this fish were exhibited at the meeting of the American Association in Montreal, in 1882, and it was subsequently described in the *Geological Magazine* with the name of *Titanichthys Agassizii*.

Of this species, the cranium is somewhat triangular in outline, and four feet eight inches broad at the occiput. The mandibles of this fish were long, slender rods, gently bent upward at the anterior extremity, and there excavated in a deep furrow, apparently for the reception of some kind of dental organs.

Recently, Dr. William Clark, of Berea, O., has found in the banks of Rocky River, near his residence, a second and still larger species of *Titanichthys*, which I have named, from its discoverer, *T. Clarkii*. Several skeletons, more or less complete, were obtained by him, all of which have been kindly submitted to me for examination. From the more full and complete description of these interesting remains, which I have prepared for the U. S. Geological Survey, I take the following brief notes.

The cranium is broadly triangular in outline, five feet or more between the posterior lateral angles. It is concave behind, and the central point of the arch is marked by a broad depression similar to that in *Dinichthys*. The post-temporal plates are articulated with the cranium as in *Dinichthys*, but by a very different joint. In the last-mentioned genus, a conical socket is vertically excavated in the posterior lateral angle of the cranium, into which a thimble-like condyle, projecting from the anterior margin of the post-temporal, is fitted. In *Titanichthys,* the condyle of the post-temporal bone is horizontal and broad, and is clasped in a furrow at the angle of the cranium. The post-temporals are a foot and a half wide, and, as in *Dinichthys,* are overlapped by the clavicles below and by the dorso-median plate above. This plate is subcircular in outline, and has a long, slender, furrowed process, projecting backward and downward. Like all the other bones of *Titanichthys,* it is much thinner than in *Dinichthys.* The suborbital bones are ovoid, pointed anteriorly, with a broad but shallow excavation above; they are eighteen inches in length. The mandibles are three feet long, the posterior end spatulate, six inches wide, and turned downward instead of upward, as in *Dinichthys.* The anterior end is turned up like a sled runner, and is excavated in a deep furrow somewhat as in *Titanichthys Agassizii,* but the whole jaw is much heavier and broader. The under side of the body was protected by a triangular plate three feet long and nearly as broad, having a deep sinus posteriorly and a rounded projecting angle near the middle of either side. In honor of the discoverer, this great fish has been named *Titanichthys Clarkii.*

PROF. HENRY DRUMMOND, F.R.S.E., F.G.S., of Glasgow, delivered a lecture, entitled:

THE HEART OF AFRICA.

MR. GEORGE F. KUNZ exhibited and described polished sections of

JASPERIZED AND AGATIZED WOODS FROM ARIZONA.

At the meeting of the ACADEMY on October 5th, 1885, the writer described jasperized and agatized woods of Arizona, and called attention to the magnificent colors and the remarkably large sections of trees, which, to all appearances, would furnish art objects such as had never been seen before, and it was suggested that possibly perfect sections could be produced from two to three feet in diameter. Until very recently, however, it has seemed as if, although the material might exist, it would be impossible to have art so assist nature as to show all its beauties.

After many attempts both here and abroad, the task of polishing such large sections was about given up; but American ingenuity and perseverance have at last conquered this hard material, and we have here to-day the finest sections of silicified trees that have ever been seen—finest not only for their beauty of coloring and polish, but also for their large size.

The following objects are exhibited: One column cut transversely across the tree, so that the heart is visible on two sides of the column, the rings radiating from it in all directions. It is $11\frac{1}{4}$ inches wide and 21 inches high, and is a most remarkable piece of lapidary work. Five sections, measuring 25, $19\frac{1}{2}$, 24, $17\frac{1}{2}$, and 13 inches respectively in diameter, with such a high polish that when turned with the back toward the light a perfect mirror is formed. The color of all is unsurpassed. They were cut by a gang of seven saws, and polished on wheels 14 feet in diameter, at Sioux Falls, Dakota, the power being furnished by water from the falls.

Mr. Kunz also showed a cast of the meteorite from Cabin Creek, Arkansas, which he had exhibited and described at the meeting of May 9th, 1887. He stated that this meteorite had been sent to the National Museum, and under the careful supervision of Prof. F. W. Clarke a most perfect cast had been made. So perfect is the copy that, in appearance, it is scarcely distinguishable from the original.

The President announced that, following adjournment, the Academy would give a reception in honor of the *American Association for the Advancement of Science,* and that a collation would be served in the basement of the building.

The Secretary made some announcements in behalf of the American Association.

Adjourned to the first Monday evening in October.

LIST OF EXCHANGES.

The following Societies and Institutions exchange publications with the Academy.

(The number following each title indicates the position of the the publication on the shelves of the library. Members of the Academy desiring to consult any of these works are requested to cite the title *and number*, as this will save loss of time in searching or consulting catalogues.)

N. L. Britton,
Librarian.

North America.

United States.

The New York State Library, Albany, N. Y. 027.

The New York State Museum of Natural History, Albany, N. Y. 507.

Amherst College, Amherst, Mass. 378.

The University of Michigan, Ann Arbor, Mich. 378.

U. S. Naval Academy Library, Annapolis, Md. 027.

The Biological Laboratory, Johns Hopkins University, Baltimore, Md. 507.

The University of California, Berkeley, Cal. 378.

Blue Hill Meteorological Observatory, Blue Hill, Mass. 551.5.

The Boston Society of Natural History, Boston, Mass. 506.1.

The Ornithologist and Oölogist, Boston, Mass. 598.2.

The Boston Public Library, Boston, Mass. 027.

The Brooklyn Library, Brooklyn, N. Y. 027.

The Long Island Historical Society, Brooklyn, N. Y. 906.

The Brookville Society of Natural History, Brookville, Ind. 506.1.

Bowdoin College, Brunswick, Me. 378.

The Buffalo Historical Society, Buffalo, N. Y. 906.
The Buffalo Society of Natural Sciences, Buffalo, N. Y. 506.1.
The American Academy of Arts and Sciences, Cambridge, Mass. 506.1.
The Astronomical Observatory at Harvard College, Cambridge, Mass. 522.1.
Harvard University, Cambridge, Mass. 378.
The Museum of Comparative Zoology at Harvard College, Cambridge, Mass. 507.
The Peabody Museum of American Archæology and Ethnology, Cambridge, Mass. 571.
The Illinois State Laboratory of Natural History, Champaign, Ill. 507.
The Elisha Mitchell Scientific Society, Chapel Hill, N. C. 506.1.
The American Chemical Review, 242 Burling street, Chicago, Ill. 540.5.
The Cincinnati Society of Natural History, 108 Broadway, Cincinnati, Ohio. 506.1.
The Ohio Mechanics' Institute, Cincinnati, Ohio. 506.1.
Hamilton College, Clinton, N. Y. 378.
Ohio State University, Columbus, Ohio. 378.
The Academy of Natural Sciences, Davenport, Iowa. 506.1.
The Colorado Scientific Society, Denver, Col. 506.1.
The Des Moines Academy of Sciences, Des Moines, Iowa. 506.1.
Denison University, Granville, Ohio. 507.
Dartmouth College, Hanover, N. H. 378.
Trinity College, Hartford, Conn. 378.
The Department of Geology and Natural History, Indianapolis, Ind. 557.72.
Cornell University, Ithaca, N. Y. 378.
The Geological Survey of Arkansas, Little Rock, Ark. 557.67.
The University of Wisconsin, Madison, Wis. 378.
The American Antiquarian and Oriental Journal, Mendon, Ill. 571.
Meriden Scientific Association, Meriden, Conn. 506.1.
Wesleyan University, Middletown, Conn. 507.

The Natural History Society of Wisconsin, Milwaukee, Wis. 506.1.

The Public Museum, Milwaukee, Wis. 507.

The Minnesota Academy of Natural Sciences, Minneapolis, Minn. 506.1.

The Geological and Natural History Survey of Minnesota, Minneapolis, Minn. 557.76.

Geological Survey of New Jersey, New Brunswick, N. J. 557.49.

Rutgers College, New Brunswick, N. J. 378.

The Connecticut Academy of Arts and Sciences, New Haven, Conn. 506.1.

Yale University, New Haven, Conn. 378.

The Newport Scientific Society, Newport, R. I. 506.1.

The New Orleans Academy of Sciences, New Orleans, La. 506.1.

The American Chemical Society, N. Y. University, New York. 540.6.

The American Institute of Mining Engineers, 13 Burling slip, N. Y. 622.6.

The American Geographical Society, 11 W. 29th street, N. Y. 910.6.

The American Museum of Natural History, New York. 507.

The Astor Library, New York. 027.

Columbia College, New York. 378.

The Torrey Botanical Club, New York. 580.6.

The College of the City of New York, New York. 378.

The School of Mines Quarterly, Columbia College, New York. 605.

The Mercantile Library Association, New York. 027.

The New York Historical Society, 70 Second ave., New York. 906.

The New York Microscopical Society, 64 Madison ave., New York. 578.

The University of the City of New York, New York. 378.

The Scientific Association, Peoria, Ill. 506.1.

The Portland Natural History Society, Portland, Maine. 506.1.

The Academy of Natural Sciences of Philadelphia, Philadelphia, Pa. 506.1.
The American Philosophical Society, Philadelphia, Pa. 506.1.
The Engineers' Club of Philadelphia, Philadelphia, Pa. 620.6.
The Polyclinic, Philadelphia, Pa. 910.
The Zoological Society of Philadelphia, Philadelphia, Pa. 590.6.
The Franklin Institute, Philadelphia, Pa. 506.1.
The Wagner Free Institute of Science, Philadelphia, Pa. 506.1
The Vassar Brothers' Institute, Poughkeepsie, N. Y. 506.1.
The E. M. Museum of Geology and Archæology, Princeton, N. J. 507.
The University of Rochester, Rochester, N. Y. 378.
The Warner Observatory, Rochester, N. Y. 522.1.
The California State Mining Bureau, Sacramento, Cal. 622.
The American Association for the Advancement of Science, Salem, Mass. 506.1.
The Essex Institute, Salem, Mass. 506.1.
The Peabody Academy of Science, Salem, Mass. 506.1
San Francisco Microscopical Society, San Francisco, Cal. 578.
The California Academy of Sciences, San Francisco, Cal. 506.1.
Union College, Schenectady, N. Y. 378.
The Academy of Sciences, St. Louis, Mo. 506.1.
The Library of Syracuse, Syracuse, N. Y. 027.
The University of Syracuse, Syracuse, N. Y. 378.
The Natural Science Association of Staten Island, Tompkinsville, N. Y. 506.1.
The Kansas Academy of Sciences, Topeka, Kan. 506.1.
The Washburn College Laboratory of Natural History, Topeka, Kan. 507.
The Trenton Natural History Society, Trenton, N. J. 506.1.
The Geological Survey of Alabama, University, Ala. 557.61.
The American Antiquarian Society, Worcester, Mass. 571.
The Bureau of Ethnology, Washington, D. C. 572.
The Philosophical Society, Washington, D. C. 506.1.
The Congressional Library, Washington, D. C. 027.
The Chief of Engineers, U. S. A., Washington, D. C. 620.
The Smithsonian Institution, Washington, D. C. 506.1.

United States Bureau of Education, Department of the Interior, Washington, D. C. 370.7.

United States Coast and Geodetic Survey, Washington, D. C. 526.9.

United States Commission of Fish and Fisheries, Washington, D. C. 639.

United States Entomological Commission, Department of Agriculture, Washington, D. C. 595.7.

United States Geological Survey, Washington, D. C. 557.3.

United States National Museum, Washington, D. C. 507.

United States Signal Office, War Department, Washington, D. C. 551.5.

United States Military Academy, West Point, N. Y. 378.

Williams College, Williamstown, Mass. 378.

Dominion of Canada.

The Nova Scotian Institute of Natural Science, Halifax, N. S. 506.11.

Queen's College and University, Kingston, Ont. 378.

The Hamilton Association, Hamilton, Ontario. 506.11.

The Canadian Entomologist, London, Ont. 595.7.

The Natural History Society of Montreal, Montreal. 506.11.

The Royal Society of Canada, Montreal. 506.11.

The Geological and Natural History Survey of Canada, Ottawa. 557.1.

The Ottawa Field Naturalists' Club, Ottawa. 506.11.

The Canadian Institute of Toronto, Toronto, Ont. 506.11.

The Entomological Society of Ontario, Toronto, Ont. 595.7.

Le Naturaliste Canadien, Cap Rouge, Quebec. 505.

The Historical and Scientific Association, Winnipeg, Manitoba. 506.11.

Mexico.

El Museo Nacional de Mexico, Mexico. 507.

La Sociedad Mexicana de Historia Natural, Museo Nacional, Mexico. 506.12.

El Secretario de Fomento Colonizacion Industria y Comercio, Mexico. 600.

SOUTH AMERICA.

La Academia Nacional de Ciencias en Cordoba, Buenos Ayres, Republica Argentina. 506.13.
La Revista Argentina de Ciencias Medicas, Buenos Ayres. 610.
El Museo Nacional de Rio de Janeiro, Rio Janeiro, Brazil. 507.

EUROPE.

Great Britain and Ireland.

Dun Echt Observatory, Aberdeen, Scotland. 522.1.
The Belfast Naturalists' Field Club, Belfast, Ireland. 506.22.
The Chemico-Agricultural Society of Ulster, Belfast, Ireland. 630.6.
The Belfast Natural History and Philosophical Society, Belfast. 506.22.
The Birmingham Natural History and Microscopical Society, The Mason College, Birmingham, England. 506.2.
The Birmingham and Midland Institute, Archæological Section, Birmingham, England. 506.2.
The Mining Association and Institute of Cornwall, Tuckingmill, Camborn, England. 620.6.
The Cambridge Philosophical Society, Cambridge, England. 506.2.
The Royal Dublin Society, Dublin, Ireland. 506.22.
The Royal Geological Society of Ireland, Dublin, Ireland. 550.6.
The Dumfriesshire and Galloway Scientific, Natural History and Antiquarian Society, Dumfries, Scotland. 506.21.
The Royal Physical Society, Edinburgh, Scotland. 530.6.
The Fishery Board for Scotland, Edinburgh, Scotland. 639.
The Scottish Meteorological Society, Edinburgh, Scotland. 551.5.
The Edinburgh Botanical Society, Edinburgh, Scotland. 580.6.
The Edinburgh Geological Society, Edinburgh, Scotland. 550.6.
The Royal Cornwall Polytechnic Society, Falmouth, England. 606.
The Folkestone Natural History Society, Folkestone, England. 506.2.
The Geological Society of Glasgow, Glasgow, Scotland. 550.6.

The Natural History Society, Glasgow, Scotland. 506.21.
The Philosophical Society of Glasgow, Glasgow, Scotland. 506.21.
The Yorkshire Geological and Polytechnic Society, Clevinedge, Halifax, England. 550.6.
The Hertfordshire Natural History Society and Field Club, Hertford, England. 506.2.
The Liverpool Geological Society, Liverpool, England. 550.6.
The Liverpool Polytechnic Society, Liverpool, England. 606.
The Literary and Philosophical Society, Liverpool, England. 506.2.
The Meteorological Society, London, England, 551.5.
The British Association for the Advancement of Science, London, England. 506.2.
The British Museum, London, England. 507.
The Royal Institute of Great Britain, London, England. 506.2.
The Geological Society, London, England, 550.6.
The Linnæan Society, London, England. 580.6. (Botany.) 590.6. (Zoology.)
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