

MEMOIR
OF
ALEXANDER DALLAS BACHE.
1806-1867.

BY
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BIOGRAPHICAL MEMOIR
OF
ALEXANDER DALLAS BACHE.

GENTLEMEN OF THE ACADEMY:—

ALEXANDER DALLAS BACHE, whose life and character form the subject of the following memoir, was the son of Richard Bache, one of eight children of Sarah, the only daughter of Dr. Benjamin Franklin. His mother was Sophia Burret Dallas, daughter of Alexander J. Dallas, and sister of George M. Dallas, whose names are well known in the history of this country, the former as Secretary of the Treasury, and the latter as Vice-President of the United States, and subsequently as minister to the Court of St. James.

The subject of our sketch was born in Philadelphia, on the 19th of July, 1806. At an early age he became a pupil of a classical school, and was distinguished by an unusual aptitude in the acquisition of learning. Shortly before arriving at the age of fifteen he was appointed a cadet at the National Military Academy at West Point. Here, though the youngest pupil, he soon attained a high grade of scholarship, which he maintained during the whole of his course, and was finally graduated in 1825, at the head of his class. His merit was in this case the more conspicuous, inasmuch as the class is shown to have been one of unusual ability, by having numbered no less than four successful candidates for the honor of adoption into the Corps of Engineers. It has been mentioned as a solitary instance in the history of the Academy, noted for its rigid discipline, that young Bache passed through the entire course of four years without having received a mark of actual demerit, and, what is perhaps not less uncommon, without having called forth the least manifestation of envy on the part of his fellow-pupils. On the contrary, his superiority in scholarship was freely acknowledged by every member of his class, while his unassuming manner, friendly demeanor, and

fidelity to duty secured him the affection as well as the respect of not only his fellow-pupils, but also of the officers of the institution. It is also remembered that his classmates, with instinctive deference to his scrupulous sense of propriety, forbore to solicit his participation in any amusement which in the slightest degree conflicted with the rules of the Academy. So far from this, they commended his course, and took pride to themselves, as members of his class, in his reputation for high standing and exemplary conduct. His room-mate, older by several years than he was, and by no means noted for regularity or studious habits, constituted himself, as it were, his guardian, and sedulously excluded all visitors or other interruptions to study during the prescribed hours. For this self-imposed service, gravely rendered as essential to the honor of the class, he was accustomed jocularly to claim immunity for his own delinquencies or shortcomings. But whatever protection others might require on account of youth and inexperience, young Bache needed no guardian to keep him in the line of duty. Impressed beyond his years with a sense of the responsibility which would devolve upon him as the eldest of his mother's family, entertaining a grave appreciation of the obligations involved in his education at the National Academy, he resolved from the first to exert his energies to the utmost in qualifying himself for the duties which he might be called upon to discharge, whether in professional or private life. Nor was he uninfluenced in this determination by a consciousness that as a descendant of Franklin he was, in a certain degree, an object of popular interest, and that on this account something more than an ordinary responsibility rested upon him. On a mind constituted like his an influence of this kind could not but exert a happy effect.

The character which he established for gentleness of manner and evenness of temper was not entirely the result of native amiability, for when a child he is said to have been quick-tempered, and at later periods of his life, when suddenly provoked beyond his habitual power of endurance, he sometimes gave way to manifestations of temper which might have surprised those who only knew him in his usual state of calm deportment. These ebullitions were, however, of rare occurrence, and always of short duration. His marked characteristic was the control which he had acquired over his passions and feelings, and it was this which

enabled him to suppress all tendency to self-indulgence, to pursue with unremitting perseverance the course he had marked out, to observe an undeviating regard for truth and justice, and to cherish habitually all that would tend to exemplify the kindlier affections of the heart.

Although young Bache was perhaps predisposed, from hereditary influence, to form correct habits and adopt high moral principles, yet these dispositions might have remained dormant had it not been for the early training and the watchful care of his noble mother. From his earliest days she checked with gentle reproof every indication of childish revolt against wholesome restraint, and steadily carried out her system of discipline so gently and yet so effectually that it met with scarcely any opposition, and left the conviction that she was always in the right. Her maternal solicitude did not end with his being placed under military rule, but was continued through his whole course by means of a ready pen. In the language of one who was permitted to read her letters to her son while at West Point, "nothing could be more admirable than the way in which, amid pleasant gossip and family news, she would inspire her son with high sentiments and encourage him to persevering industry."

As an illustration of his persistency of purpose, it is related that, when a recitation of more than common length or difficulty was to be prepared for the morrow, it was no unusual practice of his to place himself on a seat of unstable equilibrium, which by giving way when volition was about to lose its power recalled his flagging attention to the allotted task.

After graduating he was selected, on account of his scholarship, to remain at the Academy as an assistant professor. In this position, which gave him an opportunity to review his studies and extend his reading, he continued one year; when, at his own request, he was assigned to engineering duty under the late General, then Colonel, Totten, at Newport, Rhode Island. Here he remained two years, engaged in constructing fortifications, devoting his extra hours to the study of physics and chemistry, and, as a recreation, collecting and labelling the shells of that region. But the most important event of this period of his life, and that which, doubtless, contributed in a large degree to his future success, was his becoming acquainted with and subsequent betrothal to Miss Nancy Clarke Fowler, the daughter of an old

and highly-respected citizen of Newport. With the stinted pay of a lieutenant of engineers, out of which his mother and her younger offspring were to be provided for, marriage was not to be thought of, excepting as an event in the remote distance. Fortunately as unexpectedly, however, a change now took place in his circumstances which enabled him to gratify the earnest wish of his heart and to secure to himself a companion and help-mate who lavished upon him all her affections, and through his life ardently devoted all her thoughts and energies to sustain, assist, and encourage him. The change alluded to, and which opened to him an uninterrupted career of usefulness during the whole of his active life, was the result of an invitation to the chair of natural philosophy and chemistry in the University of Pennsylvania, at Philadelphia. He accepted the position with that unaffected diffidence which is the usual concomitant of true but untried merit, though, as might have been anticipated, his eventual success was commensurate with the industry and ability which had marked his previous progress. Having already had some experience as a teacher, he the more readily gained the entire confidence of the authorities of the University and the affection of his pupils. He did not, however, rest satisfied with the occupation of teacher, or with merely imparting knowledge obtained by the labors of others, but sought to enlarge the bounds of science by discoveries of his own. As auxiliary to this, he became a member of the Franklin Institute, a society then newly established for the promotion of the mechanical arts. This society, which still maintains a vigorous existence, was well calculated to exhibit his talents and develop his character. It brought him into intimate association with the principal manufacturers, engineers, and artisans of the city, and into relations of friendship with a large number of young men destined, in more advanced life, to exert an extended influence on public affairs. He was appointed chairman of one of the most important of its committees, and was chosen as the expounder of the principles of the institute at its public exhibitions. Facilities were thus afforded him for the prosecution of science, which he could not have well commanded in any other position. Workshops were thrown open to him, and skilful hands yielded him ready assistance in realizing the conceptions of his suggestive mind. His descent from the illustrious statesman and philosopher whose name the institute

bears, and who is almost regarded as the tutelar saint of Philadelphia, no doubt contributed to a prepossession in his favor, but the influence which he acquired and maintained was due to his own learning, industry, ability, and courtesy. To these he owed the favor and distinction of having conferred upon him the principal directorship of the scientific investigations of the institute, and the opportunity which it afforded him of so greatly contributing to the usefulness of the society and to the advancement of his own reputation.

For a full account of the labors in which he was engaged in his connection with the Franklin Institute we must here be content with referring to the volumes of its journal from 1828 to 1835 inclusive. We may pause a moment, however, to notice the investigations relating to the bursting of steam-boilers, of which he was the principal director. The public mind had, at that epoch, been so frequently and painfully called to this subject that the institute was induced to organize a series of systematic researches in regard to it, the importance of which was soon recognized by the General Government in the form of an appropriation for defraying the attendant expenses. In the prosecution of these inquiries a large amount of information relative to explosions, and suggestions as to their causes, was first collected by correspondence, and on this was based a series of well-devised experiments, which were executed with signal address, and the results interpreted with logical discrimination. The conclusions arrived at were embodied in a series of propositions, which, after a lapse of more than thirty years, have not been superseded by any others of more practical value. The most frequent cause of explosion was found to be the gradual heating of the boiler beyond its power of resistance; and next to this, the sudden generation of steam by allowing the water to become too low, and its subsequent contact with the overheated metal of the sides and other portions of the boiler. The generation of gas from the decomposition of water as a cause of explosion was disproved, as was also the dispersion of water in the form of spray through superheated steam. These experiments were not unattended with danger, and required, in their execution, no small amount of personal courage. Accidents were imminent at almost every stage of the investigation; and in some instances explosions were produced which alarmed the neighborhood. So true is it that in the pursuit of

science dangers are oftentimes voluntarily encountered, exacting no less courage or firmness of nerve than that which animates the warrior in the more conspicuous but scarcely more important conflicts of the battle-field.

The attention of Mr. Bache at this period was not exclusively devoted to his labors in connection with the Franklin Institute. He was also a member of the American Philosophical Society, and, as such, in association with Hare, Espy, and others interested in the pursuit of various branches of physics and chemistry. He erected an observatory in the yard of his dwelling, in which, with the aid of his wife and of his former pupil, John F. Fraser, he determined with accuracy, for the first time in this country, the periods of the daily variations of the magnetic needle, and by another series of observations the connection of the fitful variations of the direction of the magnetic force with the appearance of the aurora borealis.

Again, in connection with his friend, Mr. Espy, he made a minute survey of a portion of the track of a tornado, which visited New Brunswick, in New Jersey, on the 19th of June, 1835, and from the change of place and relative position of the trees and other objects, as left by the wind, he succeeded in establishing the fact, in accordance with the hypotheses of Mr. Espy, that the effects of the storm were due to an ascending and progressive column of air, by which all objects within the influence of the disturbance, on either side the track, were drawn inward, and not due, as had been supposed, to a horizontal rotation at the surface, which would tend to throw them outward by centrifugal projection. In co-operation with Professor Courtenay, he also made a series of determinations of the magnetic dip at various places in the United States. Indeed, terrestrial magnetism was with him a favorite subject, to which he continued to make valuable contributions at intervals during his whole life. The phenomena of heat likewise engaged much of his attention, and he was the first to show, contrary to generally-received opinion, that the radiation and consequent absorption of dark heat is not affected by color. His investigations in this line were suddenly brought to a close by an accident, which we may be allowed to mention as furnishing an illustration of his self-control and considerate regard for the feelings of others. After an expenditure of money which he could ill afford, and of time withdrawn from the hours

due to repose, he had procured and arranged on a stand a series of delicate instruments intended for a long-meditated experiment on radiant heat. During his temporary absence his mother, in hurriedly passing through the apartment, accidentally caught in her dress the support of the apparatus and brought the whole to the floor, a mass of mingled fragments. The author of this disaster was so painfully affected by the destruction, of which she had been the unintentional cause, as to be obliged to leave to his wife the task of breaking the unwelcome tidings to her son. On receiving the information, he stood for a moment, perfectly silent, then hurried out into the open air to conceal his emotion and tranquillize his feelings. After a short interval he returned, calm, affectionate, and apparently cheerful, and neither by word nor look gave any indication of the pain and disappointment he had so severely experienced.

It should not be forgotten that the labors to which we have alluded were performed in hours not devoted to his regular duties as a professor in the University. To these he was obliged to give three hours a day, besides other time to the preparation of illustrations for his lectures, while several evenings of the week were claimed by committees of the Franklin Institute and the Philosophical Society. He was enabled to execute these multifarious labors by a division of his time into separate periods, to each of which was allotted its special occupation. By a rigid adherence to this system he was always prompt in his engagements, was never hurried, and found time, moreover, to attend to the claims of friendship and society. He was a zealous and successful teacher, to whom the imparting of knowledge was a source of unalloyed and inexhaustible pleasure. His pupils could not fail to be favorably impressed by his enthusiasm and influenced by his kindness. He always manifested an interest not only in their proficiency in study, but also in their general welfare. They regarded him with affection as well as respect, and while in other class-rooms of the University disorder and insubordination occasionally annoyed the teachers, nothing was to be witnessed in his, but earnest attention and gentlemanly deportment.

His success as an instructor affords a striking confutation of the fallacy which has not unfrequently been advocated in certain quarters, that men devoted to original research and imbued with habits of mind which it generates are not well qualified for the

office of instructors. So far is the proposition from having any foundation in fact, that it is precisely among the most celebrated explorers of science of the present century that the most successful and noted teachers have been found. In proof of this the illustrious names of Priestley, De Candolle, Dalton, Davy, Oersted, Faraday, and a host of others, immediately occur. At the same time it cannot be denied that it is questionable economy to devote to the drudgery of drilling youth in the elements of knowledge, a mind well qualified by nature and training to enlarge the boundaries of thought and increase the stores of knowledge. But it is equally clear that the practice of teaching is, to a certain extent, not incompatible with the leisure and concentration of mind requisite for original research; that the latter must, in fact, act beneficially alike on the instructor and instructed; the former gaining in clearness of conception in the appreciation of the new truths he is unfolding by imparting a knowledge of their character to others, while the latter catch, by sympathy, a portion of the enthusiasm of the master, and are stimulated to exertions of which they would otherwise be incapable.

In 1836, when Professor Bache had just attained the thirtieth year of his age, his attention and energies received a new direction, constituting, as it were, a new epoch in his life. This change was caused by a movement on the part of the trustees of the Girard College for Orphans, an institution munificently endowed by a benevolent citizen of Philadelphia. Preparatory to organizing this institution it was thought desirable to select a suitable person as president, and to send him abroad to study the systems of education and methods of instruction and discipline adopted in Europe. The eyes of the entire community were with one accord directed to our professor as the proper man for this office. He had, however, become enamored with the pursuit of science, and it was with difficulty that he could bring himself to regard with favor a proposition which might tend to separate him from this favorite object. The consideration of a more extended field of usefulness at length prevailed, and he accepted, though not without some lingering regret, the proffered position. No American ever visited Europe under more favorable circumstances for becoming intimately acquainted with its scientific and literary institutions. His published researches had given him a European reputation, and afforded him that ready access to the

intelligent and influential classes of society which is denied the traveller whose only recommendation is the possession of wealth. It cannot be doubted that he was also favored in this respect by the admiration which in Europe still attaches to the name of his renowned ancestor.¹ He was everywhere received with marked attention, and from his moral and intellectual qualities did not fail to sustain the prepossessions in his favor and to secure the friendship and esteem of the most distinguished savants of the Old World.

He remained in Europe two years, and on his return embodied the results of his researches on education in his report to the trustees of Girard College. This report forms a large octavo volume, and is an almost exhaustive exposition of the scholastic systems and methods of instruction in use at the time in England, France, Prussia, Austria, Switzerland, and Italy. It has done more, perhaps, to improve the theory and art of education in this country than any other work ever published; and it has effected this not alone by the statement of facts derived from observation, but also by the inferences and suggestions with which it abounds. The accounts which are given of the different schools of Europe are founded on personal inspection; the results being noted down at the time with the writer's habitual regard to accuracy.

After completing his report he was prepared to commence the organization of the Girard College, but the trustees, partly on account of the unfinished condition of the building, and partly from a delay in the adjustment of the funds of the endowment, were not disposed to put the institution into immediate operation. In the mean time Professor Bache, desirous of rendering the information he had acquired of immediate practical use, offered his services gratuitously to the municipal authorities of Philadelphia, to organize, on an improved basis, a system of public education

¹ The force of this sentiment was quaintly but strongly marked by a slight incident which occurred when he was in Germany. An elderly savant, on being introduced, clasped him in his arms, saluted him with a kiss on either cheek, and greeted him with the exclamation, "Mein Gott, now let me die, since I have lived to see with mine own eyes an emanation of the great Franklin!" This compliment was perhaps more flattering than agreeable, since the old professor in question was wont, after the fashion of his day, to stimulate his lagging faculties by frequent and profuse extractions from the snuff-box.

for that city. This offer was gladly accepted, and he commenced the work with his usual energy and with the cordial support of the directors and teachers of the common schools. At the end of the year, finding that the trustees of the college were still unprepared to open the institution, he relinquished the salary, but retained the office of president, and devoted his time mainly to the organization of the schools. He was now, however, induced to accept from the city, as the sole and necessary means of his support, a salary much less than the one he had relinquished. The result of his labors in regard to the schools was the establishment of the best system of combined free education which had, at that time, been adopted in this country. It has since generally been regarded as a model, and has been introduced as such in different cities of the Union.

In 1842, having completed the organization of the schools, and Girard College still remaining in a stationary condition, he resigned all connection with it, and, yielding to the solicitations of the trustees of the University, returned to his former chair of natural philosophy and chemistry, in order that he might resume the cultivation of science. Not that it is to be inferred that in his devotion to the advancement of education he had relinquished or deferred the scientific pursuits to which the habit of his mind and the bent of his genius continually impelled him, for during his travels in Europe he had been careful to provide himself with a set of portable instruments of physical research, and, as a relief from the labors imposed by the special object of his mission, he instituted a connected series of observations at prominent points on the Continent and in Great Britain, relative to the dip and intensity of terrestrial magnetism. These observations were made with the view of ascertaining the relative direction and strength of the magnetic force in Europe and America, by the comparison of parallel series of observations in the two countries with the same instruments. They also served, in most instances, to settle with greater precision than had previously been attained the relative magnetic condition of the points at which they were made.

Though the organization of the schools of such a city as Philadelphia might seem sufficient to absorb all his energy and self-devotion, yet even in the midst of this labor we find our late colleague actively co-operating in the great enterprise of the British

Association to determine by contemporaneous observations, at widely separated points, the fluctuations of the magnetic and meteorological elements of the globe. This co-operation, in which no doubt a feeling of national pride mingled itself with his ardor for the advancement of science, consisted primarily in the establishment of an observatory, to which the trustees of Girard College contributed a full series of instruments, combining all the latest improvements, and which was supported by the American Philosophical Society, and a number of liberal and intelligent individuals. The observations which were here continued at short intervals, both by day and night, for five years, form a rich mine of statistics, from which, until within the last few years of his life, the professor drew a highly interesting series of results, without exhausting the material. In addition to these observations, he made during his summer vacations a magnetic survey of Pennsylvania.

He was not destined to remain long in his old position in the University. Before he had become fairly settled in it and had renewed his familiarity with its duties, he was called in November, 1843, on the occasion of the death of Mr. Hassler, Superintendent of the United States Coast Survey, to fill the important sphere of public duty thus rendered vacant. His appointment to this position was first suggested by the members of the American Philosophical Society, and the nomination fully concurred in by the principal scientific and literary institutions of the country. In this movement he himself took no part, and indeed regarded the position as one not to be coveted; for while it opened a wide field for the exercise of talent and the acquisition of an enviable reputation, it involved responsibilities and presented difficulties of the gravest character. Professor Bache was not one of those who, abounding in self-confidence, imagined themselves equal to every exigency, or who seek the distinctions and emoluments of office without any regard to the services to be rendered or the duties discharged. On the contrary, though early and continued success must have tended to increase his self-esteem, each new position to which he was called was entered upon with feelings of solicitude rather than of exultation. He rightly judged that the proper moment for self-congratulation is not at the beginning of an arduous and precarious enterprise, but at the time of its full and successful accomplishment. Nor can it be necessary to add

that this characteristic contributed largely to his success. In civil service as in the camp, the leader to whom all look with confidence is not he who, with blind and arrogant self-reliance, disdains caution as unworthy of courage, but he who, sensitively alive to the dangers to be encountered, exerts every faculty in calling to his aid every resource which may tend to secure victory or facilitate retreat.

With whatever misgivings Professor Bache may have undertaken the task to which he was assigned, it may be truly said that no living man was so well qualified as himself to secure the results which the nation and its commercial interests demanded. His education and training at West Point, his skill in original investigations, his thorough familiarity with the principles of applied science, his knowledge of the world, and his gentlemanly deportment, were all in a greater or less degree essential elements in the successful prosecution of the survey. It would appear as if the training and acquisition of every period of his life, and the development of every trait of his character, had been specially ordained to fit him in every respect to overcome the difficulties of this position. Besides the qualifications we have enumerated, he possessed rare executive ability, which enabled him to govern and guide the diverse elements of the vast undertaking with consummate tact and skill. Quick to perceive and acknowledge merit in others, he rapidly gathered around him a corps of men eminently well qualified for the execution of the tasks to which he severally assigned them.

The Coast Survey had been recommended to Congress by President Jefferson as early as 1807, but it was not until ten years afterward that the work was actually commenced, under the Superintendence of Professor Hassler, an eminent Swiss engineer, whose plans had been previously sanctioned by the American Philosophical Society. Though the fundamental features of the survey had been established on the most approved scientific principles, yet so frequent were the changes in the policy of the government, and so limited were the appropriations, that even up to the time of Professor Bache's appointment, in 1843, little more than a beginning had been made. The survey, so far as accomplished, extended only from New York Harbor to Point Judith, on the east coast, and southward to Cape Henlopen. The new Superintendent saw the necessity of greatly enlarging

the plan, so as to embrace a much broader field of simultaneous labor than it had previously included. He divided the whole coast line into sections, and organized, under separate parties, the essential operations of the survey simultaneously in each. He commenced the exploration of the Gulf Stream, and at the same time projected a series of observations on the tides, on the magnetism of the earth, and the direction of the winds at different seasons of the year. He also instituted a succession of researches in regard to the bottom of the ocean within soundings, and the forms of animal life which are found there, thus offering new and unexpected indications to the navigator. He pressed into service, for the determination of the longitude, the electric telegraph; for the ready reproduction of charts, photography; and for multiplying copper-plate engravings, the new art of electrotyping. In planning and directing the execution of these varied improvements, which exacted so much comprehensiveness in design and minuteness in detail, Professor Bache was entirely successful. He was equally fortunate, principally through the moral influence of his character, in impressing upon the government, and especially upon Congress, a more just estimate of what such a survey required for its maintenance and creditable prosecution. Not only was a largely-increased appropriation needed to carry out this more comprehensive plan, but also to meet the expenses consequent upon the extension of the shore-line itself. Our sea-coast, when the survey commenced, already exceeded in length that of any other civilized nation, but, in 1845, it was still more extended by the annexation of Texas, and again, in 1848, by our acquisitions on the Pacific. Professor Bache was in the habit of answering the question often propounded to him by members of Congress, "When will this survey be completed?" by asking, "When will you cease annexing territory?" a reply not less significant at the present day than when it was first given, and which may continue long to be applicable under the expansive tendencies of our national policy.

When Professor Bache took charge of the survey, it was still almost in its incipient stage, subjected to misapprehension, assailed by unjust prejudice, and liable, during any session of Congress, to be suspended or abolished. When he died, it had conquered prejudice, silenced opposition, and become established on a firm foundation as one of the permanent bureaus of the

executive Government. The importance of the work, which was always highly appreciated by the mariner, became strikingly obvious to the general public through the service which it rendered during the late war, in furnishing accurate charts and sailing directions for the guidance of our squadrons along the southern coast. Nor was this alone; an active participation was also borne by the officers of the survey in the attack of the United States Navy on Sumter, Port Royal, Fort Fisher, Mobile, New Orleans, and other strongholds, while constant aid was rendered by them in the navigation of the inlets and channels, and in the avoidance of hidden rocks or shoals with which none could be more minutely acquainted. Though the value of the survey was signally conspicuous on these occasions, it needs but little reflection to be convinced of its essential connection with the general prosperity of the country. Whatever diminishes the danger of departure from or an approach to our shores facilitates commerce, and thus renders more valuable the products of our industry, even in portions of our land most remote from the sea-board. But the survey should not be viewed alone in its economical relations, since, as an enlightened and liberal people, we owe it to the great community of nations and the cause of humanity to supply the world with accurate charts of our precarious coast, as well as to furnish it with all the other aids to safer navigation which the science and experience of the age may devise.

Professor Bache, with his enlightened appreciation of the value of abstract science, kept constantly in view the various problems relative to the physics of the globe, which are directly or even incidentally connected with the survey of the coast, and ever cherished the hope of being permitted to complete his labors by their solution. Among these was a new determination of the magnitude and form of the earth, and the variations in the intensity of terrestrial gravity at various points on the continent of North America; the discussion of the general theory of the tides; the magnetic condition of the continent; and the improvement of the general map of the United States, by determining its relation to the coast line, and the precise geographical positions of the most important points in the interior. Though his hopes in regard to these problems were not destined to be realized by himself, fortunately for the cause of science they have been left in charge of a successor in the person of his ardent

friend and collaborator, Professor Peirce, to whose genius and industry we may confidently look for that full exposition of the work which, while it entitles him to the highest approbation of the scientific world, will render ample justice to the labors and sagacity of his lamented predecessor.

Besides having charge of the Coast Survey, Professor Bache was Superintendent of Weights and Measures, and in the exercise of this function directed a series of investigations relative to the collection of excise duties on distilled spirits, and likewise superintended the construction of a large number of sets of standard weights and measures for distribution among the several States of the Union. He was also appointed one of a commission to examine into the condition of the lighthouse system of this country, and to report upon any improvements calculated to render it more efficient. In the investigations pertaining to this subject, involving, as they do, a knowledge of a wide range of applied science, he took a lively interest, and rendered important service in the organization of the admirable system which was adopted and still remains in operation. This commission of investigation was afterward merged in the present Lighthouse Board, of which he continued a member until the time of his death.

In 1846 he had been named in the act of incorporation as one of the Regents of the Smithsonian Institution, and by successive reelection was continued by Congress in this office until his death, a period of nearly twenty years. To say that he assisted in shaping the policy of the establishment would not be enough. It was almost exclusively through his predominating influence that the policy which has given the institution its present celebrity was, after much opposition, finally adopted. The object of the donation, it will be remembered, had been expressed in terms so concise that its import could scarcely be at once appreciated by the general public, though to the cultivators of science, to which class Smithson himself belonged, the language employed failed not to convey clear and precise ideas. Out of this state of things it is not surprising that difference of opinion should arise respecting the proper means to be adopted to realize the intentions of the founder of the institution. Professor Bache, with persistent firmness, tempered by his usual moderation, advocated the appropriation of the proceeds of the funds principally to the plan set forth in the first report of the Secretary, namely, of encouraging and

supporting original research in the different branches of science. Unfortunately this policy could only be partially adopted, on account of the restrictions of the enactment of Congress, by which provision was to be made for certain specified objects. He strenuously opposed the contemplated expenditure of a most disproportionate sum in the erection and maintenance of a costly edifice; but failing to prevent this, he introduced the resolution adopted by the board as a compromise, whereby the mischief which he could not wholly avert might at least be lessened. This resolution provided that the time of the erection of the building should be extended over several years, while the fund appropriated for the purpose, being in the mean time invested in a safe and productive manner, would serve in some degree to counterbalance the effect of the great and unnecessary outlay which had been resolved on. It would be difficult for the secretary, however unwilling to intrude anything personal on this occasion, to forbear mentioning that it was entirely due to the persuasive influence of the Professor that he was induced, almost against his own better judgment, to leave the quiet pursuit of science and the congenial employment of college instruction to assume the laborious and responsible duties of the office to which, through the partiality of friendship, he had been called. Nor would it be possible for him to abstain from acknowledging with heartfelt emotion that he was from first to last supported and sustained in his difficult position by the fraternal sympathy, the prudent counsel, and the unwavering friendship of the lamented deceased.

His demeanor in the board was quiet and unobtrusive, and his opinions sought no support in elaborated or premeditated argument; but when a topic likely to lead to difficulty in discussion was introduced, he seldom failed, with that admirable tact for which he was always noted, to dispose of it by some suggestion so judicious and appropriate as to secure ready acquiescence and harmonious action. The loss of such a man in the councils of the Institution, when we consider the characteristics which it has been our aim to portray, must, indeed, be regarded as little less than irreparable.

As a vice-president of the United States Sanitary Commission his influence was felt in selecting proper agents, and suggesting efficient means for collecting and distributing the liberal contributions offered for ameliorating the condition of our soldiers

during the war. But the services which he rendered the Government during the recent struggle were not confined to this agency, or to the immediate operations of the Coast Survey. He was called into consultations to discuss plans of attack on the part of the Navy, and for its coöperation with the Army. He acted also as a member of a commission to which various projects, professing to improve the art of war, were referred, and in this capacity it is not too much to say that his judicious counsel contributed to save the Government millions of dollars by preventing the adoption of plausible though impracticable propositions from which nothing but failure and loss could have resulted.

One of the last acts of his life was an exemplification of the devoted affection which he had always borne to his native city, whither it was his cherished intention to return when he should be at last released from official duty. At the request of the Governor of Pennsylvania, although overwhelmed with other public labors, he planned lines of defences for Philadelphia, and to a certain extent personally superintended their construction. Unaccustomed for many years to direct exposure to the sun, this work proved too much for his physical strength and brought on the first indications of that malady which terminated his life. Though apparently of a vigorous constitution, and capable, under the excitement of official life, of bearing an unusual amount of bodily fatigue, yet he was subject at intervals to "sick headache," a disease which seems to have been hereditary, and which perhaps conspired with other causes in terminating his useful and distinguished career. Previous to the war he had spent the warmer part of each summer in a tent, at some point of the primary triangulation of the survey, whence he directed the various parties in the field by correspondence; and as the point was usually at the top of a mountain, or at some elevated position, from which other stations of the survey could be seen, he did not want for invigorating air. With this, and the exercise of measuring angles, he laid in a store of health sufficient to enable him to carry on without interruption the arduous duties of the remaining portion of the year. But after the commencement of the war his presence was continually required in Washington to give advice and information as to military and naval operations, and to attend the meetings of the scientific commission to which we have previously referred. He was, therefore, no longer able to avail him-

self of the recuperating influence of mountain air, and in view of this his valuable life may be said to have been one of the sacrifices offered for the preservation of the Union. The first indications of the insidious disease which gradually sapped the citadel of life were numbness in the fingers of his right hand, and, on one occasion, for a short time only, loss of memory. Though these symptoms gave him some uneasiness, they did not diminish his exertions in the line of his duty. Other symptoms, however, exhibited themselves, which, though awaking anxiety, did not much alarm his friends, until he was suddenly deprived, in a considerable degree, of the power of locomotion and of the expression of ideas; the result, it was supposed, of a softening of the brain. But though the power of expression was paralyzed, his memory appeared to retain all the impressions of the past, and he evidently took much pleasure in having recalled to him scenes and events of years gone by. For several months he was very anxious as to the business of the Coast Survey, and it was with difficulty he could be restrained from resuming in full the duties of his office; but, as the malady increased, his perception of external objects diminished. He took less and less interest in passing events, and finally seemed to withdraw his attention from the exterior world, with which he almost ceased thenceforth to hold any active communication. It was hoped that a voyage to Europe, through the excitements of shipboard and the revival of old associations, would be of service to him; but, notwithstanding an occasional manifestation of his wonted spirit of social and intellectual enjoyment at the encounter of a friend of former times or distinguished associate in the walks of science, he returned from a sojourn abroad of eighteen months without having experienced any permanent abatement in the progress of his malady. He lingered for a short time longer, and finally resigned his breath at Newport, Rhode Island, on the 17th of February, 1867, in the sixty-first year of his age.

It would be impossible to name an American distinguished on purely scientific grounds to whom the enlightened sentiment of his own countrymen and of foreign nations has awarded more emphatic marks of admiration and esteem. The degree of Doctor of Laws was conferred on him by the principal universities of this country, and few of our leading societies were willing to forego the honor of numbering him among their associates. He

was elected in succession president of the American Philosophical Society, of the American Association for the Advancement of Science, and of the National Academy of Sciences established by Congress. Nor were foreigners less forward in acknowledging his merit. He was a member of the Royal Society of London, of the Imperial Academy of Sciences at St. Petersburg, of the Institute of France, the Royal Society of Edinburgh, the Royal and Imperial Geographical Society of Vienna, the Royal Academy of Turin, the Mathematical Society of Hamburg, the Academy of Sciences in the Institute of Bologna, the Royal Astronomical Society of London, and of the Royal Irish Academy of Dublin. In addition to these testimonies of appreciation, several medals were awarded to him by foreign governments for his distinguished services in the Coast Survey and in the cause of science generally.

The life we have here sketched is eminently suggestive, both from a philosophical and a practical point of view. It presents an unbroken series of successful efforts, with no interruptions in its sustained and constantly ascending course; all parts follow each other in harmonious continuity; and not only is each stage of its progress in advance of the one which preceded it, but it furnishes the means of education for that which succeeded. It is not merely curiosity, laudable as that might be, but a sense of the importance of the inquiry, which prompts us to ask, What were the mental and moral characteristics of the mind which produced such results? And we say intentionally, the *mind which produced these results*, for although it be true that accident has in many cases a determining influence on the fortunes of an individual, it will be clear from what precedes, or we shall have greatly failed in the task which we proposed to ourselves, that the element of casualty had but little to do with the success which crowned the life to which the question at present relates.

From long acquaintance with him and critical study of the events of his life, and the distinctive manifestations of his moral and intellectual nature, we venture, though not without hesitation, to present the following analysis of the character of one who has performed so conspicuous a part, and in whose memory so many are deeply interested.

Alexander Dallas Bache possessed, or we may perhaps say originally inherited, a mind of strong general powers, with no

faculty in excess or in deficiency, but, as a whole, capable of unusual expansion or development in any direction which early training or the education of life might determine. He also possessed strong passions, which, instead of exerting an unfavorable effect on his character by their indulgence, became, under the restraining influence to which they were in due season subjected, a reserved energy, as it were, ready to manifest itself spontaneously and at any time in the vindication of truth and justice. He was likewise endowed with a power of *will* which, controlling all his faculties and propensities, rendered them subservient to those fixed purposes which had once received the sanction of his deliberate judgment. Eminent also among his characteristics, and perhaps most conspicuous of all, was the social element of refined humanity, a regard for his fellow-man, which craved as an essential want of his nature fraternal sympathy, not only with those within the wide circle of his daily associations, but with those from whom he could expect no reciprocation of the sentiment, the entire brotherhood of mankind. These characteristics, with a nice preception of right and a conscience always ready to enforce its mandates, are, we think, sufficient to explain the remarkable career we have described.

They were perhaps indicated by himself, though with an admission not to be accepted without some reserve, in a conversation with the writer of this sketch in reference to his entrance at West Point. "I knew," he said, "that I had nothing like genius, but I thought I was capable by hard study of accomplishing something, and I resolved to do my best, and if possible to gain the approbation of the teachers, and, above all, to make myself loved and respected by my classmates."

To illustrate the progressive development of the individual traits of his character, we may be allowed to dwell for a moment on a few analytical details. The early period of his life, including that which preceded his first call to Philadelphia, was almost wholly devoted to the improvement of the mechanical, or the "doing" faculties of his mind, and but little attention was given to invention, or the exercise of original thought. His final examination at the Academy, perfect as it was in its kind, only exhibited his capacity for the acquisition of knowledge, not the power to originate or apply it. When his efforts were first turned in the latter direction, he evinced, as I well remember, no especial

aptitude for it that would indicate future success; but in a short time, and under the stimulus of the associations into which he was thrown in Philadelphia, the faculties of investigation and of generalization were rapidly developed, and, had he not been partially turned aside from such pursuits, I doubt not that he would have still more highly distinguished himself in the line of experimental research. Again, the change in the circumstances and relations of his life produced by his election to the presidency of Girard College introduced him to a familiarity with an entirely new class of ideas, which served to exercise and expand another faculty of his mind, that, namely, which observes and appreciates moral truths, though without impairing his aptitude for physical research. In like manner, his foreign mission with reference to popular education, by bringing him into intimate and friendly association with minds of the first order in the principal cities of Europe, afforded him an opportunity for enlarging the sphere of his sympathies, as well as of studying men under a great variety of social and mental peculiarities.

Again, his long residence and high social position at the seat of Government, his intimate acquaintance and friendly intercourse with statesmen and politicians, imbued him with a thorough knowledge of the working of the Government, such as few have ever possessed, while his exertions to sustain the Coast Survey and improve its condition served to call into active operation his power to appreciate character, to discern motives, and, therefore, to convince, persuade, and control men. His ability in this latter respect was remarkable; a personal interview with an opponent of the survey scarcely ever failed to convert perhaps an active enemy into an influential friend. His success in this respect often astonished those who frequently harassed Congress with propositions covertly designed to promote their own interest at the expense of public utility; hence the exclamation was not unfrequently heard, "Bache is certainly a wonderful manager." If that which is unusual constitutes an element of wonder, then the exclamation was not without truth, though not in the sense of those by whom it was uttered, for he never advocated any measure that was not just, expedient, and proper, either as concerned the interests of the country or the welfare of his species.

On the whole, if we would seek the real secret of his influence over his fellow-men, it would be found, no doubt, to have con-

sisted in the singular abnegation of self which pervaded his whole conduct; his great practical wisdom, his honesty of purpose, and his genial though quiet and unobtrusive manner. In the exercise of these characteristics, he was so far from the least appearance of dissimulation, that no one ever approached him without feeling that it was equally impossible to doubt the purity of his intentions as it was to elude the penetration of his quiet but thorough scrutiny. His calmness served as a shield from within and without; and as a guard against himself as well as a protection against others. It enabled him to weigh the motives and observe the character of those who consulted him with the view of securing his influence or gaining his patronage. His genial nature enabled him to descend gracefully from the heights of science and to enter fully and frankly into the feelings of any company with which he might be thrown. In this he was aided by a playfulness of fancy and a quiet humor which banished any reserve that might have been produced by a knowledge of his superior talents and attainments. He was, though by no means gifted with those attractions of person which influence at first sight, a favorite with all ages, and particularly with the sex whose discrimination of character is said to be least fallible. It seems almost superfluous to say of such a man that his friendship was open and unwavering, that his confidence once bestowed could be shaken by no mere difference of opinion or conflict of personal interests. Severe to himself under the responsibility of duty, and in the punctual observance of his engagements, his indulgence was reserved for the weak and the erring. Though his outer life was free from disappointments or reverses, and though he walked as it were in perpetual sunshine, all was not so within. Besides the anxiety and solicitude incident to the responsible duties of his position, occasions of trial and profound sorrow were not spared him. He was called to mourn the untimely loss of a beloved brother, who fell a victim to his zeal for the professor's service in the survey of the Gulf Stream; of another brother, the youngest and last, also an officer of the Navy, and a general favorite, who was drowned on the coast of California; and lastly of a sister, whom he had adopted and cherished as a child. In these seasons of affliction he found consolation in the steadfast convictions of religious faith. Nurtured in the forms and principles of the Episcopal Church, he was a devout worshipper in the

sanctuary, though not bigoted in his attachment to the peculiar ordinances of that communion. He fully recognized the union of science and religion, and held with unwavering constancy the belief that revelation, properly interpreted, and science, rightly understood, must ultimately join in perfect accord in reference to the great truths essential to the well-being of man.

As an evidence of his high appreciation of abstract science derived from original investigation, he left his property in trust to the National Academy of Sciences, the income to be devoted to the prosecution of researches in physical and natural science by assisting experimentalists and observers, and the publication of the results of their investigations.

I here close this imperfect sketch, in which I am conscious of having passed in silence many admirable traits of character and conduct, and of having very inadequately portrayed others, with the remark that, though our companion and brother has departed, his works and his influence still remain to us; that, sorrow as we must for his loss, we can still recall with pride and satisfaction the example he has left us of all that, in heart, in spirit, and in life, the true man of science ought to be.

The following is a list of the published scientific papers of Alexander Dallas Bache, copied from the appendix to an address by Dr. Benjamin A. Gould, before the American Association for the Advancement of Science, August 6, 1868:—

- 1829—Feb. On the specific heat of the atoms of bodies. *Journ. Phila. Acad. Nat. Sci.*, vi, 141.
- 1830—May. On the inflammation of phosphorus in a partial vacuum. *Amer. Journ. Sci.*, xviii, 372.
- 1831—Mar. Report of the committee of the Franklin Institute of Pennsylvania, appointed May, 1829, to ascertain by experiment the value of water as a moving power. *Journ. Frank. Inst.*, vii, 145; viii, ix, x, etc.
- 1831—April. Safety apparatus for steamboats, being a combination of the fusible metal disk with the common safety-valve. *Journ. Franklin Inst.*, vii, 217; *Amer. Journ. Sci.*, xx, 317.
- 1831—Oct. Meteorological observations during the solar eclipse of February 12, 1831. *Trans. Amer. Phil. Soc.*, iv, 132.
- 1832—July. Translation of Berzelius's Essay on Chemical Nomenclature. *Amer. Journ. Sci.*, xxii, 258. *Philadelphia*, 1832.

NATIONAL ACADEMY OF SCIENCES.

- 1832—July. Notice of experiments on electricity developed by magnetism. *Journ. Franklin Inst.*, x, 66; *Amer. Journ. Sci.*, xxii, 409.
- 1832—Oct. Alarm to be applied to the interior flues of steam-boilers. *Journ. Franklin Inst.*, x, 217.
- 1832—Nov. On the diurnal variation of the magnetic needle. *Trans. Amer. Phil. Soc.*, v, 1.
- 1833—Mar. Elementary view of the application of analysis to reflection and refraction. An appendix to Sir David Brewster's treatise on optics. *Philadelphia*, 1833. pp. 95.
- 1833—July. Translation of Avogadro's memoir on the elastic force of the vapor of mercury. *Amer. Journ. Sci.*, xxiv, 286.
- 1833—July. Note of the effect upon the magnetic needle of the aurora borealis, visible at Philadelphia on the 17th of May, 1833. *Journ. Franklin Inst.*, xii, 5; *Amer. Journ. Sci.*, xxvii, 113.
- 1833—Nov. Attempt to fix the date of Dr. Franklin's observation, in relation to the northeast storms of the Atlantic States. *Journ. Franklin Inst.*, xii, 300.
- 1833—Dec. Report of experiments on the navigation of the Chesapeake and Delaware Canal by steam. *Journ. Franklin Inst.*, xii, 361.
- 1834—Jan. Observations on the disturbance in the direction of the horizontal needle, during the occurrence of the aurora of July 10, 1833. *Journ. Franklin Inst.* xiii, 1; *Amer. Journ. Sci.*, xxvii, 118.
- 1834—Jan. Report of the managers of the Franklin Institute, in relation to weights and measures. Presented in compliance with a resolution of the House of Representatives of the State of Pennsylvania. *Journ. Franklin Inst.*, xiv, 6; *Philadelphia*, 1834.
- 1834—June. Analysis of some of the coals of Pennsylvania (made jointly with Professor H. D. Rogers). *Journ. Phila. Acad. Nat. Sci.*, vii, 158.
- 1834—Oct. On the variation of the magnetic needle. *Amer. Journ. Sci.*, xxvii, 385.
- 1834—Nov. Observations to determine the magnetic dip at Baltimore, Philadelphia, New York, West Point, Providence, Springfield, and Albany (made jointly with Professor E. H. Courtenay). *Trans. Amer. Phil. Soc.*, v, 209.
- 1834—Nov. Meteoric observations on and about Nov. 13, 1834. *Amer. Journ. Sci.*, xxvii, 335; *Journ. Franklin Inst.*, xvi, 369.
- 1835—Jan. Note relating to the hardening of lime under water, by the action of carbonate of potassium, etc., and to the hardening of carbonate of lime in the air, by potassa and soda. *Journ. Frank. Inst.*, xv, 6.

- 1835—Mar. Meteorological observations made during the solar eclipse of November 30, 1834. *Trans. Amer. Phil. Soc.*, v, 237.
- 1835—May. Experimental illustrations of the radiating and absorbing powers of surfaces for heat, of the effects of transparent screens, of the conducting power of solids, etc. *Journ. Franklin Inst.*, xv, 303; *Amer. Journ. Sci.*, xxviii, 320.
- 1835—May. Replies to a circular in relation to the occurrence of an unusual meteoric display on the 13th of November, addressed by the Secretary of War to the military posts of the United States, with other facts relating to the same question. *Amer. Journ. Sci.*, xxviii, 305; *Journ. Franklin Inst.*, xvi, 149.
- 1835—June. Experiments on the efficacy of Perkins's steam-boilers or circulators. *Journ. Franklin Inst.*, xv, 379.
- 1835—July. On the comparative corrosion of iron, copper, zinc, etc., by a saturated solution of common salt. *Journ. Franklin Inst.*, xvi, 2.
- 1835—Nov. Inquiry in relation to the alleged influence of color on the radiation of non-luminous heat. *Journ. Franklin Inst.*, xvi, 289; *Amer. Journ. Sci.*, xxx, 16.
- 1835—Dec. Historical notice of a hypothesis to explain the greater quantity of rain which falls on the surface of the ground than above it. *Journ. Franklin Inst.*, xvii, 106.
- 1836—Jan. Observations upon the facts recently presented by Professor Olmsted in relation to meteors seen on the 13th of November, 1834. *Journ. Franklin Inst.*, xvii, 33; *Amer. Journ. Sci.*, xxix, 383.
- 1836—Jan. Historical note on the discovery of the non-conducting power of ice. *Journ. Franklin Inst.*, xvii, 182.
- 1836—Jan. Report of experiments made by the committee of the Franklin Institute of Pennsylvania, on the explosions of steam-boilers, at the request of the Treasury Department of the United States. *Journ. Franklin Inst.*, xvii, 1, 73, 145, 217, 289.
- 1836—Feb. Remarks on a method, proposed by Dr. Thomson, for determining the proportions of potassa and soda in a mixture of the two alkalies; with the application of a similar investigation to a different method of analysis. *Journ. Franklin Inst.*, xvii, 305.
- 1836—April. Notes and diagrams illustrative of the directions of the forces acting at and near the surface of the earth, in different parts of the Brunswick tornado of June 19, 1835. *Trans. Amer. Phil. Soc.*, v, 407.
- 1836—May. On the relative horizontal intensities of terrestrial magnetism at several places in the United States, with the investigations of corrections for temperature, and comparisons

NATIONAL ACADEMY OF SCIENCES.

- of the methods of oscillation in full and in rarefied air (jointly with Professor E. H. Courtenay). *Trans. Amer. Phil. Soc.*, v, 427.
- 1836—July. Proposed forms of diagrams for exhibiting to the eye the results of a register of the direction of the wind. *Journ. Franklin Inst.*, xviii, 22.
- 1837—May. Corresponding magnetic observations, in connection with Professor Lloyd of Dublin, to determine the relative magnetic intensity in Philadelphia, Dublin, and Edinburgh. *Proc. R. Irish Acad.*, i, 71.
- 1838—Aug. Note on the effect of deflected currents of air on the quantity of rain collected by a rain-gauge. *Rep. Brit. Assoc. Adv. Sci.*, 1838, ii, 25.
- 1839—May. Report on education in Europe, to the trustees of the Girard College for Orphans. 8vo. pp. 666. *Philadelphia*, 1839.
- 1839—Nov. Comparison of Professor Loomis's observations on magnetic dip with those obtained by Professor Courtenay and himself. *Proc. Amer. Phil. Soc.*, i, 146.
- 1839—Nov. Simultaneous magnetic observations, made in correspondence with Professor Lloyd of Dublin. *Proc. R. Irish Acad.*, i, 462; *Amer. Journ. Sci.*, xli, 212.
- 1840—Mar. Observations of the magnetic intensity at twenty-one stations in Europe. *Trans. Amer. Phil. Soc.*, vii, 75; *Proc. Amer. Phil. Soc.*, i, 185.
- 1840—Nov. Determination of the magnetic dip at Philadelphia and Baltimore. *Proc. Amer. Phil. Soc.*, i, 294.
- 1840—Dec. On an instrument for measuring the changes in the vertical component of the force of terrestrial magnetism. *Proc. Amer. Phil. Soc.*, i, 311.
- 1841—May. Diagram of the direction and force of the wind, and amount and rate of rain-fall during the severe gust of April 2, 1841. *Proc. Amer. Phil. Soc.*, ii, 56.
- 1841—July. On observations of the magnetic dip, made at Baltimore by Mr. Nicolle and Major Graham. *Proc. Amer. Phil. Soc.*, ii, 83.
- 1841—Nov. Account of the formation of cumulus cloud from the action of a fire. *Proc. Amer. Phil. Soc.*, ii, 116.
- 1842—Mar. Semi-annual report of the principal of the High School, and report to the controllers of the public schools. *Twenty-fourth Annual Report of Controllers of Public Schools of Philadelphia*, pp. 23, 50.
- 1842—April. On the application of the self-registering rain-gauge to registering the fall of snow. *Proc. Amer. Phil. Soc.*, ii, 164.
- 1842—July. Report of the principal of the Central High School for the year ending July, 1842. 8vo. pp. 120. *Philadelphia*.

- 1842—Oct. Address delivered at the close of the twelfth exhibition of American manufactures, held by the Franklin Institute.
- 1842—Dec. On a modification of Lloyd's induction inclinometer. *Proc. Amer. Phil. Soc.*, ii, 237.
- 1843—Jan. On a new dew-point hygrometer. *Proc. Amer. Phil. Soc.*, ii, 249.
- 1843—May. Results of two years' observations of the magnetic elements, and of the temperature, pressure, and moisture of the atmosphere at the magnetic observatory of Girard College. *Proc. Amer. Phil. Soc.*, iii, 90.
- 1843—May. Account of an instrument for determining the conducting power of bodies for heat. *Proc. Amer. Phil. Soc.*, iii, 132.
- 1843—May. Account of observations at Philadelphia and Toronto, during the magnetic disturbance of May 6, 1843, and their bearing upon the question of the kind of instruments and observations appropriate to determine such phenomena. *Proc. Amer. Phil. Soc.*, iii, 175.
- 1845—Feb. Report to the Treasury Department on the progress of construction of standard weights and measures. *Senate Doc. 149, 28th Congress, 2d Session.*
- 1847—Dec. Description of a new base apparatus used in the United States Coast Survey. *Proc. Amer. Phil. Soc.*, iv, 368.
- 1848—Dec. On a new method of observing transits. *Monthly Not. R. Astr. Soc.*, ix, 123; *Bull. Acad. Sci., Brussels*, xvi, 313; *Astr. Nachr.*, xxviii, 273.
- 1849—Aug. Comparison of the results obtained in geodesy by the application of the theory of least squares. *Proc. Amer. Assoc. Adv. Sci., Cambridge*, 1849, p. 102.
- 1849—Aug. On the progress of the survey of the coast of the United States. *Proc. Amer. Assoc., Cambridge*, 1849, p. 162.
- 1850—Mar. Notes on the results of observations of the direction and force of the wind at the Coast Survey stations at Mobile Point and at Cat Island, Gulf of Mexico. *Proc. Amer. Assoc., Charleston*, 1850, p. 50.
- 1850—Mar. Abstract of a communication on the recent progress of the telegraphic operations of the United States Coast Survey. *Proc. Amer. Assoc., Charleston*, 1850, p. 122.
- 1850—Aug. Method used in the Coast Survey for showing the results of current observations. *Proc. Amer. Assoc., New Haven*, 1850, p. 70; *C. S. Rep.*, 1850, p. 136.
- 1850—Aug. Remarks upon the meeting of the American Association at Charleston, in March, 1850. *Proc. Amer. Assoc., New Haven*, 1850, p. 159.
- 1850—Aug. Notes of a discussion of tidal observations, in connection with the Coast Survey, made at Cat Island, in the Gulf

NATIONAL ACADEMY OF SCIENCES.

- of Mexico. *Proc. Amer. Assoc., New Haven*, 1850, p. 281; *Amer. Journ. Sci.*, xii, 341; *C. S. Rep.*, 1851, p. 127.
- 1851—May. Current chart of New York Bay, from observations in the Coast Survey. *Proc. Amer. Assoc., Cincinnati*, 1851, p. 43.
- 1851—May. Comparison of curves showing the hourly changes of magnetic declination at Philadelphia, Toronto, and Hobarton from April to August, and from October to February, and for March and September. *Proc. Amer. Assoc., Cincinnati*, 1851, p. 62.
- 1851—May. On the determination of the velocity of sound by the method of coincidences. *Proc. Amer. Assoc., Cincinnati*, 1851, p. 75.
- 1851—May. Notes on the use of the zenith telescope in determining latitudes in the Coast Survey by Talcott's method, and on the reduction of the observations. *Proc. Amer. Assoc., Cincinnati*, 1851, p. 151; *Amer. Journ. Sci.*, xiv, 191.
- 1851—Aug. Additional notes of a discussion of tidal observations made in connection with the Coast Survey at Cat Island, Louisiana. *Proc. Amer. Assoc., Albany*, 1851, p. 94; *Amer. Journ. Sci.*, xiv, 346; *C. S. Rep.*, 1852, p. 111.
- 1851—Aug. Notes on the tides at Sand Key, near Key West, Florida. *Proc. Amer. Assoc., Albany*, 1851, p. 138.
- 1851—Aug. Address on retiring from the duties of president of the American Association for the Advancement of Science. *Proc. Amer. Assoc., Albany*, 1851, p. 41.
- 1852—Mar. Report on the harbor of Charleston, South Carolina (as chairman of a committee).
- 1853—July. On the tides at Key West, Florida, from observations made in connection with the United States Coast Survey. *Proc. Amer. Assoc., Cleveland*, 1853, p. 32; *Amer. Journ. Sci.*, xviii, 305; *C. S. Rep.*, 1853, p. 71.
- 1853—July. On the tides of the western coast of the United States, from observations at San Francisco, California, in connection with the United States Coast Survey. *Proc. Amer. Assoc., Cleveland*, 1853, p. 42; *Amer. Journ. Sci.*, xxi, 1; *C. S. Rep.*, 1853, p. 77.
- 1854—May. Preliminary determination of co-tidal lines on the Atlantic coast of the United States, from the Coast Survey tidal observations. *Proc. Amer. Assoc., Washington*, 1854, p. 107; *Amer. Journ. Sci.*, xxi, 14; *C. S. Rep.*, 1854, p. 147.
- 1854—May. Comparison of the diurnal inequality of the tides at San Diego, San Francisco, and Astoria, on the Pacific coast of the United States, from observations in connection with the Coast Survey. *Proc. Amer. Assoc., Washington*, 1854, p. 161; *Amer. Journ. Sci.*, xxi, 10; *C. S. Rep.*, 1854, p. 152.

ALEXANDER DALLAS BACHE.

- 1854—May. On the distribution of temperature in and near the Gulf Stream, off the coast of the United States, from observations made in the Coast Survey. *Proc. Amer. Assoc., Washington*, 1854, p. 134; *Amer. Journ. Sci.*, xxi, 29; *C. S. Rep.*, 1854, p. 156.
- 1854—June. Second report on the harbor of Charleston, South Carolina.
- 1855—Feb. Discussion of observations for the isodynamic, isogonic, and isoclinal curves of terrestrial magnetism, on and near the line of the boundary survey between the United States and Mexico, made in 1849-1852, under the order of W. H. Emory, and combined with observations at San Francisco, California, and Dollar Point (E. Base), and Jupiter, Texas. *Mem. Amer. Acad. Arts and Sci.*, v, 1872.
- 1855—Aug. Approximate co-tidal lines of the Pacific coast of the United States, from observations in the United States Coast Survey. *Proc. Amer. Assoc., Providence*, 1855, p. 144; *C. S. Rep.*, 1855, p. 338.
- 1855—Aug. Notice of the tidal observations made on the coast of the United States, on the Gulf of Mexico, with type-curves at the several stations, and their decomposition into the curves of diurnal and semi-diurnal tides. *Proc. Amer. Assoc., Providence*, 1855, p. 152; *Amer. Journ. Sci.*, xxi, 128; *C. S. Rep.*, 1855, p. 346.
- 1855—Aug. Notice of earthquake waves on the western coast of the United States on the 23d and 25th of December, 1854. *Proc. Amer. Assoc., Providence*, 1855, p. 153; *Amer. Journ. Sci.*, xxi, 37; *C. S. Rep.*, 1855, p. 342.
- 1855—Dec. Report to New York harbor commissioners, on surveys of New York Harbor.
- 1856—Jan. Annual Address before the American Geographical Society, being a paper upon the Gulf Stream. *Bulletin Amer. Geogr. Soc.*, ii, 94.
- 1856—Aug. Approximate co-tidal lines of diurnal and semi-diurnal tides of the coast of the United States on the Gulf of Mexico. *Proc. Amer. Assoc., Albany*, 1856, p. 168; *Amer. Journ. Sci.*, xxiii, 12; *C. S. Rep.*, 1856, p. 252.
- 1856—Aug. On the general distribution of terrestrial magnetism in the United States, from observations made in the United States Coast Survey and others (in connection with Mr. J. E. Hilgard). *Proc. Amer. Assoc., Albany*, 1856, p. 187; *Amer. Journ. Sci.*, xxvi, 1; *C. S. Rep.*, 1856, p. 209.
- 1856—Aug. Observations to determine the cause of the increase of Sandy Hook, made by the Coast Survey for the commissioners on harbor encroachments. *Proc. Amer. Assoc., Albany*, 1856, p. 171; *Amer. Journ. Sci.*, xxiii, 16; *C. S. Rep.*, 1856, p. 263.

NATIONAL ACADEMY OF SCIENCES.

- 1856—Aug. Notice of observations to determine the progress of the tidal wave of the Hudson River, made by the Coast Survey for the commissioners on harbor encroachments. *Proc. Amer. Assoc., Albany*, 173; *Amer. Journ. Sci.*, xxiii, 17.
- 1856—Aug. Notes on the progress made in the Coast Survey in prediction-tables for the tides of the United States coast. *Proc. Amer. Assoc., Albany*, 1856, p. 166; *C. S. Rep.*, 1856, p. 249.
- 1856—Oct. Anniversary address before the American Institute of the city of New York, during the twenty-eighth annual fair. *New York*, 1857, pp. 60.
- 1856—Dec. Report to New York harbor commissioners on the progress of the survey of New York harbor.
- 1856—Dec. Notes on the winds of the coast of the United States on the Gulf of Mexico. *C. S. Rep.*, p. 272.
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ALEXANDER DALLAS BACHE.

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NATIONAL ACADEMY OF SCIENCES.

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ALEXANDER DALLAS BACHE.

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- 1844 to 1863. Annual reports of the progress of the United States Coast Survey.
- 1844 to 1848. Annual reports of Superintendent of Weights and Measures.
- 1855 to 1864. Tide tables for the use of navigators, prepared from the Coast Survey observations, annually.

Also, the following reports concerning harbors, jointly with Messrs. Totten and Davis:—

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- 1854—Oct. Report of Portland harbor commission.
- 1855—Mar. Second report of the commissioners on Portland harbor.
- 1855—Dec. Report of advisory council of the New York harbor commission. *New York Assembly Doc.*, 1856, No. 8.
- 1856—July. Report of the advisory council of the New York harbor commission, recommending certain lines in the East and North Rivers, and in Brooklyn. *New York Senate Doc.*, 1857, No. 40, p. 107.
- 1856—July. Report of the advisory council of the New York harbor commission on Gowanus Bay and its improvements. *New York Senate Doc.*, 1857, No. 40, p. 118.
- 1856—Sept. Report of the advisory council of the New York harbor commission on the Hell Gate Passage, regarded as a channel of approach to New York harbor. *New York Senate Doc.*, 1857, No. 40, p. 137.
- 1856—Oct. Second general report of the advisory council to the harbor commissioners, on lines in New York harbor. *New York Senate Doc.*, 1857, No. 40, p. 81.
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NATIONAL ACADEMY OF SCIENCES.

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- 1857—Mar. Report of the advisory council to the New York harbor commissioners upon the comparative map of New York Bay and harbor, and its approaches, prepared by the Coast Survey in March, 1857. *New York Senate Doc.*, 1857, No. 126, p. 12.
- 1860—Mar. Preliminary reports of commissioners on Boston harbor. *Boston City Doc.*, 1860, No. 37.
- 1860—Dec. Second report of United States commissioners on the condition of Boston harbor. *Boston City Doc.*, 1860, No. 97.
- 1860—Dec. Special report of the United States commissioners on Boston harbor, on the relation of Mystic Pond and River to Boston harbor. *Boston City Doc.*, 1861, No. 12.
- 1860—Dec. Report of the advisory council of the joint committee of the Massachusetts legislature on the subject of a ship-canal to connect Barnstable Bay and Buzzard's Bay. *Mass. Pub. Doc.*, 1864, No. 41.
- 1861—Sept. Fourth report of the United States commissioners on Boston harbor. *Boston City Doc.*, 1861, No. 62.
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