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ROBERT SIMPSON WOODWARD

1849–1924

BY

F. E. WRIGHT

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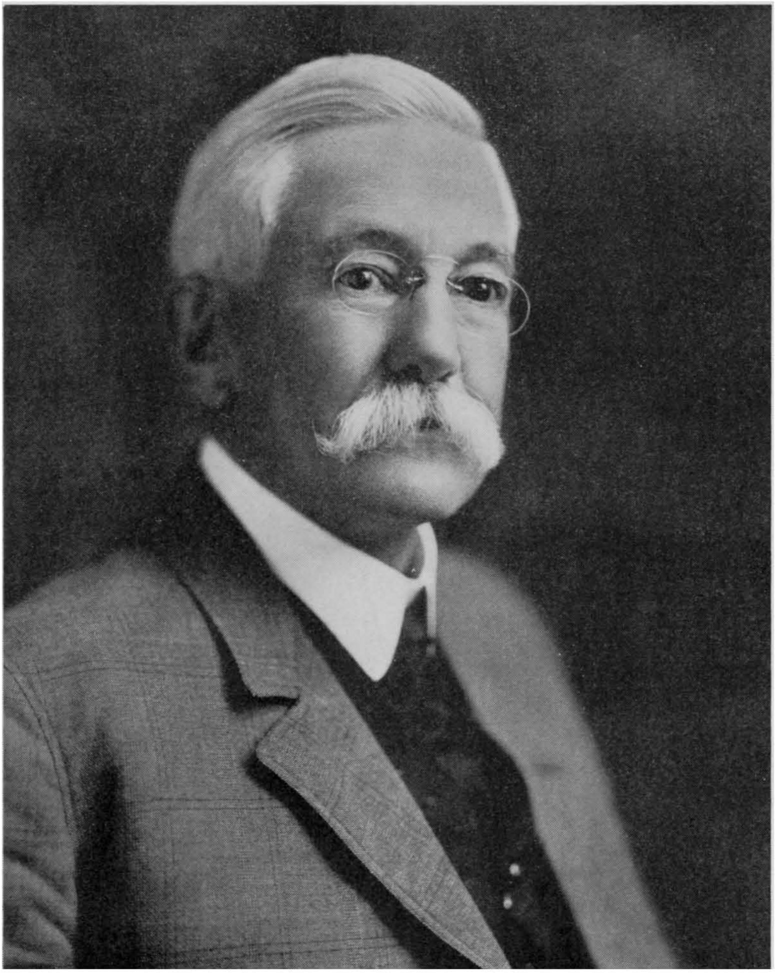

Robert S. Woodward

ROBERT SIMPSON WOODWARD [1]

1849–1924

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A thorough knowledge of mathematics and physics is an excellent introduction to creative work in astronomy, geology, and engineering. In the early days of the National Academy of Sciences this close connection between mathematics and physics, on the one hand, and astronomy, geology, and engineering, on the other, was recognized in the names of the Sections to which Academy members were assigned. Thus Dr. Woodward belonged for many years to the Section of Mathematics and Astronomy and to the Section of Physics and Engineering. He was one of a group of investigators whose interest was primarily in mathematical physics; but who, in his own words, realized that "the earth furnishes us with a most attractive store of real problems"; that "its shape, its size, its mass, its precession and rotation, its internal heat, its earthquakes and volcanoes, and its origin and destiny are to be classed with the leading questions for astronomical and mathematical research." To these problems men like Laplace, Fourier, Gauss, G. H. Darwin, and Lord Kelvin devoted much attention, and in so doing advanced both geology and astronomy and their own mathematical physical sciences.

Dr. Woodward's contributions to geology were in the domain of geophysics, and, although his articles were printed many years ago, they still rank as the most important papers on these subjects thus far published in America. His influence, moreover, in stimulating and encouraging geological work and, in his later years, as president of the Carnegie Institution of Washington, in organizing and administering research projects in geophysics and astrophysics has been an important factor in the progress of geology, astronomy, and other sciences.

Robert Simpson Woodward was born on July 21, 1849, at Rochester, Michigan; he died on June 29, 1924, at Washington,

[1] Revision of "Memorial of Robert Simpson Woodward," by Fred. E. Wright, published in the Bulletin of the Geological Society of America, Vol. 37, pp. 115-134, 1926.

D. C., at the age of nearly seventy-five years, after a long period of illness and suffering, following an attack of influenza.

His early life was spent on a farm near Rochester, a village in Oakland County about 30 miles north of Detroit. His father, the Hon. Lysander Woodward, was one of the most progressive farmers in the State; he sought to apply scientific principles to the operation of his farm and took a keen interest in public affairs. Farm land in this part of the State is of excellent quality and responds well to proper treatment. Without question, this attitude of mind of the father was passed on to the son, who ever afterward was an enthusiastic student of farming methods and in later years acquired and successfully operated, for recreation, a farm in Montgomery County, Maryland, not far from Washington. The following biographical sketch of his father, given in C. R. Tuttle's General History of the State of Michigan, Detroit, 1873, pages 167-168, is significant:

"Lysander Woodward, one of the most prominent men in Oakland County, was born in the town of Columbia, Tolland County, Connecticut, November 19, 1817. His parents, Asahel Woodward and Harriet House, were natives of that State. In 1825, with his parents, he removed to the town of Chili, Monroe County, New York. From here he emigrated to Michigan in the fall of 1838. He married Miss Peninah A. Simpson on the 11th of May, 1843, and settled near the village of Rochester, Oakland County, Michigan, where he still resides. Mr. Woodward's chief occupation is that of a farmer, but he has held many important offices in his township. In 1860 he was elected representative from the first district of Oakland County to the State Legislature, and served with considerable distinction during one regular and two extra sessions. He was county treasurer of Oakland County two terms and performed his duties in a thoroughly satisfactory manner. Mr. Woodward was also president of the Oakland County Agricultural Society for three years, and in this position did great service in advancing the agricultural interests of the Detroit and Bay City Railroad and has been instrumental in canvassing for and promoting its construction. He was chosen the first president of this company in 1871, which important office he held up to May 15, 1873, and he still remains one of the directors of the company. Mr. Woodward owns one of the largest and best cultivated farms in Oakland County."

Doctor Woodward's mother belonged to the Simpson family, a name prominent in the annals of Connecticut. From his mother he inherited many genial traits of character and an interest in his fellow-man, traits that were an integral part of his personality.

His boyhood days were passed in an atmosphere of pioneer farm development, coupled with a broad interest in public affairs. His school training was excellent. The Rochester Academy which he attended ranked well among the schools of the State, and his teachers, especially one, were better than the average. On finishing the academy he wished to go to the university, but his father was not in sympathy with university training and only after the most earnest appeals was he persuaded to allow his son to attend. Four years later, in 1872, the son graduated from the University of Michigan with the C. E. degree. Several summers during the college period were spent in field-work as aide on the United States Lake Survey. After graduation he became assistant engineer on the United States Lake Survey and retained this position for ten years, until 1882, when the work was practically finished.

During this period he was engaged chiefly in primary triangulation work on the Great Lakes, under the leadership of General Comstock of the Corps of Engineers, War Department. This gave him a most thorough training in primary triangulation, in latitude and longitude determinative work, in the testing of field instruments and field methods, and in the office adjustment of field observations by least-square methods. The results of this work were published in chapters 16 to 20 and 24 and 25 of General Comstock's Monographic Report on the Survey of the Lakes, Professional Paper No. 24 of the U. S. Army Engineers; also in several articles in technical journals. During this period Dr. Woodward acquired an interest in the earth as a whole—in its shape, its tides, its atmosphere, and in the host of geophysical problems, many of which still await solution. This keen interest was maintained throughout his life and led him during the next decade to investigate some of the outstanding geophysical problems, and to solve them in spite of formidable mathematical difficulties. To him they had an irresistible fascination, and in later years he looked eagerly forward to the time when he could lay aside administrative duties and return to his research work in geophysics.

On leaving the Lake Survey Dr. Woodward joined the United States Transit of Venus Commission as assistant astronomer and was associated with it for two years, 1882 to 1884, with Professors Asaph Hall and William Harkness. During the transit of 1882 he was with the observing field party under Professor Hall at San Antonio, Texas. There were eight field parties, four in the United States and four in foreign countries, and each party took a number of photographs during the transit of Venus across the sun's disk. These photographs were deposited with the Naval Observatory, where they were carefully measured, and the data of measurement were used in computations to obtain a more nearly correct value of parallax than had hitherto been possible. An immense amount of labor was put into this task, but, as a result of improvements in methods along other lines, the parallax values thus derived were superseded before the final report was completed and it was accordingly not issued.

The twelve years thus spent by Dr. Woodward in geodetic and astronomic work of the highest precision, but always with an immediate practical bearing, trained him to an engineer's sense of values and proportion. Whenever a problem arose he instinctively sought not only the means of solving it, but also the most direct method that would give results of the desired degree of accuracy with the least expenditure of energy. We shall now see how in the next decade he utilized this training to the utmost and made to geology and geodesy remarkable contributions that would otherwise have been impossible. This same resourceful attitude of mind also makes for success in administrative work. It was inevitable, therefore, that in later years Dr. Woodward's balanced judgment should be sought on all sorts of technical and scientific problems, and that he should be drawn eventually into executive work.

From the Naval Observatory Dr. Woodward was called in 1884 to the United States Geological Survey as astronomer, where he soon became geographer, and then chief geographer in charge of the Division of Mathematics. The Geological Survey was at this time still young and had much to learn in all its branches; but its members were men—like Gilbert, Dutton, King, and Chamberlin—who, as masters in geology, with a virgin country to investigate, were full of enthusiasm and eager to accomplish much. It was a congenial atmosphere to enter, and during the next six years Dr. Woodward wrote his most important scientific papers.

His tasks on the Geological Survey were of two kinds, namely, those arising from the topographic branch in connection with field methods and map-work, and the investigation of problems of a geologic nature, but involving the behavior of the earth as a whole. To the first group of tasks Dr. Woodward had long been accustomed. They included latitude and longitude determinations at critical stations in different States, problems on map projection, and the testing of field methods. He prepared a set of formulas and tables to facilitate the construction and use of maps. These tables, in amplified form, are still in use at the Geological Survey and constitute the basis for its topographic sheets. He prepared sets of instructions on methods best adapted for field use in primary and secondary triangulation. With the aid of several members of his division, he set up a small observatory for use in testing field instruments and in giving instruction to topographers in field topographic methods, especially latitude and longitude determinations. As a result of this work, the field methods were put on a practical engineering basis, thus securing the desired degree of accuracy with the minimum expenditure of funds and energy.

Geology at this time was moving forward rapidly, and the geologists of the Survey naturally turned to Dr. Woodward for assistance in problems of a mathematical physical nature. G. K. Gilbert found, for example, that within the area covered originally by Lake Bonneville the shoreline observed on an island in the central part of the lake was 129 feet higher than the strandline at its margin. The question arose, Was this difference in elevation due to the disappearance of the water? T. C. Chamberlin wished also to know to what extent the form and position of the sealevel may have been modified by the attraction of the Pleistocene ice-cap. A general solution to these two problems was given by Dr. Woodward in Bulletin of the U. S. Geological Survey No. 48 on the "Form and position of sealevel, with special reference to its dependence on superficial masses symmetrically disposed about a normal to the earth's surface." This problem was one requiring for its solution mathematical work of the highest order and, in addition, the experience of the engineer, so to shape his formulas that they could be applied directly by the computer. The problem, as Dr. Woodward attacked it, became that of the deformation of the terrestrial geoid (as expressed by the surface of the sea) by the attraction of an ice-cap or other mass. It meant the investigation, by means of the potential theory, of the change in the equipotential surface of a large lake or sea as a result of the presence of an ice-cap, or of a body of water, or of a continental mass. The new set of formulas developed by this investigation sufficed to answer not only the questions of Gilbert and Chamberlin, but also other related questions concerning the distribution of density in the earth's mass and regarding the effect of continental masses on sealevel. In an historical note appended to this paper, Dr. Woodward analyzes the work of Croll, Archdeacon Pratt, D. D. Heath, and Sir William Thomson on this subject and shows the scope of each treatment. The work of these mathematicians demonstrated clearly the limitations that arise when the analyst is satisfied with a general solution to a problem, but fails to obtain a solution that is suitable for computation purposes. On this point Dr. Woodward insisted repeatedly. Thus, in his papers on the free cooling and on the conditioned cooling of a homogeneous sphere, he "sought to express the solutions in such terms that the computer can, without undue labor, assign the temperature at any point within the sphere for any value of the time, having in mind always an application of the theory to the earth." Again, in his paper on the diffusion of heat in a homogeneous rectangular mass, he refers to the extraordinary studies of Fourier and Poisson and notes that "we must extend their work and adapt it to the practical needs of the computer."

Other problems were referred to Dr. Woodward while he remained with the Geological Survey. Thus Mr. Gilbert, in the course of his studies on the moon's face, wished to ascertain the average angle of incidence of meteors and moonlets impinging on the moon. Mr. Gilbert favored the meteor impact theory for the formation of the moon's craters and sought an explanation for the absence of elliptically shaped craters, which one might expect to find if the meteorites struck the moon at angles other than about normal to its surface. Dr. Woodward solved the general problem of the frequency of the different angles of incidence and showed how they vary with the assumptions made.

For the Division of Chemistry he studied the ratios of the weights of the chemical elements and made least-square adjustments involving the solution of 30 simultaneous equations.

From the geologist's viewpoint, Dr. Woodward's most important contributions of this period are his papers on the free and conditioned cooling of a homogeneous sphere and his application of the results presented therein to the secular cooling of the earth and to its age. Geological thought with respect to the age of the earth had been dominated for a generation by the conclusions of Lord Kelvin, who in 1862 and again in 1883 stated, after a detailed mathematical investigation of the subject, "We must allow very wide limits in such an estimate as I have attempted to make; but I think we may with much probability say that the consolidation can not have taken place less than 20,000,000 years ago, or we should have more underground heat than we actually have, nor more than 400,000,000 years ago, or we should not have so much as the least observed underground increment of temperature; that is to say, that Leibnitz's epoch of emergence of the *consistentior status* was probably between those dates." Geologists accepted this statement by Lord Kelvin because his arguments, so far as they could follow them, seemed sound. Nevertheless, although they could not refute his statements, they found it difficult to reconcile them with a mass of geological evidence. Dr. Woodward undertook to reexamine the entire problem, and carried the solution much further than had Lord Kelvin or his predecessors.

The problem of a cooling sphere was not new.

"It was very thoroughly discussed in its purely mathematical features by Fourier and Poisson, the pioneers in the theory of heat, and has been much studied by mathematicians of later date. Able and elaborate as their work is, however, it is not well adapted to the needs of practical application; it does not enable one to trace readily and accurately all the phenomena of cooling throughout their entire history. My investigations of this problem were necessarily made partly with a view to supplying the defect just named."

In his paper Dr. Woodward gives the data necessary for calculation of the secular cooling of the earth; the age of the earth derivable from such data; the distribution of the isogeotherms; the rate of increase of underground temperature and its variation with the time; the radial and volume contraction; the stratum of no strain.

He summarized his conclusions in an address in 1889 as vice-president of the Section of Mathematics and Astronomy of the American Association for the Advancement of Science. After presenting an excellent digest of the work of his predecessors, Dr. Woodward remarks that the conclusions of Lord Kelvin are very important if true.

"But what are the probabilities? Having been at some pains to look into this matter, I feel bound to state that, although the hypothesis appears to be the best which can be formulated at present, the odds are against its correctness. Its weak links are the unverified assumptions of an initial uniform temperature and a constant diffusivity. Very likely these are approximations, but of what order we can not decide. Furthermore, if we accept the hypothesis, the odds appear to be against the present attainment of trustworthy numerical results, since the data for calculations, obtained mostly from observations on continental areas, are far too meager to give satisfactory average values for the entire mass of the earth. In short, this phase of the case seems to stand where it did twenty years ago, when Huxley warned us that the perfection of our mathematical mill is no guaranty of the quality of the grist, adding that as the grandest mill will not extract wheat flour from peas-cods, so pages of formulæ will not get a definite result from loose data."

This statement by Dr. Woodward, together with his published re-treatment of the entire problem, set the minds of geologists at rest concerning the restrictions imposed by Lord Kelvin. Some years later the generation of heat by transformations in radioactive substances within the earth's crust was discovered as a factor tending to retard the rate of cooling of the earth and to increase the limits set by Lord Kelvin.

In this same vice-presidential address Dr. Woodward summarized also the opinions regarding the contractional theory of the earth and the theory of isostasy which had been propounded only a few months before by Dutton, and he inferred "that isostasy is competent only on the supposition that it is kept in action by some other cause tending constantly to disturb the equilibrium which would otherwise result. Such a cause is found in secular contraction and it is not improbable that these two seemingly divergent theories are really supplementary." With reference to the solidity or the liquidity of the earth's interior he notes that "the difficulties appear to be due principally to our profound ignorance of the properties of matter subject to the joint action of great pressure and great heat. It is not clear how our knowledge is to be improved without resort to experiments of a scale in some degree comparable with the facts to be explained." Dr. Woodward was a firm believer in experiment. In his own words, "The price of progress, like that of liberty, is eternal vigilance. One must be ever active, ever patiently persistent, proving all things and holding fast to that which is good."

Dr. Woodward was also interested in the possible laws of arrangement of density in the earth's mass under the assumption that the density increases continually from the surface toward the center. Realizing the dependence of the arrangement of density on certain known properties of the earth, such as its mean density, its surface shape and surface density, and its constant of precession, he sought to determine the most probable law of increase, but found that the available data were not adequate for the purpose.

In 1890 Dr. Woodward resigned from the Geological Survey to accept a position with the United States Coast and Geodetic Survey. Major J. W. Powell, in his Report of the Director of the Geological Survey for 1889-1890, states that Dr. Woodward's "resignation was accepted with regret, as this Survey can ill afford to lose his rare ability for mathematical research. Since his first association with the Survey, in 1884, he has not only supervised the computations made in connection with the triangulation and astronomic determinations, conducted the computation of a series of tables for the use of the Topographic Branch, and given aid to geologists having occasion to read their data by mathematical methods, but he also made important additions to geologic science by discussing and advancing, on several lines, the theories of terrestrial physics. His discussion of the form and position of sealevel of the earth as dependent on superficial distribution of matter yielded formulas and numerical results of importance in the discussion of the physical results of the filling and emptying of the Bonneville Basin, of the formation and dissolution of the northern ice-sheet, and of all other phenomena involving the influence of superficial masses on the geoid. His discussion of the problem of a heated sphere, such as is presented by the earth, and of the contraction resulting from its slow cooling, is especially valuable for its indication of the additional work needed for the determination of the constants involved, and for the illustration of the dependence of the mathematical results upon important postulates, the possibility of whose future demonstration is not apparent. He has also studied and discussed the distribution of density and pressure within the earth and made a preliminary study of the stresses and strains involved in the deformation of the earth's crust within the limits of elasticity."

Dr. Woodward was called upon by the Coast and Geodetic Survey, because of his long experience in precise triangulation, "to devise means of testing in the most thorough way practicable the efficiency of the various forms of base apparatus used by the Survey, especially the efficiency of long steel tapes or wires." To this congenial task he applied himself with pleasure and enthusiasm. He devised the iced bar apparatus for measuring base lines and for calibrating steel tapes. His method for calibrating steel tapes was adopted by the Coast and Geodetic Survey and remains still the standard method. He was also the first to measure primary base lines with long steel tapes, and to prove that these tapes furnish the required degree of accuracy, namely, one part in one million. This work was of fundamental importance to geodesy and not only resulted in the saving of much money and time in field-work, but placed the primary triangulation work of the Coast and Geodetic Survey on a higher plane than had been theretofore possible. He insisted, moreover, that, in the field, measurements only of the kind and number be taken that are necessary to insure the desired degree of accuracy. His influence led Hayford some years later to revise and standardize the field and computational methods of the Coast and Geodetic Survey, thereby greatly increasing the speed of the work, lowering the costs, and placing the results on a uniformly high level of known precision. In this respect the Coast and Geodetic Survey set the example for other surveys the world over.

Maps constitute a very important item in geology, and for this contribution alone geology owes much to Dr. Woodward.

While at the Coast and Geodetic Survey Dr. Woodward prepared for the Smithsonian Institution the Smithsonian Geographical Tables. In the introductory part (93 pages) of this volume useful formulas are given for the geographer and cartographer, the geodesist and astronomer; also a brief statement of the theory of errors is included. The tables cover 180 pages and furnish data of interest to geographers and students of allied sciences. The third edition of these successful Tables was issued in 1906 and was reprinted in 1918.

In 1893 Dr. Woodward was called to Columbia University as Professor of Mechanics and Mathematical Physics. From that time on, his work was that of the teacher and administrator. In 1895 he became dean of the College of Pure Science and was confronted with many problems that required tact and perseverance for their solution. His influence on the student body and on the students directly under him at Columbia was remarkable. He insisted on good work from each student, but he was ever ready to give help where it was needed. His thorough knowledge of mechanics and of the needs of the engineer enabled him to give to his engineering students the kind of information they most needed, and to train them to the attitude of mind essential to successful accomplishment in engineering work.

Intensely interested in the human element, and with a most attractive, genial, and lovable personality, his advice was sought on every side, both by the student body and by the faculty; so that, in spite of the best intentions and very hard work, he could not obtain for himself the desired periods of quiet to pursue his mathematical work, to which he looked ever forward.

He did, however, undertake, with the aid of Professor Wills and Dr. Deimel, an investigation into the possibilities of the double suspension pendulum for the determination of the value of gravity. The advantage of this method over the ordinary method is the ease with which the length of the pendulum can be ascertained; its disadvantage is the uncertainty regarding the elastic behavior of the suspension fibers or ribbons. Dr. Woodward made a thorough mathematical investigation into the subject, but was called to another position before the experimental work had been completed, and he never found an opportunity to finish the task. The records of the investigation, so far as they were carried, are on file in the Physics Department of Columbia University.

His interest was also aroused by A. L. Queneau in the cooling and crystallization of intrusive igneous masses as an example of a special case of the general theory of the cooling of a heated mass (bar or sphere), as developed by Woodward in 1888. Dr. A. C. Lane was the first to treat this problem, but his solution was somewhat different from that of Dr. Woodward. Queneau adopted Woodward's mode of treatment and applied it to a study of certain igneous rocks, arriving at essentially the conclusions reached by Dr. Lane.

On December 13, 1904, Dr. Woodward became president of the Carnegie Institution of Washington, and met the problems of this new kind of research institution with the same good common sense that characterized all his executive work. He analyzed each problem thoroughly, including that of personnel, and insisted that the institution be run on a thoroughly businesslike basis, that it live within its income, and that its money be spent with fair expectation of a good return. He established several departments of the institution and organized the institution about them. Miscellaneous appropriations to aid individual pieces of research were carefully scrutinized and every effort was made to spend the money entrusted to his care wisely and in the interests of science. Dr. Woodward showed keen appreciation of scientific activities outside his own sphere of astronomy and earth science and in his later years was much interested in archæology and in the humanities generally.

He believed that he who thinks clearly writes clearly. "It is so much easier to appear to write well, or even brilliantly, than it is to think clearly, that facile expression is often mistaken for sound thought." He himself wrote exceedingly well and coined many apt and telling phrases.

In his relations with the men of the institution under him he showed the keenest interest and encouraged them wherever possible. His home life was of the ideal kind. Both he and Mrs. Woodward had a genius for hospitality and made each visitor feel at ease. Their home in Washington was ever the meeting place for scientific and other folk, just as it had been at Columbia University.

In the early days of the Carnegie Institution the effort to find and to aid the unusually talented man in his scientific work, in accordance with the expressed wish of the founder, Mr. Carnegie, led to the placing of numerous small grants with men over the country who had special problems to solve. When Dr. Woodward became president he examined carefully into these random grants and found that a surprisingly small number yielded returns to science commensurate with the outlay. He therefore concluded that, so far as possible, the efforts of the Carnegie Institution should be concentrated on projects of large scope, which would probably not otherwise be attempted, and that these efforts for the most part should be carried forward by investigators in the employ of the Institution. The result was greater emphasis on the departments of the Carnegie Institution, such as the Geophysical Laboratory and the Mount Wilson Observatory, and the more intensive development of all these departments. A few research associates who were able to give their entire time to special research problems were also maintained as integral members of the Institution, but the voting of small grants to aid in the solution of specific problems under attack by individuals connected with other institutions was minimized as a policy of the Institution.

At the outbreak of the war Dr. Woodward was much disturbed by the trend of events in Europe, and, when this country entered the war, he was influential in persuading the trustees to offer the services of the entire Institution to the Government.

The war work of the Carnegie Institution covered many fields of activity, from the manufacture of optical glass to military intelligence work, and to it all Dr. Woodward offered the most effective support. He himself was a member of the Naval Consulting Board, as one of the two representatives from the American Mathematical Society to the board.

Dr. Woodward was president of the Carnegie Institution from December 13, 1904, to January 1, 1921, a period of sixteen years. The first president of the Institution, Dr. D. C. Gilman, president emeritus of Johns Hopkins University, had retired from active life, and he undertook the task only temporarily, until the best man for the position could be selected. When Dr. Woodward entered upon his duties the Institution was two years old and had still to establish itself in the minds of the public and to determine on the best policies to follow. It needed at this critical period the mature judgment and experience that Dr. Woodward had acquired in governmental and educational positions; it needed also an enthusiastic and genial personality to carry through successfully the projects that merited encouragement and at the same time to avoid the far greater number of suggested projects which, although urged upon the Carnegie Institution most insistently, really promised little return. On looking back over his years of activity, he states in his last report as president that "probably no other organization in the evolution of learning has been so beset by what Dr. Johnson called the anfractuosities of the human mind as the Carnegie Institution of Washington." But his keen sense of humor carried him over the rough places and his kindly, well-balanced attitude instilled in those with whom he came in contact the feeling of assurance that each proposal would be dealt with fairly and on its merits. Thus it was that the Carnegie Institution grew and flourished and contributed much to the development of science in this country.

Dr. Woodward received many honors from different scientific societies. He was vice-president of the Section of Mathematics and Astronomy of the American Association for the Advancement of Science, in 1889; its treasurer, 1894-1924, and its president in 1900; president of the American Mathematical Society, 1898-1900; of the New York Academy of Sciences, 1900-1902; of the Washington Academy of Sciences, 1915; of the Philosophical Society of Washington, 1910, and of the Literary Society of Washington, 1913-1914. He was a member of the National Academy of Sciences, the Astronomical Society, and the American Physical Society, and fellow of the American Academy of Arts and Sciences and of the American Philosophical Society. He was elected a member of the National Academy of Sciences in 1896. He served as member of its Council from 1909 to 1915 and on the following Academy committees: Weights, Measures, and Coinage (1906-1924); Gould Fund (1915-1924). He was Chairman of the Section of Physics and Engineering (1908-1913); and Chairman of the Special Committee appointed in 1913 to advise the Secretary of Agriculture on the selection of a new Chief for the United States Weather Bureau. He was a member of the Executive Board of the National Research Council, 1918-1920; of the Executive Committee of its Division of Physics, Mathematics, Astronomy, and Geophysics, 1918-1920; and of the Section of Geodesy, of the American Geophysical Union, 1919-1920.

He was associate editor of *Science* from 1884 to 1924, and of the *Annals of Mathematics* from 1888 to 1889. Together with Prof. Mansfield Merriman, he edited a series of mathematical monographs; he himself contributed in 1896 to the series the monograph on the "Theory of Probabilities."

From the universities he received many honorary degrees: University of Michigan, Ph. D. in 1892; LL. D. in 1912; University of Wisconsin, LL. D. in 1904; University of Pennsylvania, Sc. D. in 1905; Columbia, Sc. D. in 1905; Johns Hopkins, LL. D. in 1915. He was a member of the Century Association of New York and of the Cosmos Club in Washington.

In 1876 he married Miss Martha Gretton Bond of Detroit who with three sons survived him.

In addition to his great attainments, Dr. Woodward possessed a simplicity and open friendliness of manner and character that endeared him to young and old alike. It was a privilege to know him, to feel his radiant enthusiasm, and to be uplifted by his hopeful outlook on this world and its many problems.

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