NATIONAL ACADEMY OF SCIENCES

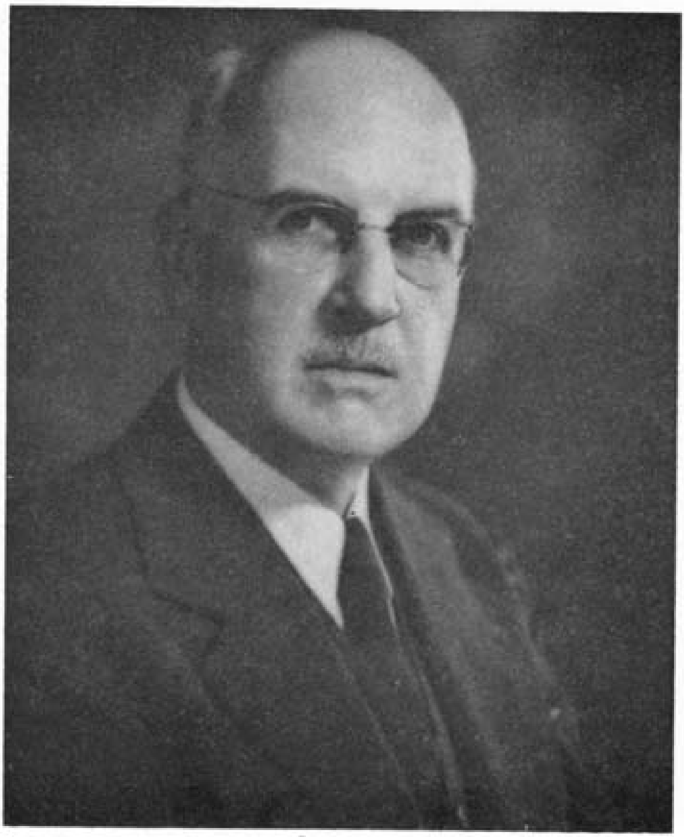
WARREN JUDSON MEAD

1883—1960

A Biographical Memoir by

ROBERT R. SHROCK

Biographical Memoir



W J Mead

WARREN JUDSON MEAD

August 5, 1883–January 16, 1960

BY ROBERT R. SHROCK

An outstanding geologist, W. J. Mead served his science with distinction in four separate but closely related fields of activity. For more than forty-five years he was an inspiring teacher of structural and engineering geology to thousands of students. He was an ingenious and imaginative research scientist, who brought to his inquiry deep insight and great power to visualize in three dimensions and who used the quantitative and experimental approach to gain a better understanding of natural phenomena. As a versatile professional consultant he served many clients as an engineering geologist on problems involving mine subsidence, earth and rock slides, tunnels, dam sites, mineral deposits, exploration programs, and surface and underground mining. As a department head at M.I.T. he broadened and liberalized the curriculum in geology, recruited additional staff for new subjects of instruction, sponsored new research projects, and in general oriented instruction and research in a more quantitative and experimental direction. Because of his keen scientific insight, his quick imagination, his great powers of visualization and extrapolation, and his canny ability at judging people, he added something new and important to every problem and situation he seriously considered.

Early Life and Education. Warren Judson Mead was born on August 5, 1883, in the small town of Plymouth in northeastern Wisconsin. He was the second of four children born to Major C Mead and

Rose Anna (Robinson) Mead. Both the Mead and Robinson families had lived in northeastern Wisconsin for several generations and both traced back to earlier forebears in New York State.

As a youth, Mead attended the primary and secondary schools of Plymouth and normally would have been graduated from the local high school in 1899. However, on the invitation and advice of the principal, and with his father's strong approval, he volunteered to postpone graduation and take an extra year of special instruction. Forthwith, the principal, who obviously was an unusually resourceful and imaginative teacher, took in hand the dozen bright youngsters (Mead was fifteen) who had volunteered for the extra year, and gave them special instruction in mathematics and science. In discussing his early education Mead always gave him full credit for developing the power of three-dimensional visualization that stood him in such good stead later in structural geology and for arousing a lifelong interest in how machines worked and how natural phenomena were to be explained.

It is worth brief notice to describe one of the principal's techniques because of its great effect on the youthful Mead. In the class in plane and solid geometry, the boys had to close their eyes and "visualize" the problem as it developed on an imaginary blackboard. There were no drawings on the regular blackboard, nor on paper, to be scanned before the exercise began. One by one the boys had to describe a construction in detail. If the one reciting made a mistake, the boy detecting the error took over and continued. Little wonder that Mead had unusual ability to visualize the relations of lines, planes, and curved surfaces in three dimensions! There could well be an important lesson here for many of our present high school teachers of mathematics.

After graduation from high school in 1900, Mead wanted to enter the University at Madison, but the family could not afford it, so he set about looking for a way to earn some money. About the most likely work for a young high school graduate at the time was to teach a country school. He took the examination for a teacher's certificate, then given by the County Superintendent of Schools, and qualified for a First Grade Teachers Certificate, which permitted him to take any teaching position in the county.

With certificate in hand he found a one-room school in the neighboring village of Johnsonville that needed a teacher and immediately accepted the position for the school year 1900–1901 at $40 per month for seven months. After paying his living expenses, including board and room in the home of one of the German families, at $8 per month, he saved about $200. His pupils, about twenty in number, came from the village and surrounding farms and ranged in age from five to eighteen years, and he had to teach all eight grades. The next year, 1901–1902, he taught the "upper" grades in a two-room school in another neighboring village named Hingham. His seven-month salary for teaching some forty pupils was $75 per month, from which he had to pay $12 per month for room and board. Mead often remarked that the lessons he learned during his two years as a country schoolteacher, when he had to control and teach boys bigger and older than he was, stood him in good stead many times in later years when called on to deal with difficult and recalcitrant persons. With the money saved from these two years of teaching, he was able to plan on entering the University at Madison in the fall of 1902.

Student Years at Wisconsin. As the twentieth century opened, the age of electricity was being rapidly ushered in with the introduction of electric bells, motors and lights, trolley cars, telephones and the like. The youthful Mead was greatly impressed by all of the wonderful changes going on around him and became much interested in electricity. When his high school teacher—the same one who taught him "visual" geometry so effectively—took him and a schoolmate to the school basement and showed them the wet batteries that made the electricity, and the magnets and bells that had been installed, Mead's interest was deeply excited. Soon he was volunteering to help the electricians who came from Milwaukee to wire the local houses, and he and a schoolmate made their own telegraph sets, strung up wires between their homes several blocks apart, learned the Morse Code, and carried on many lengthy telegraphic conversations. It was natural, therefore, that when he entered the University of Wisconsin in the fall of 1902, he enrolled as a freshman in electrical engineering. Furthermore, Mead's father, being a lawyer and politician and having struggled through the early years of his own legal career, felt that his son would do much better to prepare for a career in electrical engineering, so that he could get a good job and start earning a good salary immediately after graduation. And so the die seemed cast that Mead would become an electrical engineer! How he became a geologist instead is an interesting and instructive story.

A toy camera at eight years of age led him to a lifelong interest in photography; an imaginative and resourceful teacher of high school geometry, already referred to, helped him to develop an unusual ability to visualize relationships in three dimensions; a senior student in trouble with his petrographic thesis was responsible for creating an immediate interest in geology; an able college teacher led him to leave electrical engineering and enter geology seriously; another great teacher and research geologist, sensing his latent abilities, motivated him to alter his course for the last time and to devote his efforts to the quantitative aspects of geological problems. Once his course was firmly set, he never left it, and during his long and productive life he added something new and important to every problem he touched.

The first two years in college were fine so far as mathematics, physics, and chemistry were concerned, but Mead found the electrical engineering subjects dry and uninteresting because students were told to "study and remember what is in the books; memorize the formulae; don't try to understand anything, just learn it!" Strongly motivated by the desire to know how and why things worked the way they did, Mead naturally found this kind of instruction dull indeed.

One Sunday morning, near the end of his sophomore year, Mead found his next-door fraternity brother, a senior in geology, trying unsuccessfully to make for his thesis drawings of what he saw in a petrographic microscope. He asked him why he did not photograph what he saw. The senior replied that the geology department did not have any equipment for taking photographs through a microscope. But Mead had had several cameras as a youngster—the first a toy one obtained at age eight as a prize for getting new subscriptions to a youth's magazine, knew all about them, was an ardent amateur photographer, as he continued to be all of his life, and felt certain that they could photograph anything they could see. So after lunch the two students went to Science Hall, taking the microscope, the thin sections, and Mead's 5 x 7 view-camera loaded with plate holders and dry plates. Using sunlight, they made a series of excellent photographs, and in doing so Mead became so excited over the problems of the senior's thesis that he decided to take some geology courses the following fall to learn more about the subject.

Thus it came about that he enrolled in general geology with N. M. Fenneman, then a professor at Wisconsin. He was so stimulated by Fenneman's lectures that he soon changed his course to General Engineering with a major in geology. Incidentally, he never regretted the training in engineering, for many years later, when he sat with planning boards to discuss power dams, he understood the technical language of the electrical engineers as well as that of the engineering geologists.

Fenneman suggested that he investigate the physiography of Sheboygan Marsh, the remnant of a former glacial lake near his home at Plymouth, and write up its history for his thesis. Accordingly, Mead spent the summer of 1905 mapping the old shoreline features and gathering field data. When he returned to Madison in the fall, he had to take a heavy schedule of geology subjects to make up for what he had missed while a student in electrical engineering. Mineralogy was with W. O. Hotchkiss, who was to become his lifelong friend; metamorphic geology and structural geology were with C. K.

Leith, then head of the department, with whom he was to be closely associated for the next thirty years.

To his subjects in geology Mead brought an understanding of mechanics and strength of materials and facility with the slide rule, both learned as an engineering student and essentially unknown to geology students at the time. No doubt Leith quickly sensed these capabilities, as well as Mead's desire to work things out quantitatively, for he persuaded him to abandon the thesis on the Sheboygan Marsh and attack a challenging problem in metamorphic geology. The problem, in effect, was this:

"Assuming that all sedimentary rocks have come from the natural destruction of older rocks, and that the earliest sedimentary rocks came from still older igneous rocks, work out the relative amounts of the principal types of sedimentary rocks (shale, sandstone, and limestone) that have been produced by the redistribution of the materials of the igneous rocks."

Quite a thesis problem for a senior, but Mead tackled it with enthusiasm!

As the end of the spring term of his senior year approached, he had not yet completed his thesis because he couldn't decide how to relate the chemical data. Then, in the middle of a May night, the "visual" geometry he had learned with his principal in that extra year in high school came to him, and he decided to develop a three-dimensional graph that would establish limits within which the shale/sandstone/limestone ratio had to fall. Within a few days he had constructed a three-dimensional model, and his thesis was complete. It won him the Science Medal of the Science Club of the Faculty for "the best Baccalaureate thesis in Science" for the year 1906, and he was granted his A.B. in geology.

The thesis, which was the basis for his first published paper—*Redistribution of Elements in the Formation of Sedimentary Rocks,* soon came to the attention of Charles R. Van Hise, then President of the University of Wisconsin. Van Hise had only recently completed his monumental *A Treatise on Metamorphism* (1904) and had estimated the ratio of shale/sandstone/limestone to be 65/30/5, whereas the young senior's estimate was 80/11/9, and the latter could demonstrate the validity of his ratio by an ingenious three-dimensional model that he had thought up and constructed specially for the problem! Great man that he was, Van Hise came down the hill from the President's office and visited Mead in his student cubby-hole in Science Hall, listened eagerly to the young student explain his model and defend his conclusions, and then expressed his delight and satisfaction with the new ratio which he immediately accepted. This meeting of student and master made a great impression on Mead, and he often spoke of it to his students and colleagues as an example of how a really great scientist reacts when a youngster proves that he had reached an incorrect conclusion.

Having come under the influence of three of America's great teachers of geology—Fenneman, Leith, and Van Hise—Mead was now fully convinced that he wanted to follow a geological career. Because of his engineering training and of his interest in the quantitative approach, it was natural that his future work would lead into the quantitative and experimental aspects of geological problems.

Skilled in observation, both by eye and with camera; possessed of keen scientific insight and unusual ability to visualize in three dimensions; master of the slide rule and of the engineer's knowledge of the mechanics of solids; of original bent and facile of hands in the use of machine-tools; and strongly motivated toward science by a keen interest in determining ways and means of demonstrating these phenomena, Warren Mead was unusually well equipped to attack both quantitatively and experimentally the whole broad front of physical geology as he entered the graduate school of the University of Wisconsin in the fall of 1906.

Recognizing the unusual abilities of his young protégé, and desirous of taking advantage of his engineering training, Leith appointed Mead a student assistant for the school years 1906–1907 and 1907–1908. While carrying on graduate work toward a master's degree, Mead was also to devise problems for the students to solve quantitatively in three new laboratory courses that Leith was initiating—one in structural geology, one in metamorphic geology, and one in ore deposits. These new laboratory courses, with their many challenging and ingenious problems and numerous experimental models, all developed by Mead, immediately became established parts of the geology curriculum at Wisconsin. Subsequently, the problems and laboratory devices came to be widely used in other schools, particularly where Wisconsin graduates accepted teaching positions. As a consequence Mead's contributions to geological instruction have had a long and widespread effect throughout North America.

Teaching and Research at Wisconsin. Upon receiving his A.M. degree in 1908, Mead was appointed instructor in geology, and thus commenced his twenty-six-year period of teaching, during which time Wisconsin's department of geology came to be considered one of the greatest in the entire world. Under the continued stern and demanding but nonetheless friendly guidance of Leith, and with inspiring encouragement from the great Van Hise, Mead's special abilities, quick mind, and boundless energy were put to the fullest test. From his fertile imagination and ingenious experimentation during the next two decades (1908–1928) came an array of ideas, instruments, and devices that have had a profound effect on geology and geological research through the first half of this century.

In these earlier years at Wisconsin, Mead was greatly interested in the purely scientific aspects of geology, and his early publications were the results of this interest. However, he was soon faced by the dilemma in which many a young college instructor has found himself. Should he continue to be a research scientist and teacher, which he really wanted to do, but on a near-starvation salary, or change to a career of teaching and applied geology, which would afford a better income? Necessity dictated the decision, and he was forced to choose the latter course. Had he continued on his earlier path as a research scientist, there seems little doubt that he would have contributed even more than he did to some of geology's most perplexing problems. Unfortunately the dilemma is still with us, and there is a strong likelihood that many a promising young scientist or teacher is today being forced by circumstances to choose the more profitable career just as Mead had to do at an early age.

From 1908 to 1934, Mead taught geology at Wisconsin, advancing from instructor in 1908 to full professor in 1918. In 1916 he was asked to organize and give a course in engineering geology for civil engineers, and for nearly forty years afterwards he taught the subject to a host of young engineers, from 1916 to 1934 at Wisconsin, and from 1934 to 1954 at M.I.T. His was certainly one of the earliest courses offered anywhere in America, and he brought to his teaching not only excellent lectures, spiced with numerous examples drawn from his experiences as an engineering geologist, but laboratory demonstrations made memorable by the use of models and devices of his own invention. As many of his students will agree, it was an unforgettable experience to hear and see him demonstrate some basic principle, such as dilatancy, as it applied to geology or engineering.

In 1926, before leaving on a year's leave of absence, to be a visiting professor at the University of California—Berkeley (1926–1927), he was granted a Ph.D. degree in geology upon the recommendation of the department he had served for twenty years.

During his many years at Wisconsin, Mead not only gave his own course in engineering geology, but also shared with Leith three other major courses that most graduate students took—metamorphic, structural, and economic. Leith generally gave the opening lectures, to sketch "the broad general setup," and Mead then followed, in addition to giving the accompanying laboratory work. Many of the students who took these courses will recall that not infrequently Mead would unexpectedly appear as lecturer when Leith was expected. This would generally be on a warm sunny day when the golf links beckoned and Leith suddenly had a luncheon engagement at the Madison Club.

While many of the students who took these "hard-rock" courses with Leith and Mead did go into mining with outstanding success, it is an indication of their fundamental and far-reaching content that many other students have become distinguished petroleum geologists.

Teaching and Administration at M.I.T. When M.I.T.'s great Waldemar Lindgren was approaching retirement age, a world-wide search was made for his replacement as head of the Department of Geology. Mead was the unanimous choice of the selection committee, and in the summer of 1934 he accepted the chairmanship of the department, which he held until retirement in 1949. After retirement as professor and chairman, he continued for five years as Honorary Lecturer, giving his course in engineering geology until June 1954 when he was made Professor Emeritus.

Soon after arriving in Cambridge, Mead set about finding what he might do in his new position. Lindgren had brought international fame in mineral deposits and economic geology, and the department was especially strong in these fields as well as in ore geology and mineralogy (Newhouse and Buerger), stratigraphy and paleontology (Shimer), geophysics (Slichter), petroleum and field geology (Whitehead), and general geology (Morris). Mead disliked the rigid curriculum that allowed the student little or no choice in electing subjects. He proceeded promptly to liberalize the curriculum by reducing the number of required subjects and granting some choice of electives. He himself immediately started to offer lecture courses in structural geology and engineering geology, and within a few years had brought into the department four new staff members to broaden the instructional offerings—Fairbairn (petrology), Shrock (sedimentology and paleontology), Parks (mineral economics and mineral industries), and Hurley (mineral deposits and geochronology).

Following his own interests, he sponsored staff research that gave more emphasis to the quantitative and experimental approaches to geological problems. In order to assist the research of Louis Slichter in geophysics and M. J. Buerger in x-ray crystallography, he engaged an instrument maker and had a small machine shop set up. When

Walter Newhouse desired to use a spectrograph to study the variation in minor element content in minerals and ores, Mead induced Godfrey L. Cabot of Boston to provide funds for construction of the desired instrument, a 21-foot, 30,000 line grating spectrograph in a Wadsworth mount covering the range between 2500 Å and 6000 Å. When Robley D. Evans, a young physics Ph.D. from Cal Tech, arrived at M.I.T. in 1934 with a keen interest in how radioactivity might be used to determine the age of rocks, he found an immediate and enthusiastic supporter in Mead, who not only gave him every possible assistance but did likewise for one of Evans' associates, Clark D. Goodman, who was later to help initiate several lines of age-work in the department of geology with W. L. Whitehead and P. M. Hurley.

In helping staff members and graduate students to get a research project started, his influence was not always evident, but it was always important because it came at the very beginning when assistance was critical. Though listed as director of several projects, Mead nearly always left publication of results to those who actually did the work and refused to have his name included in the authorship.

He was noted for his generosity to and support of young scientists who went to him for advice and assistance. If one had a legitimate request he was certain to find Mead receptive and enthusiastic. If he could not find the needed funds in his official budgets, he actively sought them from some of his friends. Failing this, he reached into his own pocket. More than one graduate student and young staff member received such personal aid under the guise of a gift from some other source. He strongly supported his younger staff members in every way and never hesitated to speak in their support in the councils where such support was important. He was a friendly but rigorous critic in editing manuscripts and was always willing to sit down and discuss a problem with one of his students.

Geological Consultant and Engineering Geologist. During his long academic career (1906–1954) at Wisconsin and M.I.T., Mead was frequently engaged in non-academic professional work that occupied most of his summers and many shorter periods of time during the regular school year. In his years at Wisconsin, he was frequently on leave for part or all of one term, and students carefully planned their schedules so as to be able to take every course that he offered when he was in Madison.

His earlier assignments were largely concerned with field exploration for iron, copper and nickel, particularly in the Lake Superior Region, and for bauxite in Arkansas. In his intermediate years he examined many dam sites and a few tunnel sites and areas of subsidence due to mining. Then, in his later years he turned again to metals and metallic ores, but also did work on non-metallics, underground water, industrial minerals, and a few dam sites and tunnels.

His professional reports, all carefully bound and numbered in chronological order, total almost a hundred, and his clients more than twenty-five, of which the following were some of the more important—Aluminum Company of America, 1912–1950 (bauxite exploration; geological advice on dam sites and tunnels), Panama Canal Commission, 1916 (earth slides), South Manchurian Railway Company, 1921 (coal, iron ore), Colorado River Board, 1916 (Boulder Dam), U.S. Army Corps of Engineers, 1932–1937 (Garrison Dam; Fort Peck Dam; some 35 other dam sites), Federal Emergency Administration of Public Works, 1935 (flood control and conservation), and Reynolds Metals Company, 1941–1960 (bauxite exploration; research center).

In addition to the services rendered his clients, three other very important results came from his professional work. First, he drew frequently and extensively on this work for examples in his teaching, and he often remarked that he was a much better teacher because of his consulting work. Second, knowing the needs of his clients and of industries in general, he was able to guide students more effectively in their preparation for later applied work and to recommend them for the positions for which they were best trained. Third, and perhaps most important, the problems he encountered in his applied work drove him to the laboratory in order to find satisfactory explanations and answers. From such necessities he designed and built a considerable array of devices, models, and instruments that aided him in solving structural problems, discovering new ore, creating order out of some great mass of data, or demonstrating some problem requiring three-dimensional visualization. From his field work also came at least two of his chief original contributions to geology—his theory for the origin of the Arkansas bauxite deposits and his application of dilatancy to the deformation of granular and solid materials.

A minor part of his consulting work took the form of acting as an expert witness in a few court cases involving litigation over mining problems. He did not enjoy this kind of work, however, and did it only under special conditions.

Research Scientist and Inventor. Mead had a lifelong interest in scientific research and was quick to see how new ideas, methods, techniques, and instruments could be applied to geological problems. If he got an idea himself and could find no device or instrument to test or apply it, he made one.

Thus when Leith assigned him a senior thesis that was more difficult than many a doctor's, he proceeded to solve the problem by an ingenious three-dimensional model, which is described and illustrated in his first publication, *Redistribution of Elements in the Formation of Sedimentary Rocks* (1907). Scarcely a year later, when Leith again assigned him another complex and time-consuming task—that of reducing a great mass of diverse physical measurements of iron ore to cubic-feet-per-ton of ore in the ground—he struggled with his slide rule for two days. Then, mentally calculating that it would take him all summer at the rate he was going, he stopped for a day, designed a nomograph for the purpose, and in a few days graphically completed his calculations. At the request of H. Foster Bain, then Director of the U.S. Bureau of Mines, and W. C. Mendenhall, then Director of the U.S. Geological Survey, Mead described the widely useful nomograph in his second publication, *The Relation of Density, Porosity, and Moisture to the Specific Volume of Ores* (1908).

Field studies with Leith of the Cuban iron ores led to several joint papers in which the lateritic origin of these ores was proposed, *Origin of the Iron Ores of Central and Northeastern Cuba* (1911) and *Additional Data on Origin of Lateritic Iron Ores of Eastern Cuba* (1915). This work no doubt influenced him considerably in reaching the conclusion that the bauxite deposits of Arkansas resulted from the natural weathering of the underlying nepheline syenite, as set forth in his classic paper, *Occurrence and Origin of the Bauxite Deposits of Arkansas* (1915). These studies of the Cuban iron ores and Arkansas bauxite, together with his earlier work on the chemical characteristics of the Lake Superior iron ores, were basic studies in a more ambitious program on changes that take place in rocks. The research done on this program culminated in the jointly published textbook—*Metamorphic Geology* (Henry Holt and Co., 1915)—long since a collector's item and a book that played an important part in getting quantitative work on geological problems started in America. As an aid in much of the work on the book, Mead invented a circular slide rule and several special graphical diagrams to convert analyses of ores and rocks from oxides to minerals, and published them in—*Some Geological Short-cuts* (1912).

Leaving the subject of chemical rock changes more or less behind, Mead turned next to the study of rock structures and the mechanics of granular and solid materials under deforming stresses. Out of this interest came a series of papers, starting in 1920, which soon became classic references in structural geology. The more important of these are: *Notes on the Mechanics of Geologic Structures* (1920), illustrating by a special device the importance of shearing by rotational stress and fracturing by torsional warping; *Determination of Attitude of Concealed Bedded Formations by Diamond Drilling* (1921), in which he described and illustrated an ingenious apparatus he had invented for determining the attitude of concealed beds from diamond drill data; *Some Applications of the Strain Ellipsoid* (1930), in which he pointed out how the ellipsoid of strain can be used to gain a better understanding of how brittle rocks fail under deforming stresses; and finally *Folding, Rock Flowage, and Foliate Structures* (1940), in which he reviewed the whole question of foliate structures and how they are formed.

When he first became aware of the phenomenon of dilatancy—the expansion of granular masses when deformed due to the rearrangement of grains—he immediately saw that the phenomenon could be extended to include all volume increase due to deformation. He pointed out the far-reaching geologic and engineering significance of the consequences of dilatancy by deformation in two well-known papers, *The Geologic Role of Dilatancy* (1925) and *The Role of Dilatancy in Engineering* (1930). In both papers are illustrations of models that he made to illustrate the phenomenon. Interestingly, he never lost interest in dilatancy, and in his later years he demonstrated to medical men, by means of some sand-filled rubber bags and glass tubing, how they could reproduce a faithful impression of the tender stump of a severed limb without pain to the patient, and in his last paper, published in 1954, entitled *The Principles of Dilatancy Applied to Techniques of Radiotherapy,* he again shows how his sand-filled bag and assorted components can be used to provide a comfortable but rigid support for any part of a patient's body during radiotherapy.

This late interest in medical application of dilatancy was accompanied by another medical interest aroused by his youngest son, a research physiologist, who needed certain nonexistent devices for his studies of the physiology of respiration at Harvard's School of Public Health. Although retired from teaching, and with eyes somewhat dimmed, he nevertheless proceeded to design and build several ingenious devices in his own shop, and these are all in present-day use. Probably more than any other single activity, Mead loved most working on some gadget in his well-equipped basement shop, and he spent many happy hours with his admired fellow inventor, Vannevar

Bush, talking about such matters either in the shop or in the adjoining room where the two of them exerted some of their ingenuity in attempting to control three little ivory balls on a billiard table.

Summation. Mead's life was full, active, challenging and satisfying because he made it so. He early found science in general, and geology in particular, to his liking and he never wavered once he set his course on a geological career. To challenging problems he brought a keen and analytical mind which quickly swept aside the unimportant details and came directly to grips with the heart of the problem. Once the essentials of the problem were apparent, he addressed his most intense efforts and inquiry to them and rarely failed to find a satisfactory solution. His greatest motivation was to learn how something worked, or why some situation existed, and then to set about explaining it. In following this motivation, his discoveries and explanations, and the devices and instruments he designed and built to help others understand, make an enviable record of achievement and will long continue to influence teaching and research in geology. He used well what he learned from others, and he was always learning, but he also contributed something new to be learned and used by his associates and students, and with these he always enthusiastically shared his latest discovery or gadget. As one of his oldest and most devoted students wrote me recently,

"I thought of Warren Mead and how well he exemplified the connection 'between the mind of man and the nature of things, which is more precious than anything on earth' and of his mathematical power and scientific insight, which he shared so willingly with those of us who were fortunate enough to come under his influence."

Mead was highly respected by his professional associates and gratefully esteemed by his many students. He was elected president of the Society of Economic Geologists and vice-president of the Geological Society of America. He also held membership in the American Institute of Mining and Metallurgical Engineers and the American Society of Civil Engineers. He was elected to the National Academy of Sciences in 1939, and to the American Academy of Arts and Sciences in 1935.

On June 17, 1909, he married Bertha May Taylor of Madison, Wisconsin, and seven months before his death they celebrated their Golden Anniversary happy with thoughts of their ten grandchildren, three daughters-in-law, and three sons—Warren, the eldest, associated with radio-television Station KWWL in Waterloo, Iowa; Judson, professor of geophysics at Indiana University; and Jeremiah, the youngest, associate professor of physiology in the School of Public Health of Harvard University.

Death came quietly to Warren Judson Mead in his seventy-seventh year on January 16, 1960, at his home in Belmont, Massachusetts.

I am deeply indebted to Mrs. Warren J. Mead and her sons for allowing me free access to and use of the private papers and records left by Dr. Mead.

KEY TO ABBREVIATIONS

Amer. Assoc. Pet. Geol. Bull. = American Association of Petroleum Geologists, Bulletin
Amer. Inst. Min. Eng. Bull. = American Institute of Mining Engineers, Bulletin
Amer. Inst. Min. Eng. Trans. = American Institute of Mining Engineers, Transactions
A.P.I. Ann. Rept. Prog. = American Petroleum Institute, Annual Report of Progress
A.P.I. Rept. Prog. = American Petroleum Institute, Report of Progress
Amer. Jour. Roent., Radium Therapy and Nuclear Med. = American Journal of Roentgenology, Radium Therapy and Nuclear Medicine
Bull. Assoc. State Eng. Soc. = Bulletin of the Association of State Engineering Societies
Econ. Geol. = Economic Geology
Geol. Soc. Amer. Bull. = Geological Society of America, Bulletin
Geol. Soc. Amer. 50th Ann. Vol. = Geological Society of America, 50th Anniversary Volume
Jour. Geogr. = Journal of Geography
Jour. Geol. = Journal of Geology
Pan-Amer. Geol. = Pan-American Geologist
The Tech Eng. News = The Tech Engineering News
The Wis. Eng. = The Wisconsin Engineer

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197; Penokee-Gogebic District, pp. 235–250; Marquette District, pp. 270–282; Swanzy District, p. 286; Crystal Falls, Iron River and Florence Districts, pp. 323–326; Felch Mountain and Calumet Districts, pp. 326–328; Menominee District, pp. 346–354; Baraboo District, pp. 362–364; and The Iron Ores of the Lake Superior Region, pp. 460–572.

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