BIOGRAPHICAL MEMOIR

OF

SAMUEL LEWIS PENFIELD.

1856—1906.

BY

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The subject of this memoir came of a prominent family and was born in Catskill, New York, January 16, 1856, spending his boyhood in that beautifully situated village on the banks of the Hudson. His father, George H. Penfield, a highly esteemed and useful man in his community, was a shipping merchant, as had been his father before him. The mother of our mineralogist, Ann Augusta Cheeseman, was a native of Stratford, Connecticut. She was a woman of strong character and rare culture, and it is interesting to know that members of her family have displayed much mechanical ingenuity.

There is a record of seven generations of Penfields in America before our scientist. The emigrant, William, was born in Wales in 1650 and settled in Massachusetts. The succeeding ancestors lived in Wallingford, Connecticut, and then in Fairfield, in the same state, until the grandfather, Samuel L. Penfield, as a young man, removed to Catskill. Penfield possessed, as a cherished family heirloom, a portrait in oil of his great-great-grandfather, Samuel Penfield of Fairfield. This picture shows an evidently prosperous gentleman in the costume of the Revolutionary period, and with strong, interesting features. Another of his valued possessions was the Yale diploma of the next Samuel Penfield, his great-grandfather, who was graduated in 1783, and became a lawyer, residing in Fairfield.

Penfield's early home was one of refinement, cheerfulness, and great hospitality. He received from his parents an inheritance and a training which gave him high ideals and made him the upright, absolutely honest man that he was. As a boy he was active, fond of long walks among the mountains near his home, an expert swimmer, and a skilled oarsman. Never particularly strong or athletic, he was so energetic and possessed such endurance that all his life he was able to accomplish an astonishing amount of work. The youthful trait which probably had the most significance in regard to his future career was his unusual skill in the use of tools. This, together with his general

mechanical ability, enabled him, apparently without instruction and with little practice, to produce remarkable pieces of handiwork. In his youth he built a beautiful bookcase which adorned his library to the end of his life, and during the same early period he made a light cedar rowboat, a fine specimen of boat-building, which he used for years in taking exercise upon the Hudson.

It is not known that the future mineralogist showed any marked precocity in his earlier studies, but he graduated with honor at the Catskill Academy, and then went to the academy at Wilbraham, Massachusetts, to prepare for college. From the time when he was a small boy he had desired to go to Yale, but there is no doubt that his interest in science, leading to his selection of the Sheffield Scientific School, was awakened during his course at Wilbraham. In after years he often spoke of having received excellent instruction in physics there, and of having taken much interest in that course of study. It would be a pleasure to acknowledge here this service of the Wilbraham teacher, but his name is not known with certainty.

Penfield appeared in New Haven as a freshman in the autumn of 1873. He was a handsome young man, rather slender, somewhat above the average height, with black, slightly curling hair, and a rather dark, rosy complexion. He was a quiet, but sociable person, with pleasing manners and a happy disposition. It was my good fortune to be his classmate, to take exactly the same course of study in our undergraduate career, and afterwards to be his room-mate and intimate companion for many years. This long acquaintance and close intimacy revealed no flaw in his fine character and led to ever-increasing admiration of him.

He was a most conscientious student, a diligent and faithful worker. He did not attract immediate attention for ability, however, for he had little facility in reciting, while subjects requiring mere memory, particularly languages, were difficult for him. It may be mentioned in this connection that he improved remarkably in fluency of expression as years went by, and that he showed much aptitude in acquiring the German language a few years later, when it was presented to him practically in its own country. In contrast to the difficulties just mentioned, it

became evident very early in his college course that he was acquiring a more thorough understanding of mathematical and scientific subjects than most of his apparently more brilliant companions. Besides this, he did excellent work in the free-hand and mechanical drawing of freshman year, as was to be expected of one with his natural manual skill.

Upon taking up the study of analytical chemistry and determinative mineralogy during the next year, he astonished his fellow-students by the ability and deftness which he displayed in these practical lines of work. His skill with his hands was such that he was from the outset a master in chemical manipulation and in the use of all kinds of scientific apparatus. During this year he had an attack of typhoid fever which interrupted his studies for many weeks. Most men, under the circumstances, would have dropped back into the next class, but he not only made up the large amount of work that he had missed, but actually took the prize in determinative mineralogy for that year.

The course just mentioned was Penfield's first introduction to the science in whose service he afterwards labored so long and successfully. The beauty of crystallized minerals at once appealed to him strongly, as did also the ingenious tests by blow-pipe and the other means for identifying them. Although at that time he had no intention of becoming a mineralogist, he began to develop the wonderful skill that he afterwards displayed in recognizing minerals at sight. It is much to the credit of Professor George J. Brush and his assistant, the late Dr. George W. Hawes, that they aroused in Penfield such an interest in mineralogy.

During the third and last year of his undergraduate course, Penfield's success in chemical laboratory work was even greater. He soon finished the prescribed work of the course, at that time confined almost entirely to inorganic analysis, and took up more advanced investigations. As a subject for his graduation thesis he undertook a study of the basic sulphates of copper obtained by precipitation. This subject was not of his own selection, and the amorphous precipitates were found to be variable mixtures of little interest, so that the results were never published; but he made a great number of preparations and

analyzed them with such rapidity and skill that his work must have been a revelation to some of his instructors. He then took up the analysis of minerals, and among other things analyzed triphylite from Grafton, New Hampshire. This phosphate, containing iron, manganese, calcium, lithium, and sodium, presented analytical difficulties which had not been surmounted, as it appeared later, by several chemists who had published analyses of it. It might have been expected that so young and inexperienced a chemist would have been unable to solve this problem, but there were several circumstances in his favor. The first was that of his personal qualifications of manipulative skill and enthusiasm. Another favorable condition was that of the excellent traditions and practice of analytical chemistry in the Sheffield laboratory, due to the instruction and example of Professors Brush, Brewer, Johnson, Mixter, and Allen, all of whom had studied chemistry abroad and counted among their teachers such masters as Liebig, Bunsen, and Plattner. Finally, in making this analysis, Penfield had the benefit of the direct advice of Professor Allen, a man of rare judgment in the selection of analytical methods. As a result, this was the first good analysis ever made of triphylite, indicating a much simpler formula than the one previously accepted. This was the beginning of Penfield's important work in simplifying the formulas of minerals by means of accurate analyses of pure material, and it led to the publication of his first scientific paper.

Penfield was graduated with honors in 1877. He had studied his books faithfully and much of the time had worked in the chemical laboratory almost constantly from morning until night; but, being of a very companionable disposition, he had nevertheless found time to make many close friendships among his fellow-students.

The first three years after his graduation formed a most important period in Penfield's scientific development. Two of these years he spent as assistant in the chemical laboratory, the third as assistant in mineralogy. It was the writer's privilege to return as a graduate student, to be Penfield's room-mate during these three years, and to work beside him in the laboratory during much of this time.

We were now able to work at night in the laboratory, which was so small in those days that Professor Allen frequently worked in the same room with us. His chemical sagacity has been previously mentioned, and it was fortunate indeed that he was most generous in discussing chemical matters and giving valuable advice, particularly during those evening hours. Penfield was exceedingly quick at acquiring knowledge in a conversational way, but, being essentially an experimentalist, he was not much inclined to gain information by reading; hence there is no doubt that Professor Allen's influence upon his development was a very important one.

A most fortunate circumstance, during the first year of Penfield's graduate study, was the bringing to light of the Branchville mineral locality by Professors Brush and E. S. Dana. These gentlemen labored most enthusiastically in developing it, and soon several new phosphates and other interesting species, new and old, were disclosed. Penfield took up the chemical examination of the new phosphates, eosphorite, triploidite, and dickinsonite, and soon analyzed them with masterly skill and precision. Sharp ratios and beautifully simple formulas resulted from these analyses, except in the case of dickinsonite, where the material could not be obtained in a pure condition. Mr. F. P. Dewey and the writer also worked on Branchville phosphates at this time, but their work was not as extensive as that of Penfield. As far as the writer is concerned, he was conscious of being but a poor imitator of Penfield's skill and rapidity, and it was only by working all night on one occasion that he finished an analysis more quickly than his gifted friend had done a similar one.

Those difficult phosphate analyses were wonderfully beneficial to the group of young chemists, led by Penfield, advised by Professor Allen, and encouraged by Professor Brush. Experience led to improvements in methods and greater facility and rapidity in applying them, so that the difficulties rapidly disappeared.

The next year, 1878-79, Penfield analyzed several triphylites, and by his remarkably beautiful results placed beyond question the simple formula now accepted for that mineral. He analyzed also the new Branchville phosphates, fairfieldite and fillowite, as well as samples of chabazite and rhodocrosite from the same

locality. In that same remarkably productive year, while also attending faithfully to his duties as laboratory assistant, he turned out a masterpiece in the shape of eight analyses of amblygonite, from various localities, which gave a new and simple formula for that mineral, under the assumption previously put forward by Brush and Dana that fluorine and hydroxyl play the same part in minerals. This view was based on Penfield's analysis of triploidite, a compound containing hydroxyl, which was observed to have the same form as triplite and wagnerite, analogous fluorine compounds. In his work on amblygonite, Penfield showed that fluorine and hydroxyl replace each other in the same mineral—a generalization which was destined to play an important part in his future work in simplifying mineral formulas. The publication of this work on amblygonite brought down upon him the wrath of the great German authority, Rammelsberg, who characterized the hydroxyl-fluorine idea as "unchemical," and remarked that the analysis of amblygonite was no theme for beginners. From Rammelsberg's point of view, this was indeed a difficult problem; but our beginner was already a past master in mineral analysis, and, besides, he was in a position to employ methods far superior to those previously used in the examination of such phosphates; so that he solved the problem where his critic, the great authority of much experience, had failed. The hydroxyl-fluorine idea prevailed in spite of Rammelsberg's attack upon it, and it is interesting to relate that Penfield visited Rammelsberg many years later, when the latter was near the end of his long life, and was most cordially received by his predecessor in mineralogical fame. No allusion to past differences was made in that memorable interview, although it appears that Rammelsberg never accepted the hydroxyl-fluorine theory.

In connection with his amblygonite analyses, Penfield incidentally devised a new volumetric method for the determination of fluorine, which has been extensively commended and employed since its publication.

The following year, as usual, he did many things in addition to his work of instruction, which was now carried on in the mineralogical laboratory. He made a most skillful examination

of childrenite, using less than a gram of material for this complicated analysis and obtaining duplicate determinations upon most of the constituents. He showed that its composition was analogous to that of the eosphorite which he had previously analyzed, as was to be expected from the similarity in form of the two minerals. It appeared that Rammelsberg, as well as another chemist, had failed to find a large part of the alumina in childrenite, and had thus arrived at an incorrect formula.

In mentioning some of Rammelsberg's analytical failures here it is not intended to give discredit to the reputation of that celebrated mineralogist, who made a vast number of excellent analyses; but such mention seems to be necessary in order to emphasize the difficulty and importance of Penfield's work.

This same year Penfield analyzed three samples of manganiferous apatite, and also did a very important piece of work in the chemical examination, for Brush and Dana, of spodumene and its alteration products from the Branchville locality. This investigation included an analysis of unaltered spodumene, three analyses of the mixture called β-spodumene, an elaborate chemical examination of this mixture, which led to the discovery of the new mineral eucryptite as one of its constituents, and two analyses of the mixture called cymatolite, which led to a satisfactory explanation of its composition as a mixture of albite and muscovite. In connection with the same investigation, he also made analyses of specimens of muscovite, microcline, and killinite. The high character of this series of silicate analyses was shown by the sharpness of the ratios, the simplicity of the formulas, and the importance of the deductions that Brush and Dana were enabled to draw from them in regard to the two puzzling microscopic mixtures.

It would not appear that even a wonderful analyst could have done any further work that same year, but during that time he did a large amount of technical work in analyzing cereals, in connection with some Government work under the direction of Professor William H. Brewer. This was done with the purpose of furnishing means for studying in Germany, which he was planning to do at the end of the college year. The cereal analyses being arranged for at a fixed price for each, Penfield

set up his apparatus and turned out the work with such speed and skill as were simply astonishing to the writer, who was doing similar work in the same building—South Sheffield Hall—for the Connecticut Agricultural Experiment Station. In this connection it may be mentioned that in after years Penfield made it a principle to refuse outside technical work, in order that he might devote his spare time wholly to his scientific investigations. This course involved much self-denial on his part, because at times the demands upon his purse were large in proportion to his salary.

At the end of three years of postgraduate work, when only twenty-four years of age, Penfield was a truly great analytical chemist, and had turned out an astonishing amount of fine work. In future years he was destined to produce much more work of this kind, and to broaden his experience with methods, but he had already come so near perfection in the management of analyses that there was little room for future improvement in the quality of his investigations. Difficult analyses always appeared to attract rather than to discourage him. He had perfect confidence in himself, was full of enthusiasm, and anxious to arrive quickly at his results; but at the same time he was exceedingly conscientious about his work, and this strict honesty led him to examine his methods and test his results so carefully that he never made poor analyses. Accidents and failures, so common with most analysts, were very rare in his case, on account of his manipulative skill and good judgment. It was a pleasure and an education to see him work, and to observe his neatness, deftness, and orderly arrangements. He enjoyed the work greatly, too, and often said that making an analysis was one of his chief pleasures. The writer of these lines owes very much to the privilege of having worked beside him and having had such an example to follow.

In the spring of 1880 Penfield went to Germany for further study. After residing for some time in Hanover, in order to become more familiar with the language, he took up the study of organic chemistry under Fittig in Strassburg, and remained there for two semesters. From our present point of view, this course of study appears to have been unnecessary, as he after-

wards took little interest in the subject; but at that time it was his intention to make a career as a chemist, and organic chemistry was then a very prominent subject. However, while at Strassburg he heard some lectures by the mineralogist Groth and also took a course in experimental physics. He was much interested in the organic work, and afterwards was glad that he had taken it, as it gave him a broader education. It led to the publication of a paper in conjunction with Fittig upon an unsaturated organic acid and some of its salts.

Upon his return from Germany in 1881 Penfield accepted the instructorship in mineralogy in the Sheffield Scientific School, thus determining his future career, for he devoted the remaining twenty-five years of his life to that department. This return to mineralogy appears to have been a fortunate circumstance, for he was particularly well fitted for this work and had already become a leader in one branch of the subject. He soon took the entire charge of the instruction in mineralogy, as his predecessor, Professor Brush, was obliged to give up this work on account of his increasing duties as director of the school.

In order to fit himself more thoroughly for his mineralogical work, Penfield went to Germany again in 1884, and for one semester studied the optical properties of minerals and crystallography under Rosenbusch in Heidelberg. These studies he took up with much enthusiasm, for his natural aptitude in mathematics, his skill with instruments of precision, and his great interest in minerals made the work very congenial to him.

His mastery of physical mineralogy was as rapid and thorough as his development in chemistry had been, and from that time he followed both lines of investigation in an impartial manner, but with an increasing tendency toward crystallography. The fact that he covered so ably both the chemical and physical sides of mineralogy is particularly noteworthy, for other distinguished mineralogists have usually been prominent in only one of these directions. His ardent devotion to mineralogy was such that he was decidedly a specialist, but in that specialty he was broad.

Penfield became assistant professor of mineralogy in 1888, and was advanced to full professorship in 1893. His enthusiasm

and skill in mineralogical research never diminished, and he continued this work throughout his lifetime with remarkable industry.

After taking charge of the mineralogical department he often generously gave important chemical work to his advanced students, but this work was under his close personal supervision, and he frequently took part in it, so that its quality was similar to his own. His occasional work in coöperation with investigators outside of his university should also be mentioned. In these cases he usually took the crystallographic part, as was the case in his work with Professor Genth, of Philadelphia.

In all but his earliest chemical researches he made extensive and very effective use of heavy solutions in purifying his material for analysis. In many cases this was the only means of removing impurities and obtaining the minerals in a sufficiently pure condition, and, always desiring the greatest possible accuracy, he applied this method whenever it could be of assistance. He exhibited his usual remarkable dexterity in applying the various heavy solutions for this purpose, and in one instance he devised a special form of apparatus for the use of the fused mixture of thallium and silver nitrates.

We owe to Penfield, besides the volumetric method for the determination of fluorine, a number of other improvements in analytical methods, for it was his practice in many cases to study carefully the methods that he used by applying them to known mixtures, so that he arrived at a number of new inventions or important modifications. His work on the determination of water in minerals was one of the most noteworthy cases of this kind.

Besides his analyses, already mentioned, of six new minerals for Brush and Dana, Penfield described, sometimes in conjuction with other workers, no less than fifteen new minerals, a brief account of which will now be given.

Gerhardite (with H. L. Wells, 1885) is a basic nitrate of copper, in orthorhombic green crystals, and is the only nitrate insoluble in water known as a mineral.

Nesquehonite (with F. A. Genth, 1890) is an orthorhombic, hydrated magnesium carbonate, $MgCO_3.3H_2O$.

Spangolite (1890) is a hydrated sulphate and chloride of copper and aluminium remarkable for its composition and beautiful, hexagonal, green crystals.

Hamlinite (with W. E. Hidden, 1890) is a hydrous fluophosphate of aluminium, strontium, and barium, and is remarkable in being the only known natural phosphate containing barium or strontium.

Canfieldite (1894) is a sulphostannate of silver, containing also the exceedingly rare element germanium.

Pearceite (1896) is a sulpharsenate of silver, or arsenical polybasite.

Roeblingite (with H. W. Foote, 1897) is a complex silicate and sulphite of calcium and lead, the only known natural sulphite.

Bixbyite (with H. W. Foote, 1897) is a combination of iron and manganese oxides, essentially $FeMnO_3$.

Clinohedrite (with H. W. Foote, 1898) is a zinc calcium silicate of peculiar monoclinic habit.

Hancockite (with C. H. Warren, 1899) is a silicate related to epidote and piedmontite, but containing a considerable quantity of lead.

Glaucochroite (with C. H. Warren, 1899) is a silicate of calcium and manganese.

Nasonite (with C. H. Warren, 1899) is a tetragonal lead calcium silicate.

Lucophœnicite (with C. H. Warren, 1899) is a hydrous silicate of manganese.

Graftonite (1900) is a phosphate of iron, manganese, and calcium, which was curiously intergrown with triphylite.

Tychite (with G. S. Jamieson, 1905) is a carbonate and sulphate of magnesium and sodium. The actual mineral was analyzed only qualitatively, but the formula was determined from an artificial product crystallizing in the same form and containing the same things.

Even more important than his work with new minerals were Penfield's investigations upon the composition and form of species which were already known. New minerals could be studied only when they happened to be found, but there was

an abundance of old material at his disposal in the Brush collection, and, besides, interesting specimens of old minerals were frequently found by him or sent to him for examination.

Mention has already been made of Penfield's early work in establishing correct formulas for the minerals triphylite, amblygonite, and childrenite. In later years he performed the same service, often in collaboration with others, with some twenty other minerals, a list of which will now be given.

Monazite (1882, and with E. S. Sperry, 1888) was found to be an orthophosphate of cerium, lanthanum, and didymium with an admixture of thorium silicate.

Ralstonite (with D. N. Harper, 1886) was purified by means of a heavy solution and given a satisfactory formula upon the basis of the fluorine-hydroxyl idea.

Herderite (with D. N. Harper, 1886) was given the simple formula $CaBe(F,OH)PO_4$.

Howlite (with E. S. Sperry, 1887), a hydrous calcium borosilicate, was given the rank of a well-defined mineral species.

Connellite (1890), a hydrous, basic combination of the sulphate and chloride of copper, was given a satisfactory formula from a remarkable analysis made with only 0.074 grams of the exceedingly scarce material.

Aurichalcite (1891), a basic carbonate of zinc and copper, was given a simple formula.

Allurgite (1893), a member of the mica group, was given a reasonable formula.

Argyrodite (1893), the remarkable silver mineral in which the new element germanium was discovered, was shown to have a slightly different composition from that originally ascribed to it.

Cookeite (1893), a mica, was given a new formula.

Chondrodite, Humite, and *Clinohumite* (with W. T. H. Howe, 1894), a group of silicates to which simple formulas were given on the basis of the replacement of fluorine by hydroxyl. These formulas were shown to have a most interesting relation to the crystalline forms of the minerals, so that an unknown member of the series was predicted, both as to its composition and form. The Swedish mineralogist Sjögren soon afterwards found a

mineral with the predicted form, and not having enough of it for an analysis, ascribed it to the predicted composition and gave it the name prolectite, from προλέγειν, to fortell.

Staurolite (with J. H. Pratt, 1894), a very common silicate, was successfully purified and given a simple formula.

Topaz (with J. C. Minor, 1894) was shown to contain hydroxyl replacing fluorine, and was provided with a good formula, $(AlF)_2SiO_4$, in which F is replaceable by OH. Moreover, it was shown that the specific gravity and optical properties of the mineral vary with the percentage of flourine, so that the latter could afterwards be determined by a physical or optical examination.

Hanksite (1885, and J. H. Pratt, 1896) was found to possess a curious composition in being composed of sodium sulphate, sodium carbonate, and potassium chloride.

Ganomalite (with C. H. Warren, 1899) was shown to be probably analogous to Nasonite, with hydroxyl taking the place of the chlorine of the latter mineral.

Tourmaline (with H. W. Foote, 1899), a mineral whose complex composition had been much discussed, was given a plausible formula, based upon the idea that the mass effect of a large complex radical determines the crystallization and permits wide variations in the remainder of the molecule.

Sulphohalite (1900) was shown to be a compound of sodium sulphate, chloride, and fluoride, in which the flourine had been previously overlooked.

Turquois (1900) was given a satisfactory formula, and the occurrence of copper in this phosphate was explained.

Amphibole (with F. C. Stanley, posthumous, 1907) was explained on an assumption similar to that used in the case of tourmaline.

Besides giving the crystallography of the new minerals that he described, Penfield established the crystalline forms of *Amarantite, Argyrodite, Bertrandite, Herderite, Lansfordite, Metacinnabarite, Penfieldite, Polybasite, Sperrylite, Tiemannite, Willemite, Calaverite,* and *Stibiotantalite* (the last two with W. E. Ford), and he published numerous observations upon interesting developments or habits of the crystals of still other species.

Nor was his crystallographic work confined to minerals, for he was very generous in giving much time to the study of artificial crystals prepared by various chemists. For instance, he described the forms of a large number of double salts and other compounds prepared by the writer, and in that connection obtained some interesting results in relation to the effect of the replacement of one element by another. Much of his work upon artificial crystals is scattered through chemical literature and does not appear in the lists of his publications.

It should not be forgotten that Penfield's liberality in encouraging the independence of others led to the publication of a large amount of work from his laboratory which did not bear his name, although he acted in an advisory capacity. Thus J. H. Pratt described a new mineral, Pratt and H. W. Foote described another, while these and other assistants and advanced students published the results of many important investigations not bearing Penfield's name, although in most cases he suggested the work and carefully superintended it.

During the last few years of his life, Penfield became much interested in the application of graphical methods, in connection with stereographic projection, for the solution of crystallographic and other problems of spherical trigonometry. He published several articles on this subject and devised several pieces of ingenious apparatus for carrying out his methods, such as engraved circles and scales, as well as a series of protractors printed on transparent celluloid sheets. These methods have since been extensively employed by other crystallographers. He also advocated the use of his graphical methods for geographical maps and sailing charts, but apparently made little impression upon the conservatism of established usage in these directions.

Professor Penfield's scientific work may be summarized as comprising mineralogical investigations of great abundance, variety, accuracy, and importance. The thoroughness with which his pieces of work were carried out is also particularly striking. He was not satisfied until he had settled every possible point in regard to a mineral that he was studying. One of his notable achievements was the establishment of the replacement of fluorine

by hydroxyl and the simplification of the formulas of many minerals upon this basis after making accurate analyses of them. Another remarkable piece of work was his discovery of such relations between composition and form in a group of minerals that he was able to predict the existence of a mineral not yet discovered.

His scientific attainments have been widely recognized. He was elected Fellow of the American Academy of Arts and Sciences in 1893, Foreign Correspondent of the Geological Society of London in 1896, Member of the National Academy of Sciences in 1900, Fellow of the American Association for the Advancement of Science, Corresponding Member of the Royal Society at Göttingen, and Member of the Scientific Society at Christiania in 1902, Corresponding Member of the Geological Society at Stockholm, and Foreign Member of the Mineralogical Society of Great Britain in 1903, and in 1904 the University of Wisconsin conferred upon him the degree of Doctor of Laws.

The result of nearly all of Penfield's researches were published in the "American Journal of Science." He brought together many of his more important articles in one of the bicentennial publications of Yale University issued in 1901, and in this volume he gave also an interesting account of the development of mineralogy at Yale, including a full bibliography.

The teaching that Penfield did was a most important part of his life work, and although the results that he achieved in this direction are less tangible than those of his researches, they are probably of even greater consequence.

In taking charge of the mineralogical course of instruction in the Sheffield Scientific School he inherited from his predecessor an excellent plan of teaching, the main feature of which he always followed. The beginners were taught blow-piping and the accompanying chemical and physical tests for minerals, and were required to identify minerals in this way. Then the mineral collection, brought together by Professor Brush with such good judgment that it was an extraordinarily good one for teaching purposes, was exhibited by means of lectures, and at the same time the principles of crystallography were inculcated.

Penfield's continual effort was to make this course in mineralogy more instructive and interesting. With this end in view he improved the collection of unlabeled minerals by adding to it typical specimens, so that the students in using small fragments for their tests could observe the appearance of the minerals with which they were dealing. He installed also a labeled collection of the more important minerals, to which the students had free access, and thus could confirm their identifications by comparison and become familiar with a wider range of characteristic specimens. He arranged neat exhibits of specimens illustrating color, form, and other physical properties of minerals, and was particularly painstaking in supplying the laboratory and lecture-room with crystal models and other apparatus elucidating crystalline structure. Much of this apparatus he made or devised with great skill and ingenuity.

He gave much attention also to the improvement of laboratory instruction by preparing printed laboratory directions and other aids for students, and the results of much painstaking experience in the testing of minerals, including many devices of his own, were incorporated in the new edition of Brush's "Determinative Mineralogy," which he rewrote, enlarged, and published in 1898.

He was a successful lecturer in the class-room, but was at his best in laboratory instruction, where he came into contact with the students individually. In this work he was kindly, patient, persistent, and thorough. He was very appreciative of good work and progress on the part of the student. He was untiring in his devotion to his advanced students and never allowed his own investigations to interfere with giving them all possible advice and assistance. He inspired his co-workers with his own enthusiasm, and imparted to them much of his knowledge and skill. Among those who worked with him and have since followed scientific careers, in some cases in geology or chemistry, are Professors L. V. Pirsson, H. W. Foote, and W. E. Ford, of the Sheffield Scientific School; Professor J. H. Pratt, of the University of North Carolina; Dr. E. O. Hovey, of the American Museum of Natural History; Dr. O. H. Farrington, of the Field Columbian Museum, and Professor C. H. Warren, of the Massachusetts Institute of Technology. The

names of many others who made investigations with him will be found in the list of his publications.

The mineralogical laboratory, during Penfield's connection with it, was situated in the Yale Peabody Museum, where the Brush collection was also deposited until 1903, when the department was moved to a new building, Kirtland Hall, on the grounds of the Sheffield Scientific School. At the time of this removal Professor Brush made a gift of his whole collection to the school, together with a liberal endowment for its care and enlargement, and Penfield was appointed as its official curator. He had previously given much attention to the collection, both in assisting Professor Brush in its care and also in connection with using it in illustrating his lectures on descriptive mineralogy and crystallography, for which purpose he had beautifully mounted and arranged many of the specimens. He now undertook and fully carried out the arrangement of the collection in its new cases in the new building, and many excellent features of this great collection, as now arranged, are due to his unequalled taste and skill.

In Kirtland Hall, Penfield had also the pleasure of planning and putting into operation a model laboratory for instruction and investigation in all branches of his department of science. This was done with his usual good judgment and common sense, and this beautiful laboratory, containing so many of his inventions and such numerous examples of his orderly arrangements of apparatus and specimens, will long remain a fitting reminder of this great mineralogist.

The removal to Kirtland Hall was practically coincident with his failure in health, so that his enjoyment of it was much diminished. However, he went on bravely and cheerfully, working to the end.

Penfield's publications are noteworthy for their general clearness and conciseness. He used great care and much time in preparing his manuscripts, usually making several revisions of them before they satisfied him. In his younger days his scientific writing was something of a hardship to him, but with practice his facility in this direction improved remarkably. Professor Miers, of Oxford, mentions his clearness of exposition as ex-

hibited in the "Determinative Mineralogy" and says: "The introductory chapters which he wrote for this book are models of clear and lucid treatment, and among the very best that can be placed in the hands of elementary students."

Penfield was naturally very friendly and sociable, he attracted others by his many good qualities, and he made enduring friendships among his associates everywhere. A classmate who retained close intimacy with him throughout his after life is Professor J. P. Iddings, of Chicago, who recently pronounced a beautiful tribute to him before the Geological Society of America, in which he spoke of him as "A genial and loveable companion whose cheerfulness, generosity, steadfastness, and absolute honesty in thought and action form his most memorable characteristics." Another classmate and close friend is Col. Morris K. Belknap, of Louisville, Kentucky. This good friend has recently founded in his memory a "Penfield Prize" in mineralogy in the Sheffield Scientific School.

Penfield remained unmarried for twenty years after his graduation, and lived, usually with two or three companions, in the upper part of South Sheffield Hall, in apartments familiarly known as "The Attic." It was my good fortune to be one of those companions during nearly all of this time. Another long resident there was Professor L. V. Pirsson, who was for a time Penfield's pupil, then his assistant, and finally his colleague in the closely related subject of petrology. This intimate friend and associate has paid worthy tribute to Penfield in a biographical essay published in the "American Journal of Science." Another member of that coterie was the late Professor C. E. Beecher, the gifted and beloved geologist, whose loss, as well as Penfield's, this academy deplores, as one of its eminent members.

Much pleasure and profit came from the companionship of those days. Many interesting conferences took place in those quarters after the day's and evening's tasks were done, in which Penfield and the others discussed the progress of their work and often obtained advice and encouragement in regard to it.

The relations of Penfield and the writer in connection with their work were particularly close. The crystallographer was frequently called upon to display his unfailing kindness in

examining crops of crystals for the chemist, to see if they were pure, or to make some other application of his knowledge and skill. On the other hand, it sometimes happened that the chemist was able to help the mineralogist by advice in regard to analytical methods, for Penfield preferred actual work to the study of books, and it was well that he did, for thereby he accomplished much more in the direction in which he was so highly gifted.

Penfield did not confine himself unduly to his laboratory, although it happened that he worked evenings as well as in the daytime, when he was particularly interested. He took outdoor exercise with considerable regularity, and participated frequently in the social gatherings of his many friends in New Haven. He usually availed himself of the vacations for rest and recreation or for mineralogical excursions. Two summers he spent in the Yellowstone Park, as assistant to his friend Iddings, then connected with the United States Geological Survey. Other summer vacations he spent partly or wholly in collecting minerals and observing their occurrences in northern New York, Colorado, North Carolina, Maine, Nova Scotia, and still other localities. It was a great pleasure to be with him on such trips, for he was full of enthusiasm and a most agreeable companion. He spent the summers of 1894 and 1897 in Europe, visiting a number of fellow-mineralogists and looking at many collections in the course of his travels. His reception on both these occasions was exceedingly cordial. One of the results of those visits was a particularly firm friendship with Professor H. A. Miers, of Oxford University, who has written a most sympathetic biographical account of him. Another valued friendship thus formed was with our Foreign Associate, the Norwegian geologist, W. C. Brögger, who has recently dedicated one of his books to Penfield.

The beauty and simplicity of Penfield's character impressed all who knew him. He was generous, sympathetic, unselfish, and unassuming. He showed unlimited loyalty to his friends and was exceedingly lenient to their shortcomings or to any opinions that they might hold which differed from his own. His good deeds were many in helping the needy and suffering, and through-

out his life he retained, with complete unobtrusiveness, the simple religious faith that he had acquired in his childhood.

In January, 1897, he married Miss Grace Chapman, of Albany, New York, thus bringing much happiness to his few remaining years. In the delightful home which he then established he took much pleasure in entertaining his many friends, for hospitality was one of the strongest traits of his character.

Penfield was always conscientiously careful of his health, being regular in his habits and extremely temperate in his manner of living. It did not appear that he was sapping his strength by overwork, for he seemed vigorous and well; but he was suddenly attacked by that much-dreaded malady which interferes with the assimilation of saccharine substances. From this he suffered for more than three years, showing wonderful fortitude and patience under the restrictions imposed upon him. Eminent medical specialists did all in their power for him, while his colleagues, Professors Chittenden and Mendel, gave his case thorough scientific attention, and his wife gave him most devoted care. Under these circumstances and by his own obedience to the prescribed regimen, his life was undoubtedly prolonged; but all efforts were unavailing, and the end came, fortunately with little suffering, on August 12, 1906, at South Woodstock, Connecticut, where he was spending the summer. Until two days before his death he had been very happy and comfortable and had been cheerfully making plans for the future.

He rests in his native village, Catskill, which he loved so well. He is survived by his wife, a sister, and a brother.

The accompanying portrait is from a photograph taken about four years before his death.

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