NOTES AND NEWS

A NOTABLE CENTENARY IN AMERICAN MINERALOGY: SAMUEL LEWIS PENFIELD, 1856–1906*

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This year is the hundredth anniversary of the birth of one of the world's greatest mineralogists, Samuel Lewis Penfield, who was born January 16, 1856, at Catskill, N. Y., and died August 12, 1906, at South Woodstock, Conn. Despite the fact that his death after three years of illness with diabetes cut short his career when he was at the height of his ability, Penfield left a record of remarkable achievements. These had brought him fame and the esteem of his contemporaries. What is more remarkable, the passing of half a century has not dimmed their luster. It is not fair to judge work done fifty to eighty years ago by comparison with what we know today, but Penfield's work can stand such a comparison.

He was trained as a chemist and his early work consisted chiefly of mineral analyses. Penfield was a remarkable analyst. His colleague H. L. Wells wrote, "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." In similar vein, J. P. Iddings wrote, "The uniformly high quality of his work is due to his absolute honesty and conscientiousness."

This conscientiousness is shown by Penfield's insistence on careful purification of every mineral he analyzed and on a full statement in each paper of just what purification procedure he used. He also described his methods of analysis and he often checked them by the analysis of material of known composition. Even so he was not always satisfied; for example, he published analyses of beryl in 1884, but two years later wrote that the separation of beryllium from aluminum had not been satisfactory and gave new determinations, with a warning, amply confirmed many years later, that the methods available were still unsatisfactory. Although few of Penfield's papers are concerned exclusively with analytical methods, he introduced many modifications of procedure that improved the speed and accuracy of inorganic analyses. A good example is his introduction in 1886 of the use of NH_4NO_3 solution to wash precipi-

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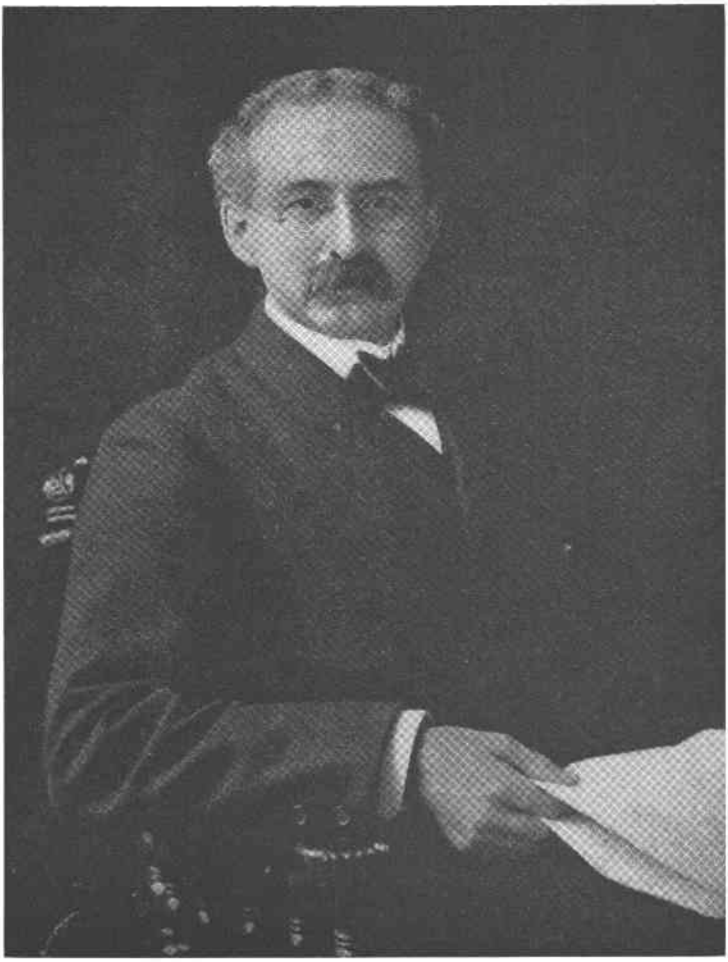

S. L. Penfield

tates of hydrous aluminum oxides. Perhaps the best known of his methods is that proposed in his paper of 1894 on the determination of water; the simple, but accurate method he devised is still the most widely used today.

We usually think of microchemical analysis as a recent art, but Penfield in 1890 made an analysis of the complex mineral connellite on 74 milligrams. In 1898, he described how he tested a sample for sperrylite:

"The crystals, weighing in all 0.0019 gram, were roasted in an open tube and yielded a volatile sublimate of arsenious oxide, crystallizing in isometric octahedrons. The residue, after roasting, had the color of platinum and when dissolved in nitro-hydrochloric acid gave a yellow solution, which when tested with potassium chloride yielded isometric octahedrons of potassium platinic-chloride." In 1902, again faced with the problem of identifying sperrylite, he first measured the crystals, showing them to be pyritohedrons, then carried out the tests as above, this time on a sample weighing 0.0004 gram!

His skill and his care are perhaps best shown by the fact that he named 18 new minerals, every one a valid species, and with two exceptions mentioned below, the compositions established by him are accepted today. He described and named scovillite (1883), gerhardtite (1885), nesquehonite (1890), spangolite (1890), hamlinite (1890), canfieldite (1893, 1894), pearceite (1896), roeblingite (1897), bixbyite (1897), clinohedrite (1898), hancockite (1899), glaucochroite (1899), nasonite (1899), leucophoenicite (1899), graftonite (1900), natrojarosite (1902), plumbojarosite (1902), and tychite (1905). The names scovillite and hamlinite are not now used; scovillite, as Penfield himself showed, was identical with rabdophane, described in England just before his paper naming scovillite appeared; hamlinite, described correctly by Penfield as a strontium aluminum phosphate, was shown 21 years later to be identical with goyazite, which had been described earlier as a calcium aluminum phosphate.

Later work has changed the formulas of only two of these minerals. Pearceite, given by Penfield as $9\ Ag_2S \cdot As_2S_3$, is now considered to be $8Ag_2S \cdot As_2S_3$. Roeblingite, described as a sulfite, was shown by Blix in 1931 to be a sulfate, as was confirmed by W. T. Schaller of the U. S. Geological Survey (private communication) on material from a tube in the Brush collection labelled in Penfield's handwriting. It is interesting that the late Professor H. W. Foote, who made the original analysis of roeblingite, could not believe in 1932, when we discussed the matter, that sulfite had not been present in the sample originally analyzed. "You don't suppose," he said, "that Penfield allowed the paper to be published on my word alone. He was much too careful to do that. He personally tested the sample for sulfite by smelling the evolved SO_2 and by checking its decolorizing action on iodine solution. Then the paper was written and Penfield followed his usual custom of setting it aside for six months, after which he reread it, again tested for sulfite, and only then submitted it for publication." There the question must rest.

More important than his description of new minerals was Penfield's work in analyzing minerals whose composition had not been understood.

He established the correct formulas for amblygonite, argyrodite, aurichalcite, childrenite, the chondrodite group, cookeite, ganomalite, hanksite, herderite, howlite, ralstonite, staurolite, sulphohalite, topaz, and turquois. His work on the chondrodite group is a classic. By careful analyses Penfield determined the correct formulas for chondrodite, humite, and clinohumite, showed that they formed a morphotropic series, and predicted the probable existence of another mineral in the series. He wrote, "Thus $Mg[Mg(F, OH.)]_2SiO_4$ is a possible and most likely compound to occur. This should crystallize either orthorhombic or monoclinic with $\beta=90°$ and should have the axial ratio $a:b:c=1.086:1:1.887$." The mineral norbergite, with the predicted composition, was found 32 years later and the *x*-ray study by Taylor and West, with axes transformed to Penfield's position, gave the axial ratio $a:b:c=1.085:1:1.855$.

He was much concerned about the role of water in minerals and successfuly elucidated the composition of such minerals as topaz, herderite, and the chondrodite group on the basis of the isomorphism of hydroxyl and fluorine. In 1884, he pointed out that alkalies and water are present in beryl, and in 1890, that water is present in anthophyllite ("that the H_2O is an essential constituent of the mineral and is not the result of alteration is proved by the fact that it is very firmly united to the molecule, requiring an intense heat to drive it off . . . "). In 1907, Penfield and Stanley concluded, "That fluorine and hydroxyl present are integral parts of the amphibole molecule and that they are to be regarded as isomorphous with the protoxides is considered as definitely proven by the results of the analyses."

Penfield was not successful in elucidating the composition of the amphiboles or of tourmaline; these problems required the advent of *x*-ray structure determinations for their solution. But he was on the right track to present-day concepts of silicate frameworks with his postulate of a "mass effect," with "uniformity in structure of the acid part of the molecule."

Penfield's interests were by no means confined to the chemical aspects of mineralogy. He was an accomplished crystallographer and established the crystallography of many minerals and of a very large number of inorganic salts. He published several papers on the use of the stereographic and gnomonic projections. In his later years, he was much interested in the optical properties of minerals. In those days, before the advent of the immersion method, the determination of optical properties was not a simple matter. As G. T. Faust recently pointed out, Penfield was the first to show, in 1894, 1895, and 1896, how isomorphous substitution of OH for F, Mn for Fe, and Fe for Mg changed optical properties in isomorphous series. His versatility is well illustrated by his paper of 1890, in which he described the new mineral spangolite, $Cu_6Al(SO_4)(OH)_{12}Cl \cdot 3H_2O$, giving a chemical analysis in duplicate, blowpipe tests, the crystallography, results of etch tests, the optical properties, measurements of the hardness on different faces, and the specific gravity (determined in triplicate).

Penfield's personal qualities must have been as remarkable as his scientific achievements. The memorials cited below all are written in glowing terms of a kindly, patient teacher. I had the good fortune to be closely associated with three of his students, H. W. Foote, W. E. Ford, and C. H. Warren. All liked to talk about him, and 25 years or more after his death, his memory was dear to them all.

The portrait reproduced was made about 1902.

Memorials to Penfield were published by L. V. Pirsson, *Am. J. Sci.*, **22**, 353-367 (1906); J. P. Iddings, *Bull. Geol. Soc. Am.*, **18**, 572–582 (1902); H. L. Wells, *Nat. Acad. Sci., Biographical Mem.* **6**, 120–146 (1909), and H. A. Miers, *Mineralog. Mag.*, **14**, 264-268 (1907). Pirsson and Wells give complete bibliographies of about 100 papers; some of those referred to here are given below. All are from the *American Journal of Science.*

(1884) On the occurrence of alkalies in beryl, **28,** 25–32.

(1886) (with D. N. Harper). Chemical composition of herderite and beryl, **32,** 107–117.

(1890) On spangolite, a new copper mineral, **39,** 370–378.

(1894) (with W. T. H. Howe). Chemical composition of chondrodite, humite, and clinohumite, **47,** 188–206.

(1894) (with J. C. Minor). Chemical composition and related physical properties of topaz, **47,** 387–396.

(1895) (with J. H. Pratt). Effect of the mutual replacement of manganese and iron on the optical properties of lithiophilite and triphylite, **50,** 387–390.

(1896) (with E. H. Forbes). Fayalite from Rockport, Mass., and the optical properties of the chrysolite group (4), **1,** 129–135.

(1897) (with H. W. Foote). On roeblingite, a new silicate from Franklin Furnace, N. J., containing SO_2 and lead, **3,** 413–415.

(1901) The stereographic projection and its possibilities from a graphical standpoint, **10,** 1–24.

(1907) (with F. C. Stanley). On the chemical composition of amphibole, **23,** 231–251.