since these are almost identical geometrically. The oriented intergrowths, by unmixing or otherwise, in some sulphide minerals also take place on those planes in which the atomic arrangement and spacing are almost alike, both minerals sharing the structural plane at the contact.[36]

Selective incrustations of the crystallization kind have been found only in nature and the origin of both these and the colloidal particle kind does not appear to have been previously recognized. The nearest approach to an experimental example is in an observation by Kreutz[37] that parallel growths of $NaNO_3$ seemed to be more perfect and easy to obtain on the (110) form of barytocalcite than on (001).

ACKNOWLEDGMENT

The writer takes this opportunity to express his gratitude to Mr. Herbert P. Whitlock for his courtesy in placing the facilities of the Department of Mineralogy in the American Museum of Natural History at his disposal and for assistance in the study of the crystallography of certain of the specimens described.

MEMORIAL OF GEORGES FRIEDEL

J. D. H. Donnay, *The Johns Hopkins University.*

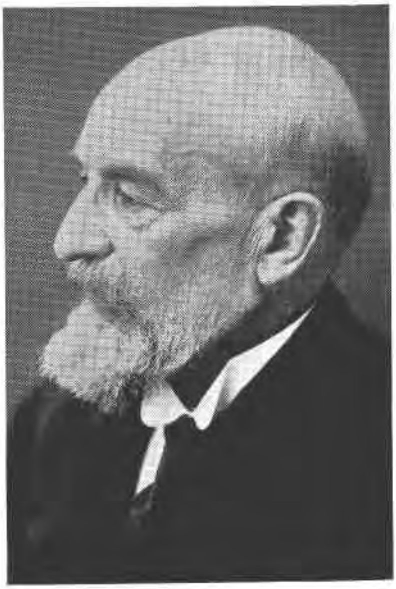
Another giant among crystallographers has passed away. Georges Friedel our distinguished honorary life fellow died at Strasbourg, France, on December 11, 1933. He was born at Mulhouse, France, on July 19, 1865. He was the son of the great French chemist and mineralogist, Charles Friedel (1832–1899) and the father of Edmond Friedel (1895–   ), the third of a dynasty of scientists.

Georges Friedel was graduated from the Paris School of Mines, where he was the enthusiastic disciple of Ernest Mallard. He had a double career: in the French Bureau of Mines, he reached the high office of *Inspecteur général des Mines;* at the same time he was engaged in teaching and research, first at the Saint-Etienne School of Mines, later at the University of Strasbourg where he was appointed the head of the Mineralogical Institute. Since 1917, he was a correspondent of the French Academy of Sciences. His publications extend over a period of 43 years. Although they deal

[36] Gruner, J. W., *Amer. Min.*, vol. **14**, p. 227, 1929.
[37] Kreutz, St., *Min. Mag.*, vol. **15**, p. 233, 1909.

primarily with crystallography and mineralogy, they also include valuable geological contributions.

I. The Geologist:—In 1902, he published a memoir on the "Firminy granite massif" and a geological map of the Saint-Etienne coal basin. In 1906–07, jointly with Pierre Termier, he showed the existence of nappes of pre-stephanian age in the Saint-Etienne region. With F. Grandjean, he published a further study of the eastern border of the "Plateau Central" (map of the Lyon



Georges Friedel
1865–1933

quadrangle). In 1907, he was awarded the *Prix Joseph Labbé* by the French Academy for his contributions to geology and the leading part he played in the discovery of a new coal field east of Lyon. In 1919, again with P. Termier, he wrote three papers on the *klippes* of the Alais plain and the structure of the Gard coal field. In 1927, he reported on the presence of a salt dome in the Haut-Rhin oligocene basin. In 1929, with V. Maikowsky, he published very pertinent notes in geophysics on temperature measurements in drill holes.

II. The Mineralogist:—G. Friedel achieved the synthetic production of a number of minerals. He began this investigation in 1890 with his father. The action of alkalies on mica gave them nepheline, sodalite, leucite, orthoclase, and anorthite. In 1909 (with F. Grandjean) chlorites were obtained by the reaction of alkaline solutions on pyroxene. In 1912, he prepared artificial potassium nepheline. He solved the riddle of the chemical nature of melanophlogite. His famous work on zeolites dates back to 1896–7; among other things, he showed the possibility of substituting various liquids or gases for water in zeolites and made the classic comparison of considering a zeolite as a sponge, able to release and again take up water, so well explained by recent X-ray studies. He investigated the etch-figures and percussion figures of mica, and the etch-figures of quartz at high temperatures. With F. Grandjean, he gave a paper on tin-bearing rutile. He reported the abundance of octahedrite in chloritized schists and granites. He also reported on analcime, on a new variety of calcite, on compact muscovite, described several new crystalline species, and found new localities for a number of rare minerals.

In later years, he became greatly interested in the diamond and published several papers on that subject: on the black inclusions of the Cape diamond; on the symmetry, forms, and habit of the diamond; on its birefringence, and (with G. Ribaud) on an allotropic transformation of diamond into graphite. Among his last publications, his paper on malformed halite crystals typically illustrates the rigid scientific honesty of his method of investigation.

III. The Crystallographer:—In 1893, Friedel developed a new method for the accurate measurement of path-difference based on the restoration of elliptically polarized light to plane polarized light. His ingenious procedure has recently been applied to the study of stressed glass by R. W. Goranson and L. H. Adams.

Along with his work on twinning, begun in 1897, Friedel carried on his celebrated studies on the *Law of Bravais*. This law had been enunciated by Bravais on theoretical considerations. In 1904, Friedel announced that it was a law of observation, independent of any speculation. His classic paper of 1907, with numerous examples, convincingly settled this point and the Law of Bravais has since then received general acceptance. Although Friedel, in his deep modesty, actually credits Haüy for having first sensed the truth of this law, it would not have been recognized had it not been for his own observations; the Law of Bravais is truly Friedel's law. In 1905, the French Academy of Sciences chose him as the laureate for the *Prix Delesse* in recognition of his crystallographic work.

Friedel's *Law of mean indices* (1908) discloses the fact that the axial elements of a crystal can be approximated simply from the list of observed crystal forms. This is another proof that the reticular density of a face is the chief factor controlling its occurrence. When Friedel, by his patient and sagacious observations, definitely established the factual character of the Bravais principle, he laid the foundation of morphological crystallography on a firm experimental basis.

Friedel's excellent discussion of the experimental bases for a reticular hypothesis of crystal structure and his lucid explanation of the difficult question of irrational trigonal axes justified A. F. Rogers' statement[1] that Friedel's *Law of rational symmetric intercepts* (1905) had "practically proved" the existence of a space-lattice in crystals before Laue's decisive experiment.

Friedel was the first to outline the theory of the *crystallographic bundle of planes* (*faisceau, gerbe*) (1905). This paved the way for the large memoir of Zaremba and Kreutz (*Fondements de la Cristallographie géométrique*) whose results were further generalized by R. Gibrat (1927). The basic importance of Friedel's *faisceau complet* is well expressed by Gibrat, who sees in it the very essence of crystallography.

The Mallard-Friedel theory of twins is by far the most satisfactory that has been advanced. Summarized in Friedel's *Leçons* (1926), it is also available in German in Niggli's textbook. The leading principle is that twinned crystals have a lattice in common, which pervades the whole of the complex crystalline edifice. The prolongation of the common lattice from one member of the twin to an adjacent member may be either exact or approximate; in each case the unit cell of the common lattice may be either the smallest cell of the individual lattices of the twinned crystals or a simple multiple cell thereof. Hence Friedel's classification of twins falls in four classes. The theory accounts for all types of twins but one: the Zinnwald twin. Friedel's very last paper (1933), in which he correlates the observations of J. Drugman on the various quartz twins with the experimental results of Gaubert, Schaskolsky and

[1] *Am. Mineral*, vol. **10**, pp. 181–7, 1925.

Schubnikow, explains the hitherto irreconcilable exception. In the Zinnwald twin, two preexistent crystals unite in such a relative orientation that the two faces in contact have one parameter (a lattice-row) in common. Friedel calls this type of twin *monoperiodic* in contradistinction to the usual kind of twins, to be termed *triperiodic*. Moreover, he points out the possibility of a third type (*diperiodic*) in which the adjacent individuals would have a two-dimensional cell (a plane lattice) in common.

Incidentally, the Mallard-Friedel theory of twins shows the true value of merohedry. The expression "deficient elements of symmetry" may be misleading but the concept of merohedry (duly divorced from it) cannot be discarded for it emphasizes the fundamental distinction between the symmetry of a crystal and that of its lattice—the key to the explanation of twinning.

Friedel began his work on the so-called *liquid crystals* in 1907 and continued it until 1931. He had various co-workers and followers (F. Grandjean, L. Royer, his son E. Friedel, C. Mauguin, Foex, etc.) and their contributions are perhaps the most outstanding ever published in Lehmann's field. Friedel recognized four different *stases* (structural types) of matter: crystalline, smectic, nematic, amorphous. They are separated from each other by *discontinuous transformations*, which is the basis of the classification. Here again, Friedel's work will stand since it is based on careful observation of facts under the microscope.

Friedel was one of the first to grasp the value of the new tool placed at the disposal of crystallographers by Laue's experiment. As early as 1913, he gave the correct proof of the law that X-ray diffraction is equivalent to a "reflexion" from reticular planes and showed that it could be derived from two hypotheses only (not three as Wulff had thought). The fact that a radiogram cannot tell whether a crystal is centrosymmetric or not is also due to Friedel (1913), who listed the eleven symmetries possible in an X-ray picture; this contribution is called Friedel's law in Bragg's new book. We are also indebted to him for valuable notes on the calculation of the intensity of diffracted X-rays (1919). His textbook (1926), which gives a clear presentation of the essentials of structural crystallography, includes a detailed treatment of several questions little known at the time.

In physical crystallography, we are indebted to Friedel for his remarkable theory of crystal growth (1924), showing the exact similarity of crystal corrosion by a slightly undersaturated solution, and crystal growth in a slightly supersaturated solution. The two phenomena are symmetrical with respect to the saturation point. The theory explains the formation of "negative crystal" or cavities (in crystals) bound by crystal forms, also the formation of curved faces by convergent or divergent diffusion (*effet d'angle, effet d'arête*). Friedel discussed and explained the failure of the former Curie-Wulff theory. His work on crystal corrosion has been continued by R. Weil (etching of negative crystals in quartz by HF).

In 1927, Friedel showed that the presence of holoaxial hemihedral forms on a crystal does not warrant the conclusion that the crystal has hemihedral symmetry. This is due to the fact that, since an optically active substance is devoid of symmetry planes, a crystal (otherwise holohedral) grown in such a substance cannot show any plane of symmetry, but can at the most exhibit holoaxial hemihedry. In 1930, jointly with R. Weil, Friedel pursued his work on the influence of the medium of crystallization on the symmetry of the crystal forms developed.

Let us also remark that L. Royer's remarkable investigation on *épitaxie* (mutual orientation of crystals of different species) of 1928, carried on in G. Friedel's laboratory, seems to have found its inspiration in Friedel's ideas on the subject as expressed in his textbook of 1911.

IV. The Teacher:—The achievements of the many students of G. Friedel testify to the excellence of his teaching. He published three textbooks: (1) Cours de minéralogie, Ecole des Mines de Saint-Etienne, 211 pp., 1904; (2) Leçons de Cristallographie, 310 pp., 383 figs., Paris, Hermann, 1911; (3) Leçons de Cristallographie professées à la Faculté des Sciences de Strasbourg, 602 pp., 578 figs., 1926. The latter is partly a revision of the second. It is now an outstanding text in geometrical and physical crystallography.

Friedel's brilliant qualities as a teacher are displayed in the layout of this book, the right emphasis placed on fundamentals rather than on mere accumulation of facts and theories, a highly critical scientific attitude, an illuminating discussion of what is known followed by the challenging outline of what remains to be found. The charm of the book is further enhanced by the elegant simplicity of its language. Very few literature references are found in Friedel's *Leçons* although due credit is given to all investigators except

Friedel himself! The old master wanted to mark his disapproval of the abuse of bibliography in teaching, which he thought was carrying us back to the medieval practice of rehashing bookish gossips.

The greatest lesson which emanates from his text as well as from his life work is the importance of meticulous observation and scrupulous acceptance of duly observed facts.

Even from this incomplete survey of Friedel's scientific contributions, one cannot fail to be impressed by the magnitude of his work as well as the fundamental nature of the problems he solved. None of the important questions of crystallography at issue during the past half-century escaped his inquisitive attention and his name remains attached to several natural laws.

The indomitable energy with which he carried on his work during his long illness gave the measure of his moral fortitude. In Georges Friedel, the man was equal to the scientist.

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Most of Friedel's papers will be found in *Bull. Soc. fr. Min.* (vols. **13** to **56**) and *C. R. Ac. Sc.* (vols. **110, 116, 122, 139, 140, 142, 151, 152, 156** to **158, 162, 168, 169, 172** to **174, 176** to **180, 182, 184** to **186, 189, 190, 197**).

See also: *Ann. Soc. géol. Belgique*, vol. **29**, Mém. 237, 1902; vol. **45**, Bull. 284, 1923; Livre jubilaire 1924 (geology, diamond). *Bull Soc. Ind. Min.*, Saint-Etienne (4) vols. **3–4**, 485 pp., 1904 (twins). *Bull. Soc. géol. France* (4) vol. **6**, p. 240, 1906; vol. **7**, p. 191, 1907; vol. **23**, p. 488, 1923; *Bull. Serv. Carte géol. France*, vol. **20**, 1910 (geology). *Jour. Chimie phys.*, vol. **11**, p. 478, 1913 (Curie theory). *Annales Phys.*, vol. **18**, p. 274, 1922; *Bull. Soc. fr. Phys.*, 1922, 1924, 1926; *Revue gén. Sc. pures et appl.* vol. **36**, p. 162, 1925; *Jour. Phys. et Radium*, (6) vol. **3**, (12); (7) **2** (5); *Z. Krist.*, vols. **72, 73, 79, 83** (liquid crystals). C. R. Congrès Soc. savantes, Strasbourg, 1920 (twinning).

NOTES AND NEWS

NOTES ON STAUROLITE AND ASSOCIATED MINERALS FROM SCHIST AT GASSETTS, VERMONT

L. W. Currier*

A certain garnetiferous mica schist in south-central Vermont has been named Gassetts schist by C. H. Richardson[1] from the excellent exposures near Gassetts station in Chester township. For the

* Published by permission of the Director of the United States Geological Survey.

[1] Richardson, C. H., The geology and petrography of Reading, Cavendish, Baltimore and Chester, Vermont: *Report of the Vermont State Geologist*, 1927–28, p. 225.