

## BOOK REVIEWS

STRUCTURAL PETROLOGY OF DEFORMED ROCKS BY HAROLD WILLIAMS FAIRBAIRN, with supplementary chapters on Statistical Analysis, by Felix Chayes; ix+344 pages; Addison-Wesley Press, Inc., Cambridge, Mass., 1949. Price, \$12.50.

This is nominally a second edition, although it is the first one to be printed and bound in book form. The first edition to be published by the Addison-Wesley Press was an amplification of the earlier mimeographed editions published by Queens University in 1935 and 1937; it was reproduced by an offset process in the same size as the previous mimeographed editions ( $8\frac{1}{2} \times 11$  in.) and had paper backs and plastic ring binder.

The current edition is cloth bound and is nicely printed on medium grade paper adequate for the line drawings, which constitute the great bulk of the illustrations. Some of the photographs are not as sharp and clear as they would have been on a better grade paper.

The format is a great improvement over that of the first edition; the text and illustrations are also considerably improved. The volume has still not developed to the stage where it could be considered a textbook; indeed the subject of petrofabrics has hardly developed to the stage where a textbook could be written. It is, however, the most complete and up-to-date single-volume reference work on the subjects of structural petrology and petrofabric analysis available in any language.

From the high price of the book one judges that the edition is extremely limited and that the publishers do not expect to sell many copies. This is unfortunate because it puts the book beyond the reach of most graduate students and probably will restrict considerably its distribution to libraries.

The book is divided into three parts. Fairbairn makes sure that Petrofabric and Experimental Facts, Part I, is sharply separated and cannot be confused with Interpretation and Application, Part II. Part III deals with Methods and Analytic Procedures. Part I summarizes the orientation rules (patterns) for the various minerals that have been studied, points out observed relations of orientation to *s*-surfaces and to folds, and outlines the available information on experimental deformation, including annealing, recrystallization and related phenomena. Comparatively little work has been done on the deformation of rock forming minerals, so many of the data are necessarily from work on metals. Part II develops hypotheses as to how the observed orientations described in Part I came about, how preferred orientation may be developed in various minerals, how *s*-surfaces can be produced, the mechanism of recrystallization in tectonites, kinds of folds and how they are formed, possible processes of rock flowage and tectonic transport, processes that could give rise to lineation, etc. Part III outlines field and laboratory techniques, including collection of oriented specimens, preparation of oriented thin and polished sections, study under the microscope both with and without the aid of the universal stage, preparation of fabric diagrams, and other techniques for presenting data. Chayes' two chapters on statistical analysis of two and three dimensional fabric diagrams are also included in Part III.

This clear separation of data from the interpretation thereof is a splendid idea. In a great many of the papers in structural petrology it is quite difficult to be sure what is ascertained fact and what is inference, i.e., the interpretation of those facts. This separate treatment has one unfortunate consequence, however; most of the grain orientation diagrams, tables, graphs, etc., are given in Part I, and when interpretation of the examples is reached in Part II the reader finds himself obliged to turn back and forth again and again and again in order to refer to the illustrations and tables so that he can follow the discussion adequately. One wonders whether a much smoother result might not have been achieved by summarizing very briefly in Part I the data for the illustrative examples used in Part II and then placing the diagrams, etc., with the detailed interpretative discussions in Part II.

The description of methods and techniques in Part III is well written and illustrated. The chapters on statistical analysis by Chayes are an innovation in this edition. He stresses the importance of using a systematic sampling plan, based on statistical methods, in the study of fabrics. In the chapter on Statistical Analysis of Two-dimensional Fabric Diagrams the application of the chi-square test of equal frequency to determine whether there is a significant degree of preferred orientation (anisotropy of fabric) is described. The familiar 0.05 and 0.01 "significance levels" are recommended in general for evaluating orientation data, but the suggestion is made that for some situations such as exploratory studies the 0.10 or even 0.20 level be used as a criterion of whether further work is justified. A scheme is offered in this chapter for the quantitative description of fabric.

In the chapter on Statistical Analysis of Three-dimensional Fabric Diagrams the chi-square test of equal frequency is examined again; the conclusion is reached that it is too sensitive for use with this type of diagram. The Winchell general test is considered and it appears to be not sensitive enough. A third test is then introduced (a correlation test developed by Chayes), "the results of which seem to be in closer accord with conclusions reached by conventional, nonstatistical methods."

It would appear when the values of significance levels must be changed for certain types of interpretations and a statistical test that accords better with nonstatistical interpretations needs to be developed that perhaps petrofabric data are not quantitative enough for precise mathematical treatment. There is considerable doubt, therefore, whether, *with our present state of knowledge*, it is worth the time and trouble required to make a statistical interpretation of petrofabric data. Chayes' choices may give the impression of juggling to make results fit hypotheses, but what he is really trying to do is to find a scheme that will be of practical use, yet not needlessly refined.

Chayes frankly discusses the limitations and restrictions of the usual statistical tests of hypotheses, but expresses the hope that the more modern developments may eventually be applied successfully to petrofabrics.

In a new edition with changed format, extensive revision and addition of much new material, errors are to be expected. Most of these are minor typographical errors which will no doubt be corrected in the next printing. There are several, however, to which attention should be called because they are likely to cause confusion. On page 12, paragraph 4, last line, "*ac*" should read "*ab*" and on page 25, paragraph 4, line 2, "parallel to *b*" should read "parallel to *a*." On page 42, line 14, "from a lamellae maximum to an axes minimum" should read "from a lamellae maximum to an axes maximum." Figure 5-2 on page 72 should be rotated 90° so that the positions of the *s*-planes will coincide with those of the corresponding *s*-planes in Figures 5-3 to 5-7. On page 79, paragraph 1, the statement is made that "The shortening is inversely proportional to the time—" What is meant is that the *rate of shortening*, or the *shortening per additional unit of time* is inversely proportional to the time. The total amount of shortening is directly proportional to the time. On page 92, paragraph 2, line 11, "at 45° to Figure 7-6" should read "at 45° to *ab* in Figure 7-6." Many commonly used metals do not even begin to anneal at 100° C., so that figure as given on page 98 is no doubt a misprint for 1000°C. It is difficult to follow the discussion of Figure 19-8 on pages 247-9 because the six letters referred to throughout the discussion have been omitted from the figure.

There are a few statements that should be rewritten in the interest of clarity. For example, if one follows the directions in footnote (1), Table 2-1, page 9, he determines a point on the *c* axis instead of the center of the plane, the point in which he is interested. The statement should be re-written to indicate that the pencil is moved *parallel to* each axis in turn rather than to an intercept on each axis. The discussion of Figure 4-10, page 63, paragraph 2 appears confused and perhaps could be recast with advantage.

In matters of interpretation of petrofabric diagrams and data there is commonly room for considerable difference of opinion. Perhaps, therefore, it is useless to mention matters of interpretation in a review, but the reviewer feels that a few examples may prove profitable to the reader. In the discussion of symmetry on page 7 most of the examples appear to be ill-chosen. Figure 2-16 is not orthorhombic, but monoclinic, with respect to the fabric axes shown. ("Figure 2-23" here is obviously a misprint for "Figure 2-32", which is all right as an example of orthorhombic symmetry.) Figure 2-35 would have been a better third example of orthorhombic symmetry than the one mentioned, Figure 2-37. Figure 2-11 is, strictly speaking, monoclinic, as stated, but it is actually more nearly orthorhombic than some of the ones cited as orthorhombic. Figure 2-14 is a much better example of monoclinic symmetry than Figure 2-15, which is really triclinic. Figure 2-43, also cited as monoclinic, is as nearly an ideal orthorhombic diagram as any shown in the entire book. Figure 2-27, cited as an example of triclinic symmetry, is almost perfectly orthorhombic. In Figure 2-66 not all of the fabric directions are shown, but the *s*-plane indicated is a symmetry plane, so the diagram is at least monoclinic. Figure 2-67 is much more obviously and completely triclinic.

On page 96, paragraph 4, the following appears, "The higher the symmetry of a crystal possessing glide planes, the more translation systems it possesses. . . ." This would appear to be inaccurate; the higher the symmetry the more glide planes a crystal *can* possess; so "possesses" should read "may possess."

On page 257, paragraph 4, Fairbairn states that another advantage of the interference figure method is the possibility of investigating the orientation of grains too small for study with the U-stage. The reviewer has found the opposite to obtain,—that grains too small for getting an interference figure can be measured on the U-stage.

In general the literature coverage of this book is excellent, which makes the few important omissions all the more noticeable. On page 149 and in Table 2-1 (p. 9) one gets the impression that no work has been done with feldspar, but Larsson<sup>1</sup> made a very exhaustive and interesting study of the orientation of plagioclase during the different phases of a complex intrusion. No discussion of regional arcuation (page 229, par. 2) is complete without mention of Sahama's monumental work in Finland.<sup>2</sup> This paper is listed (No. 215) in the bibliography, but is not mentioned in the discussion of arcuation. In the discussion of universal stage procedures (pages 257–270) Berek's<sup>3</sup> book, which is one of the most lucid and useable of all descriptions of universal stage technique, is not mentioned, nor is it listed in the bibliography.

The bibliography is one of the most complete lists of articles in structural petrology and related subjects ever assembled and it should prove most useful to other workers in the field. In addition to the omissions mentioned above, however, many early papers cited on page 235 and the following pages are left out because the references are given in Sander's "Gefügekunde der Gesteine." This is unfortunate, because many people working in structural petrology do not have access to Sander's book. Moreover, the bibliography is not consistent throughout; in many references workers' first names or initials are omitted as in Nos. 27, 36, 62, 102, 143, etc. The year is given for most of the papers but in some, such as Nos. 105, 106, 125, 126, 130, 152, etc., it is omitted. For many of the papers complete titles are given, but many others are abbreviated, which is not a pleasing effect.

<sup>1</sup> Larsson, Walter, Der Nygård Pluton: *Bull. Geol. Inst. Upsala*, **25**, 13–134 (1935).

<sup>2</sup> Sahama, Th. G., Die Regelung von Quarz und Glimmer in den Gesteinen der Finnisch-Lappländischen Granulitformation: *Bull. Geol. Comm. Finlande*, No. **113**, 119 pp. (1936).

<sup>3</sup> Berek, M., Mikroskopische Mineralbestimmung mit Hilfe der Universaldrehtischmethoden, Gebrüder Borntraeger, Berlin (1924).

Most of the shortcomings mentioned above can easily be remedied when the book is reprinted and even if they are not they will detract but little from the most complete and up-to-date compilation of this subject extant, which is exceeded in authoritativeness only by the writings of the men who are in large part responsible for the development of this field, Walter Schmidt and Bruno Sander.

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EINFÜHRUNG IN DIE GEFÜGEEKUNDE DER GEOLOGISCHEN KÖRPER BY  
BRUNO SANDER. Springer, 1948, 215 pages.

1. TEIL: ALLGEMEINE GEFÜGEEKUNDE UND ARBEITEN IM BEREICH  
HANDSTÜCK BIS PROFIL.

Gefügekunde is the science of fabrics, biological fabrics, metallurgical fabrics, soil fabrics, and others. Sander's viewpoint elevates fabric-science to a field equal to Petrology or Sedimentology. A fabric results from movements of particles in a field of force, as for instance, sedimentation under the influence of gravity, the rearrangement of minerals during folding, or the growth of minerals under hydrostatic conditions. Study of fabric is historical analysis of a succession of conditions. In its broadest sense fabric includes structural elements and not only microscopic dimensions. There is no reason why megascopic features should furnish more important information than microscopic ones and vice versa, and there is no relation between size and significance.

Stress plans result in corresponding strain plans and fabric analysis is merely the determination of movement plans resulting from force distribution. Fabric studies are the only accurate approach to the determination of the field of forces.

Symmetry of fabric is the unerring mirror of the symmetry of movement and its rhythm which produced it. Determination of the latter is essential for accurate definition of the former.

Sander's book is only the first part of what may be generally called Gefügekunde and comprises essentially non-microscopic elements. The second part is in press. The first part of this book defines Gefügekunde, and takes up the following topics: time and fabric, symmetry and rhythm of morphological and functional fabrics, affine and non-affine deformations, movement and symmetry in tectonic formation, symmetry of anisotropical fabric in superposition and homogeneous penetrations, mechanical stress and formation in homogeneous areas as functional fabrics, tectonic competence and fabric, fractures, planar and linear schistosity, tectonic streaming and flowage, movement and symmetry of deposition.

The second part deals with tectonic analysis of typical fabrics of non-microscopic order of magnitude. Important topics are a general review of linear and planar structures and their orientations, representation in spherical projection,  $B$  and  $\beta$  axes, time relationships of superimposed  $B$  axes, determination of relative movement directions perpendicular to  $B$ , types of homogeneous and inhomogeneous tectonic movement pictures with planar and linear structures, reconstruction of tectonic fabrics.

The third part supplies examples and application of fabric analysis especially to igneous, highly mobile intrusions, salt intrusions, surface flows, and a brief comparison with biological fabrics.

Literature references are not given in this volume, but promised for the second volume.

One of Sander's chief contributions is precision of observation and rigidity of analysis. He points to the many applications of measuring techniques in a field which is all too readily the object of rather vague descriptions and loose terminology.

The mystery which surrounds the subject of petrofabrics stems from the fact that the

literature is predominantly in German and that the technical language has become involved and cumbersome for those who are not thoroughly familiar with it.

This new book is to be an introduction, but really demands thorough acquaintance with the terminology. It contains a wealth of material in a minimum of space. A glossary of terms—preferably with English translation—would add to the usability, and more illustrations would help to gain friends or converts to the method. I know of few books which demand greater concentration for understanding and still fewer from whose perusal I have received more benefit.

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THE OPTICAL PRINCIPLES OF THE DIFFRACTION OF X-RAYS BY R. W. JAMES, Professor of Physics in the University of Cape Town. (THE CRYSTALLINE STATE—vol. II. Editor: Sir Lawrence Bragg.) xv+623 pp., 5½ by 8½ inches, 217+vii figs., including 19 figs. on 16 half-tone plates. London, G. Bell and Sons, Ltd. 1948. Cloth. Price, 80s.

The main value of this long awaited book lies in the thoroughness with which it covers the whole field of x-ray diffraction. It is a book of principles, giving a connected account of the theoretical foundation, but leaving out the experimental techniques and the results, of crystal-structure analysis. The author had already written one of the first textbooks on "X-Ray Crystallography," a Methuen Monograph, justly famous for its simplicity. Crystallography has gone a long way since that time, and the new volume is many times the size of its predecessor, but Professor James' lucidity of exposition has remained the same in spite of the increased complexity of the subject. This compendium—one more reason why would-be mineralogists should take integral calculus in college—is destined to become the "livre de chevet" of structural crystallographers of all feathers; its appearance has already been welcomed by a mineralogist (F. A. Bannister, *Min. Abs.*, 10, 447, 1949), a physicist (P. P. Ewald, *Science Progress*, 37, 572, 1949) and a metallurgist (C. S. Barrett, *J. Am. Chem. Soc.*, 71, 3859, 1949).

It is hard to do justice to such a monumental work in the limited space of a review—the table of contents alone fills nine printed pages. The treatment begins with the diffractions of x-rays by identical scattering points at the nodes of a lattice according to Laue's original method; it goes on immediately to the reciprocal lattice, Ewald's construction, and Laue's interference function. Then clusters of (not necessarily identical) scattering points are considered as repeated by the lattice, and diffraction by the crystal is studied, first neglecting dynamical interaction of the scattered waves and the crystal structure, then considering it in the light of Ewald's theory. As prerequisites to a comparison of this theory with that of Laue and Bragg insofar as accounting for experimental intensities is concerned, the following topics are taken up: atomic scattering factor, treated both by the classical method and by wave mechanics, dispersion, and influence of thermal motion (diffuse scattering). The intensity formulae can now be subjected to experimental test, in the cases of mosaic crystals, perfect crystals, and powders.

The author turns next to crystal analysis and gives an excellent summary of the use of Fourier series (electron density function and Patterson function), in which he stresses the relation of the diffraction of x-rays to that of light and to the formation of optical images. (Fourier integrals are introduced to determine the electron distribution in atoms.) The dynamical theory is then reexamined and fitted to the continuous crystal expressed by the Fourier series. The reciprocity theorem is applied to the study of diffraction phenomena for radiation excited within the crystal (Kossel lines, and Kikuchi lines).

The last topic is the scattering of x-rays by non-crystalline material (gaseous, liquid,

and solid) and the related diffraction by finely powdered crystals. The effect of crystal size and that of crystal distortion on the spectra is discussed, and diffraction by fibers is briefly presented.

Four appendixes deal with the vector algebra used in the book; the definition, properties, and use of the reciprocal lattice; corrections of the scattering factor (Hönl); and the derivation of the Fourier integral. A detailed index of subjects and one of authors occupy 13 two-column pages of fine print. A list of selected references is given at the end of each of the ten chapters.

In a book of this scope and size, it is difficult to avoid all the little blemishes in the first printing—the text is not free from typographical errors, some of the references are partly wrong, there are inconsistencies in the use of the sign of the exponent in the expressions of the structure factor and the electron density (pointed out already by Miss Megaw and Mrs. Lonsdale). Well printed on good paper, with excellent drawings and plates, the volume leaves nothing to be desired as to craftsmanship; it does, alas, as far as price is concerned! Even so, a copy of this book is a sound investment; in our family, we own two.

DONNAY AND DONNAY

ON THE SYSTEMS FORMED BY POINTS REGULARLY DISTRIBUTED ON A PLANE OR IN SPACE BY M. A. BRAVAIS. Translated by A. J. Shaler, from the original in *Journal de l'Ecole Polytechnic*, Cahier 33, Tome XIX, 1–128, Paris, 1850. Crystallographic Society of America, Memoir No. 1.

Every  $x$ -ray crystallographer is probably as familiar with the 14 Bravais lattices as he is with the alphabet. But the great majority of them have never, until now, had available the opportunity to follow through the original derivation of these lattices. Professor Shaler and the Crystallographic Society are to be commended for making an English translation of this classic available. Many teachers, who have developed more or less adequate derivations of their own, will be especially interested in this presentation by Bravais. By means of a series of theorems, the argument is built up, step by step, from symmetrical nets on through the various symmetrical lattices, until the 14 lattices are rigorously deduced. It is also worthy of note that Bravais included the idea of a polar lattice, the forerunner of the reciprocal lattice, which has been developed into a most useful tool in the graphical interpretation of  $x$ -ray diffraction data.

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AN INTRODUCTION TO LUMINESCENCE OF SOLIDS BY HUMBOLDT W. LEVERENZ, 569 pp. and 143 figures. Published by John Wiley and Sons, Inc. Price \$12.00.

Although this book deals principally with artificial phosphors, the attention of mineralogists and crystallographers, as well as that of physicists, may well be directed to this monographic pandect in an allied field of interest. During recent years the use of luminescent materials, stimulated by revolutionary wartime developments, has expanded along increasingly varied lines. Luminescent compounds were intensively employed in the tubes of radar sets and “night-seeing” devices, for marking dials of airplane instruments, charts, and maps, and for identifying objects during blackout restrictions. A few of the important commercial uses are in “fluorescent” lamps, television, fluoroscopic screens, oscilloscopes, photographic emulsions, and dyes.

The study of phosphors is a mushrooming subfield of science, for the phosphors known today are constantly and rapidly being improved not only in the techniques of their preparation but also in their applications and uses. Their development is one of the many

facets of the research effort toward a more efficient national defense that is undergoing polishing.

A negative definition of luminescence states that it is "any emission of light not due to incandescence." Many minerals and many more artificial compounds possess the property of absorbing electromagnetic vibrations of a certain wave length range and "rebroadcasting" the energy in another range. X-rays, gamma rays, alpha particles, cathode rays, long- and short-wave ultraviolet, as well as visible light, may be used for excitation, and the emitted vibrations also may fall outside of the visible region. Most luminescent minerals and other phosphors require the presence of an activator (a phosphorogen or luminogen), a minor or trace constituent which defines both the color and brilliance of the luminescence produced. According to Leverenz, phosphors may be separated into two main groups with respect to activators: (1) those made by adding a small proportion of an impurity to a pure host crystal upon heating and (2) those made by heating alone and thought to be "self-activated" due to a stoichiometric excess or structural displacement of one or more of the essential ingredient elements.

Chapters one and two deal with concepts of the structure of matter and of crystals. In the third chapter are described the syntheses of phosphors; the constitution and structure of phosphors follow in the next chapter. In long chapter five luminescence of phosphors is discussed under such sub-topics as excitation, storage, emission, decay, stimulation, quenching, and efficiency. Chapter six includes a correlation of host crystal and phosphor properties, and in chapter seven the uses of phosphors are summarized.

Five appendices, a glossary, a list of references (750 entries!), and three indexes (formula, i.e., by compound, name, and subject) close the book. A useful periodic table of the elements, encyclopedic in its scope of listed properties, is folded inside the back cover. Certainly the study of luminescence has progressed prodigiously from that natal evening at the Franklin plant of the New Jersey Zinc Company when a spark formed by pulling a knife-type switch for extinguishing the lights produced a fluorescent glow in willemite specimens lying nearby in the darkened room!

Although a considerable part of the volume is couched in the formulae and phraseology of a physics on a level somewhat above that with which the average geologist or mineralogist is conversant, nevertheless these readers too, when subjected to the excitation of certain selected "lengths," will absorb and store information on several energy levels for useful future emission.

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