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BOOK REVIEWS

Deformed metals and rocks

Wenk, H.-R. (Editor) 1985. *Preferred Orientation in Deformed Metals and Rocks: An Introduction to Modern Texture Analysis*. Academic Press, London. Price £55.00.

This 1985 textbook on preferred crystal orientation (texture) in metals and rocks is a latecomer for review. It is a comprehensive summary of theoretical, experimental and analytical aspects of texture development.

The stated aim of the book, which arose from the workshop on Deformation Mechanisms and Texture Development in Rocks, held as part of the 23rd U.S. Symposium on Rock Mechanics at Berkeley in 1982, is to serve as an up-to-date review of texture development. Many of the workshop participants (from such diverse backgrounds as material science, metallurgy, geology, physics and mathematics) have contributed chapters. Although originally envisaged by the editor (H.-R. Wenk) as an introductory text, many of the chapters go far beyond this level, presenting reviews of work which are at the forefront of modern texture analysis.

In Chapter 1, Weiss and Wenk emphasise the important differences (e.g. in atomic bonding) between metals and minerals which in turn is reflected in their contrasting properties of diffusivity and plasticity. They point out that whilst the metallurgist may vary the production process (i.e. deformation history) to produce a desired product of predetermined texture, the structural geologist must attempt to deduce deformation histories from observed textures in rocks.

A clear and concise review of the measurement of pole figures is given by Weiss in Chapter 2. In the first section of this chapter the construction of pole figures from orientation data is covered, whilst in the second section optical methods of texture analysis are reviewed. Optical techniques covered include universal stage methods for uniaxial and biaxial minerals, the photometric method, reflected light for opaque minerals and the rarely employed optical activity method for determining the handedness (chirality) of enantiomorphic minerals such as quartz. In Section 3 an introduction to the use of X-ray, neutron and electron diffraction techniques of texture analysis is presented. Although mentioned, it is unfortunate that more attention is not given to texture analysis using the SEM electron channelling technique.

In Chapter 3 Weiss and Wenk present an essentially mathematical treatment of pole figure and texture symmetry, covering such topics as point group symmetry, directions in crystals and pole distribution symmetry. Particular attention is paid in this chapter to black–white symmetry groups and their use in specifying the symmetry of physical situations in which two states of polarity or sign occur.

The complete crystallographic orientation of crystallites (or grains) within a single phase specimen, and its mathematical description—the Orientation Distribution Function or ODF—is dealt with in considerable detail in Chapters 4–7. A general introduction to the specification of crystal orientation for homogeneous textures and the concept of ODFs is given by Bunge in Chapter 4.

Calculation of the ODF from pole figure data is a central problem in texture analysis. Mathematical reproduction of the ODF requires the solution of a multidimensional integral equation. All existing reproduction methods try to solve this equation in a more or less comprehensive way. These methods are briefly reviewed by Bunge in Chapter 4 and include the discretization (encompassing vector method), series expansion (harmonic), inversion formulae and probabilistic methods of pole figure inversion. A detailed account of the harmonic method of calculating the ODF from pole figure data is given by Bunge and Esling in Chapter 5. With this method approximate preferred orientation is described by a continuous function. In contrast the vector method reviewed by Schaeben and Wenk in Chapter 6 features a discrete approach to preferred orientation and the problem of approximating the true ODF from experimental pole figure data.

If the ODF is derived from 'reduced' pole figures measured by normal diffraction techniques then, due to symmetry differences between the true ODF and measured pole figures, 'ghost maxima' and physically meaningless negative areas may appear in the calculated ODF. In Chapter 7 Matthews and Wenk describe a discrete ODF reproduction method incorporating a conditional ghost correction. This correction is based on the assumption that within the range of ODFs that are compatible with the pole figures the one that displays the fewest peaks that concentrate a maximum of intensity and possesses the maximum possible background, is the correct one.

In Chapters 8–12 the main mechanisms of texture development are reviewed from predominantly microstructural and mathematical viewpoints. A brief introduction to dislocation theory and microstructures is given by Barber in Chapter 8 and techniques for studying dislocations (e.g. etch pitting, decoration, TEM and X-ray topography) summarized. Examples of dislocation and subgrain structures from metals and minerals are presented in the final section of this chapter.

Processes of recrystallization are reviewed from an essentially metallurgical viewpoint by Gottstein and Mecking in Chapter 9. Aspects of recrystallization covered in this review include: terminology, recovery, nucleation and grain-boundary migration processes. The mechanisms of dynamic recrystallization are shown to be closely controlled by such factors as homologous temperature, rate of dislocation formation and grain-boundary mobility.

An informative introduction to the different regimes of plastic deformation is given by Langdon in Chapter 10. Using constitutive equations that describe the rates of flow for different deformation mechanisms, Langdon shows how deformation mechanism maps may be constructed which delineate the set of conditions (stress, temperaturer and grain size) where each individual mechanism is dominant. Examples illustrating these deformation mechanism maps are given for metals and ceramics.

In Chapter 11 the development of textures by slip and twinning is reviewed by Van Houtte and Wagner. This review consists of a brief mathematical treatment of the plastic deformation of single crystals which is followed by a more detailed introduction to Taylor–Bishop–Hill theory for polycrystals. Such texture development by intracrystalline deformation is in direct contrast to the processes of particle reorientation within a flowing matrix described by Oertel in Chapter 12.

In Chapter 13 a detailed review of texture development within metals during axisymmetric flow, rolling and annealing is presented by Mecking. Emphasis is placed on interpreting textures formed during these processes in terms of fundamental slip system principles and theoretical models for texture development. In this review the applicability of the texture models of Sachs and Taylor are considered and compared with that of relaxed constraints models derived from strict Taylor theory. Using the copper–brass transition as an example, deviations from stoichiometry are shown by Chirsch and Lucke in Chapter 14 to also have an important influence on texture development within metals.

Turning now to geological materials, available texture and rheology data on both natural and experimentally deformed evaporites (halite, sylvite, gypsum, anhydrite, cannallite and bischofite) are systematically documented by Kern and Richter in Chapter 15. Similarly in Chapter 16 deformation mechanism, rheology and texture data on both natural and experimentally deformed ore minerals are reviewed by Siemes and Hennig-Michaeli. This detailed review of oxide and (rheologically weaker) sulphide ore minerals also emphasises the importance of deviations from stoichiometry and is illustrated with selected deformation mechanism maps.

In Chapter 17 experimental data on carbonate deformation are concisely reviewed by Wenk and briefly compared with data for naturally deformed carbonates. The review, which concentrates on the experimental deformation of calcite polycrystals, emphasises the possible relationships between twinning, operative slip systems, temperature and symmetry of deformation, texture development and observed bulk rheology. Although for plane strain deformation fair correspondence is found between observed textures and those predicted by the full constraints Taylor model, no such correspondence was found in the case of axially symmetrical flattening. For coaxial flattening a relaxed constraints Taylor model involving heterogeneous deformation appears to be more applicable.

In contrast, a good correlation between the full constraints Taylor model and observed *c*-axis fabrics is found for all strain symmetries (from flattening through plane strain to extension) in the review of quartzite textures given by Price in Chapter 18. In this review symmetrical *c*-axis fabrics from 74 experimentally and naturally deformed quartzites of known strain symmetry and magnitude are presented and correlated with predicted fabrics for corresponding strain symmetries.

Deformation mechanisms applicable to upper mantle conditions are reviewed by Mercier in Chapter 19 for olivine and pyroxene. In this chapter available experimental data on the microstructures, textures and rheology of these minerals are summarized and compared with naturally occurring peridotites. Mercier points out however that, due to their different uplift histories, major fabric differences are to be expected in peridotites located within massifs compared with those occurring as xenoliths within continental rift zones and kimberlites.

In Chapter 20 phyllosilicate textures in slates are briefly covered by Oertel and (adopting the March model of rigid rotating particles—Chapter 12) their degree of preferred orientation used to estimate strain. Although good agreement is found between such strain estimates and independent strain estimates obtained from reduction spots, it is clear that the observed microstructures place considerable doubt on the applicability of the March model to these tectonites. Moving up in metamorphic grade, mechanisms of schistosity formation are reviewed by Rosenfeld in Chapter 21 using natural examples as case histories. Anisotropy of intrinsic growth rate, velocity and anisotropy of chemical diffusivity, as well as rotation, are all shown to be important mechanisms.

Returning to basic principals, the geological significance of texture analysis is reviewed by Hobbs in Chapter 22. Using quartz deformation as an example, Hobbs clearly demonstrates that texture interpretation must take account of both variation in extrinsic factors (finite strain, strain and stress history, etc.) and intrinsic factors (temperature, strain rate, chemical activity, etc.). In summarizing models for the development of crystallographic preferred orientation by slip, Hobbs points out that the models proposed by Sachs and Taylor (involving homogeneous distribution of stress and strain respectively within an aggregate of deforming grains) represent end members of a potential deformation spectrum. By considering the influence of grain shape, Hobbs also demonstrates that with progressive deformation the Taylor requirement of five independent slip systems may, at least locally, be relaxed; this will result in texture modification.

In Chapter 23 experimental techniques for determining the physical properties of rocks are reviewed by Heard. Such experimental studies clearly indicate the fundamental importance of both physical and chemical conditions (including strain rate) in governing the mechanisms of deformation. In addition single crystal experiments also illustrate the potential influence of texture on the mechanical properties of rock.

Many physical properties (e.g. Youngs Modulus, electrical conductivity) of single crystals are strongly anisotropic, being dependent on the crystal direction in which they are measured. In a polycrystalline aggregate if there is a preferred crystallographic orientation of individual grains then a macroscopic anisotropy will result. In Chapter 24 mathematical techniques for calculating such macroscopic anisotropies in single phase polycrystalline aggregates are reviewed by Bunge. Such techniques require that both the orientation dependence of a physical property within a single crystal, and the texture of the polycrystalline aggregate, are known. Using this approach relationships between texture and magnetic properties of metals are reviewed by Morris and Flowers in Chapter 25.

Finally in Chapter 26 a brief general review of anisotropy in rocks is given by Kern and Wenk. Emphasis is placed on the geological significance of the relationships between texture and the elastic, thermal and magnetic properties of rocks. Such relationships are not only of strict academic interest. For example, laboratory measurements of compressional wave velocities clearly show that seismic anisotropy is strongly influenced by texture as well as temperature and pressure. Similarly, anisotropy of magnetic susceptibility may be related to both texture and grain shape orientation.

The book is extremely well illustrated with numerous line drawings (315) and good quality photomicrographs (89). A general subject-based index is provided and the book also includes an invaluable author-based reference list which has been collated from citations in the 26 individual chapters.

Wenk is to be congratulated on editing such a wide ranging, yet generally detailed, book on texture analysis. At £55.00 the book represents good value for money, and its purchase by geology and metallurgy departmental libraries is recommended.

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Igneous and metamorphic microtextures

Bard, J. P. 1986. *Microtextures of Igneous and Metamorphic Rocks*. D. Reidel, Dordrecht. Price £49.50.

This book is designed principally for an undergraduate and post-graduate student readership. Its aim (so the author claims) is to help the reader bridge the gap between observations of rocks under the microscope and petrogeneic theories and, so far as it goes, I think it is successful. The emphasis is mainly petrological, and there is not a great deal in the book of direct interest to structural geologists.

The book is divided into two subequal parts: text (Chapters 1–5) and illustrations (Chapters 6 and 7). The first two chapters are concerned with theories of nucleation and crystal growth. The next three deal with the criteria for establishing the order of crystallization in igneous and metamorphic rocks, a topic which is rather underplayed in other texts on mineral textures. Chapters 6 and 7 give examples of microtextures for igneous and metamorphic rocks, respectively. The first part of each consists of a brief pictorial classification of principal textures (very helpful) and a condensed classification of the rocks themselves (not very useful).

The scientific content of the book is sound, but I cannot help feeling that the text is too brief to do justice to so large and complex a subject. Topics are over-simplified in many instances, and difficult concepts are not always well explained. There is a general tendency for the author to assume that by underlining a key word or phrase its meaning will immediately become apparent to the reader, in the absence of supporting explanation.

Unfortunately, the book suffers from being a translation from the French. On reading the text, it becomes obvious that it was never vetted by a geologist fluent in English before going to press. While not particularly serious, the grammatical and idiomatic errors are irritating, and some of the technical terms require a little lateral thinking (e.g. "superficial tension" for "surface tension"; "punctual imperfection" for "point defect"; "thermodynamic metamorphism" for "dynamothermal metamorphism"). The text has been published in teletyped form presumably in an effort to reduce cost, and this also has its drawbacks. A large number of typographical errors (including at least one duplicated line) have crept through and testify to poor editing. The reference list is disappointingly short and individual references are given in order of appearance in the text and without titles.

The micrographs illustrated in Chapters 6 and 7 (64 of them altogether) are full-page line drawings and are very impressive indeed. One cannot help wondering how long the author spent drawing them, and whether photographs could not have done the job just as well. Although these illustrations and their captions are largely self-explanatory, I feel that their value would have been increased by some reference to them in the text. As presented, the text and micrographs are entirely separate giving the book a rather unco-ordinated flavour.

This book is sufficiently different in content from other texts on mineral textures to merit reading, but the poor quality of the production and editing of this English-language version precludes me from honestly being able to recommend it as a mainstream teaching aid for petrology or structural geology courses.

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