Minerals: Their Constitution and Origin

Minerals: Their Constitution and Origin is an introduction to mineralogy for undergraduate and graduate students in the fields of geology, materials science, and environmental science. It has been designed as a textbook for use on a semester course and covers all aspects of mineralogy in a thoroughly modern and integrated way.

The book is divided into five parts. Part I deals with the general concepts of structures and bonding within minerals, and introduces symmetry principles as well as graphic representations such as the stereographic projection. It discusses growth, defects, and general issues of isomorphism and polymorphism. Part II centers on the physics of minerals, including determination of structural features by X-ray diffraction, an introduction to optical properties, and the use of the petrographic microscope. Part III explores the range of naturally forming minerals and introduces hand specimen identification. It gives an overview of the various modes of mineral formation, and provides a background in thermodynamics to facilitate an understanding of mineral equilibria in geological environments and phase transformations. Part IV provides a systematic treatment of mineral groups within the context of mineral-forming environments. Part V demonstrates the application of mineralogy to the fields of metal deposits, gems, cement, and human health. It also explores how minerals form in the universe, and how they have been active components at each stage of the evolution of the earth.

Throughout the text, emphasis is placed on linking minerals to broader geological processes. Unlike more traditional books on this topic, the authors also convey the importance of minerals within our everyday lives and their economic value. Complete with beautiful color photographs, handy reference tables and a glossary of terms, this textbook will be an indispensable guide for the next generation of mineralogy students.

Hans-Rudolf Wenk is Professor of Geology at the University of California at Berkeley and *Andrei Bulakh* is Professor in the Department of Mineralogy at St Petersburg State University. Both have written many research papers in the fields of mineralogy, crystallography, geochemistry and tectonophysics, and have used this extensive expertise to create a comprehensive and stimulating textbook.

Minerals

Their Constitution and Origin

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and

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Preface

Minerals: Their Constitution and Origin is an introduction to mineralogy for undergraduate students and graduate students in all fields of geology, materials science, and environmental sciences, and for those with a general interest in the subject. As a background, the reader is assumed to be familiar with general principles of physics and chemistry at the high school level. In this text we introduce principles of crystallographic and structural features of minerals, as well as the physical property characteristics used to identify them. We also provide a survey of the most important minerals (about 250 and details for about 100) and their geological occurrence. The basic types of mineral deposit, both those of scientific and those of economic importance, are discussed, often in conjunction with the systematic treatment of the mineral classes most closely associated with particular deposits. The book concludes with a series of chapters on applied mineralogy, including a survey of the main industrial uses of minerals.

There are many excellent mineralogy textbooks, ranging from the early Niggli (1920) monograph (which still contains much of the information which is needed), to modern books such as Putnis (1992), Blackburn and Dennen (1994), Perkins (1998), Nesse (2000), Hibbard (2002) and Klein (2002). Why do we add a new book to an already seemingly saturated market?

To answer this question, we need to look at how mineralogy courses have evolved. The modern earth science curriculum, particularly at American universities, is very different from that taught 25 years ago. At that time mineralogy was covered with two- to four-semester-long courses. Today mineralogy has become at best a one-semester course with two lectures per week and laboratory sessions. This change in emphasis is due to evolving fields such as geomorphology, hydrology, climatology, and geophysics that increasingly have become part of the standard earth science course load. Yet the importance of mineralogy for a wide variety of disciplines has increased. Fields ranging from igneous petrology to soils science, from archaeology to cement engineering, from materials science to structural geology make use of mineralogy, and students from these diverse disciplines need to be accommodated. Students do not have time to go into great detail but they do need to become aware of basic concepts. Our book provides an alternative to existing texts by focusing more tightly on concepts, at the expense of completeness, and by integrating geological processes and applications more closely with the discussions of systematic mineralogy.

Our goal is to be selective in including material rather than all inclusive, yet trying to remain quantitative, scientifically sound, and avoiding superficiality. It is well known that many students are frightened of mathematical expressions. We are using a few equations here and there, but they can be skipped, without losing the thread, if students do not have the necessary background. Since most geology programs require mathematics and physics courses, it seems only reasonable to show students that some of this is useful and can be applied to earth sciences. It brings satisfaction to those who have taken mathematics courses to see some quantitative relationships, for example how trigonometry can be used to calculate interfacial angles, basic thermodynamics to understand a boundary in a phase diagram, simple linear algebra to appreciate why a second-rank tensor, such as the optical indicatrix, has the shape of an ellipsoid, or how complex numbers can be used to add waves more easily analytically than graphically to obtain diffraction intensities.

One of the biggest challenges in teaching mineralogy is that some of the most difficult, theoretically demanding material, is presented relatively early in the course. There are logical reasons for focusing on crystal chemistry and crystallographic topics earlier, rather than later. Many students have already encountered some of this background in earlier courses in chemistry and physics and there is a natural connection to these concepts of mineralogy. However, we do recognize that crystallography is a notoriously difficult challenge for many students, requiring them to become adept at three-dimensional visualization, which is often initially difficult. Thus our treatment of this subject judiciously emphasizes the most important concepts so that students are not left to wade through pages of exhaustive facts that in many cases are better left for later courses.

The presentation of the text deviates somewhat from the conventional organizational approach that separates geometry (crystallography), crystal chemistry, systematic mineralogy, and petrology. Instead, throughout the book we combine theoretical subjects with experiments, and discuss larger mineral-forming processes in the context of specific mineral groups (e.g., the origin of granite with feldspars). Such an approach comes naturally and is more likely to focus student interest in the subject. The goal has been to select material that should make it easier to teach mineralogy and make learning about minerals more stimulating.

As mentioned above, our goal is to emphasize concepts and to minimize nomenclature. In order not to interrupt the flow of required material, some case studies and details are included in "technical boxes", while "enrichment boxes" contain supplementary historical material or applications. The text includes appendices covering identification of hand specimens and optical properties. Some subjects are necessary background for all aspects of mineralogy: basic rules of crystal chemistry (Chapter 2), lattice, and symmetry (Chapters 3 and 4). Many other chapters are optional and can be skipped at the discretion of the instructor.

The book is divided into five parts. Part I deals with general concepts of structures, bonding, introduces the lattice concept, symmetry and crystal forms as well as geometrical representations such as stereographic projection. It also discusses growth, defects and general issues of isomorphism and polymorphism.

Part II centers on the physics of minerals. First it shows how to determine by X-ray diffraction the structural features introduced in Part I. Chapter 8 on physical properties is optional but we include it because of the importance of this field for modern geophysics. We introduce optical properties and the use of the petrographic microscope early on because most mineralogy courses need to have this background before mineral systems are discussed in detail. Clearly parts of Chapter 10 on mineral identification with a microscope rely on access to relevant laboratory equipment. If there is no such access to microscopes, or if a separate course in optical mineralogy is available, Chapters 9 and 10 can be skipped. Chapter 12, on advanced analytical techniques, introduces equipment that may be encountered in modern mineralogical research laboratories and provides references for further study.

Part III explores the range of minerals and introduces hand specimen identification. It also discusses the wide range of mineral formation, and provides some background in thermodynamics for understanding mineral equilibria in geological environments and phase transformations. Later chapters include applications of thermodynamics to sedimentary, hydrothermal, metamorphic, and igneous processes to demonstrate its relevancy.

Part IV is a systematic treatment of mineral groups and about 200 of the most important minerals. Each chapter combines mineral characteristics with a discussion of a mineral-forming environment.

Part V on applied mineralogy deals with topics such as metal deposits, gems, cement, human health, and explores how minerals form in the universe and were active components at each stage of the evolution of the earth. This part is largely independent of the rest of the book. If there is no time in class, these chapters can be used as reading assignments and form good starting points for term projects. The chapters should illustrate to students that mineralogy is not just complicated formulas, strange names, Miller indices, and point-groups, but has some practical significance. This may raise some interest.

Appendices contain determinative tables and important technical terms are defined in a glossary.

The book is written in a modular fashion that permits instructors to select or omit some parts, depending on the level of the course, without compromising the continuity.

- The content of the whole book seems to us the minimum one would expect a *mineralogy graduate student* to know before entering a qualifying examination. In that sense it can be used as a review. Reference is made to more detailed work to pursue in-depth studies.
- A *descriptive one-semester course* may omit most of Part II, except perhaps Chapter 11 (Color), Chapters 17–18 (Thermodynamics, and Solid Solutions), as well as most of the advanced boxes. A selection of chapters from Part V can be useful.
- A more *analytical one-semester mineralogy course* at major universities would probably touch only briefly on Chapter 8 (Physical properties), may omit Chapters 9 and 10 (if no microscope laboratory session is associated with the course), Chapter 12 (Additional analytical methods), and may not have time to include much of Part V, except for reading assignments.

The origin of this book goes back to 1993, when a student from (then) Leningrad visited Berkeley on an exchange program and brought a little red book on mineralogy, written by her professor, Andrei Bulakh, that caught Rudy Wenk's attention because it was exactly the kind of brief introduction into mineralogy he was looking for. Over the following years we established further contact, in part through the exchange of another student, Anton Chakmouradyan, who came to play a considerable role in this project. After reciprocal visits to St Petersburg and Berkeley, sponsored by the University of California Education Abroad Program, the authors decided to attempt to produce an English mineralogy book, in the spirit of the Russian version, though not a translation. The different backgrounds of the authors guarantee a broad view: Andrei Bulakh is a specialist on alkaline rocks and minerals and geochemistry and has written several books that are widely used in Russian universities. Rudy Wenk's research has emphasized metamorphic rocks, including deformation, and investigations of microstructures in feldspars and carbonates. Both have taught introductory mineralogy at major universities for a long time. In this book we have tried to unite our expertise.

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A. Bulakh

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