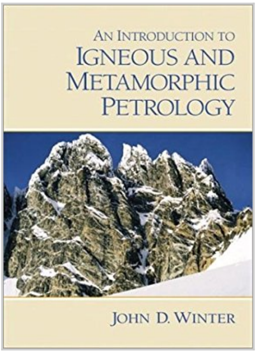

An Introduction to Igneous and Metamorphic Petrology

By John D. Winter

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Providing enough background to be rigorous, *without* being exhaustive, it gives readers good preparation in the techniques of modern petrology; a clear and organized review of the classification, textures, and approach to petrologic study; and then applies these concepts to the real occurrences of the rocks themselves. Requires only a working knowledge of algebra, and makes extensive use of spreadsheets. Includes an accompanying diskette of programs and data files. This book offers unique, comprehensive, up-to-date coverage of both igneous *and* metamorphic petrology *in a single volume* and provides the quantitative and technical background required to critically evaluate igneous and metamorphic phenomena. For anyone interested in petrology.

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Editorial Review

From the Inside Flap
Preface

This text is designed for use in advanced undergraduate or early graduate courses in igneous and metamorphic petrology. The book is extensive enough to be used in separate igneous and metamorphic courses, but I use it for a one-semester combined course by selecting from the available chapters. The nature of geological investigations has largely shaped the approach that I follow.

Geology is often plagued by the problem of inaccessibility. Geological observers really see only a tiny fraction of the rocks that compose the Earth. Uplift and erosion exposes some deep-seated rocks, whereas others are delivered as xenoliths in magma, but their exact place of origin is vague at best. As a result, a large proportion of our information about the Earth is indirect, coming from melts of subsurface material, geophysical studies, or experiments conducted at elevated temperatures and pressures.

The problem of inaccessibility has a temporal aspect as well. Most Earth processes are exceedingly slow. As a result, we seldom are blessed with the opportunity of observing even surface processes at rates that lend themselves to ready interpretation (volcanism is a rare exception for petrologists). In most other sciences, theories can be tested by experiment. In geology, as a rule, flat experiment has run to its present state and is impossible to reproduce. Our common technique is to observe the results and infer what the experiment was. Most of our work is thus inferential and deductive. Rather than being repulsed by this aspect of our work, I believe most geologists are attracted by it.

The nature of how geology is practiced has changed dramatically in recent years. Early geologists worked strictly in the observational and deductive fashion described above. The body of knowledge resulting from the painstaking accumulation of data observable with the naked eye or under a light microscope is impressive, and most of the theories concerning how the Earth works that were developed by the mid-20th century are still considered valid today, at least in broad terms. Modern post-war technology, however, has provided geologists with the means to study the Earth using techniques borrowed from our colleagues in the fields of physics and chemistry. We have mapped and sampled much of the ocean basins; we have probed the mantle using variations in gravity and seismic waves; we can perform chemical analyses of rocks and minerals quickly and with high precision; we can also study natural and synthetic specimens at elevated temperatures and pressures in the laboratory to approximate the conditions at which many rocks formed within the Earth. These and other techniques, combined with theoretical models and computing power, have opened new areas of research and have permitted us to learn more about the materials and processes of the Earth's interior. These modern techniques have been instrumental in the development of plate tectonic theory, the encompassing paradigm that guides much present geologic thought. Given the limitations of inaccessibility mentioned above, it is impressive how much we have learned about our planet. Modern petrology, because it, addresses processes that occur hidden from view deep within the Earth, must rely heavily on data other than simple observation.

In the pages that follow I shall attempt to explain the techniques employed, and the resulting insights they provide into the creation of the igneous and metamorphic rocks now found at the surface of the Earth. The reader should be aware, however, that the results of our investigations, however impressive and consistent they may appear, are still based in large part on indirect evidence and inferential reasoning. I'm sure that the many researchers whose painstaking work we shall review would join me in urging a healthy skepticism lest we become too dogmatic in our perspective. Ideas and theories are always in a state of flux. Many of today's ideas may be discarded tomorrow as new information becomes available and/or other ideas take their place. Certainly petrology is not exempt from this process. If so, it would be far too dull to pursue.

The term petrology comes from the Greek petra (rock) and logos (explanation), and means the study of rocks and the processes that produce them. Such study includes description and classification of rocks, as well as interpretation of their origin. Petrology is subdivided into the study of the three major rock types: sedimentary, igneous, and metamorphic. At the undergraduate level in most colleges and universities, sedimentary petrology is taught as a separate course, usually with stratigraphy. Igneous and metamorphic petrology are commonly combined, due to the similarity of approach and principles involved. I intend this book for either a combined igneous/metamorphic course or two separate ones. In the interest of brevity, I will henceforth use the term "petrology" to mean the study of igneous and metamorphic rocks and processes. I hope not to offend sedimentary petrologists by this, but it would prove burdensome to continually redraw the distinction.

I shall concentrate on the processes and principles involved in the generation of igneous and metamorphic rocks, rather than dwell upon lists of details to be memorized. Certainly facts are important (after all, they compose the data upon which the interpretations are based), but when students concentrate on the processes of geology, and the processes by which we investigate them, they get a deeper understanding, more lasting knowledge, and develop skills that will prove valuable beyond the classroom.

As mentioned above, modern petrology borrows heavily from the fields of chemistry and physics. Indeed, the student taking a petrology course should have completed a year of chemistry, and at least high school physics. Calculus, too, would help, but is not required. Some students, who were attracted to geology for its field bias, are initially put off by the more rigorous chemical and theoretical aspect of petrology. I intend this text to give students some exposure to the application of chemical and physical principles to geological problems, and I hope that some practice will give them confidence in using quantitative techniques. At the same time, I do not want to so burden them that they lose the perspective that this is a course in geology, not chemistry, physics, or computer science. We must bear in mind that the Earth itself is the true proving ground for all the ideas we deal with. Even the most elegant models, theories, and experimental results, if not manifested in the rocks in the field, are useless (and probably wrong as well).

All textbooks need to balance brevity, breadth, and depth. Whole books are dedicated to such subjects as thermodynamics, trace elements, isotopes, basalts, or even specialized subjects as kimberlites, lamproites, or mantle metasomatism. When distilling this sea of wisdom to an introductory or survey level, vast amounts of material must necessarily be abbreviated or left out. Of course it is up to the author to decide what is to be selected. We each have our own areas of interest, resulting; in a somewhat biased coverage. To those who object to, the light coverage I give to some subjects and my overindulgence in others, I apologize. The coverage here is not intended to replace more specialized classes and. deeper levels of inquiry for those proceeding on to graduate studies in petrology. There is no attempt to develop theoretical techniques, such as thermodynamics or trace. elements from first principles. Rather, enough background is given for a degree of competence with using; the techniques, but the direction is clearly toward application. We gain from our more general perspective a. broad overview of the Earth as a dynamic system that: produces a variety of igneous and metamorphic rocks in. a wide range of settings. We will not only learn about: these various settings and the processes that operate. there, but we will develop the skills necessary to evaluate and understand them. Once again, I urge you to be. critical as you progress through this text. Ask yourself if' the evidence presented to support an assertion is adequate. This text is different from texts only 10 years old. We might all wonder what interpretations will change in. a text published 10 years from now.

Following the traditional approach, I have divided the book into an igneous section and a metamorphic section. Each begins with an introductory chapter, followed by a. chapter on the description and classification of appropriate rock types and a chapter on the development and, interpretation of textures. The chapters on classification. and textures are intended as a laboratory supplement,, and not for lecture-discussion. I have tried to explain. most petrologic terms as they are presented, but you will. invariably run across terms with which you are unfamiliar. I usually place a new term in bold typeface. If you. forget a term, it can usually be found in the index, but a. dictionary of geological terms is also a good companion. The inside front cover l

From the Back Cover
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Chapter 4 is a review of the field relationships of igneous rocks. It is relatively simple and intended to supply a background for the more detailed concepts to follow. Students may simply read it on their own. Chapters 5 through 9 are the most intensive chapters, in which I develop the theoretical and chemical concepts that will be needed to study igneous systems. By the time many, students reach Chapter 9 they may fear that they are in the wrong course, or worse, the wrong major! Fortunately things slow down after this, and are oriented more: toward application of the techniques to real rocks. Chapter 10 addresses the generation of basaltic magma in the: mantle, and Chapter 11 deals with the evolution of such magmas once they are created. Chapters 12-20 explore; the common igneous associations, using the techniques, developed in Chapters...

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