THE STUDY OF ROCKS IN THIN SECTION

by

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Introduction

It was more than a century and a half ago that the astute James Hutton first recognized clearly that plutonic, volcanic, and sedimentary rocks were different and had had notably different modes of origin. Nevertheless, it remained for Abraham Gottlob Werner, who was never able to understand or accept Hutton's views, to devise the reasonably systematic classification of rocks which was generally employed during the first part of the nineteenth century. Werner recognized rocks as being simple or composite, and he brought out the difference between the essential and the accessory minerals making up some of the complex types.

In 1823 Carl von Leonhard published his significant *Charakteristik der Felsarten* in which he pointed out that four major groups of rocks could be recognized—but this recognition was based on their macroscopic features. Soon thereafter, in 1827, the great Scottish geologist, William Nicol, not only devised a method of preparing thin sections of fossil woods, but he constructed a polarizing microscope for the investigation of crystal structures. Then C. G. Ehrenberg, in 1839, was able to demonstrate just how useful a tool such as the microscope could be in the study of rocks. It was not until 1850, however, that Nicol's methods of examining rocks in thin section by means of transmitted light really came into modest prominence largely through the investigations of the English geologist, Henry Clifton Sorby. Then, in 1858, there appeared Sorby's significant paper on the microscopical structure of crystals. This publication really set the stage for a century of constantly increasing interest in the study of rocks in thin section.

In 1862, while Sorby was in Bonn, Germany, he introduced Ferdinand Zirkel to his thin-section study procedure. Four years later Zirkel published his *Lehrbuch der Petrographie* and in a sense modern petrography was born. Seven years later, in 1873, Zirkel published, at Leipzig, his introduction to the use of the polarizing microscope, entitled *Die mikroskopische Beschaffenheit der Mineralien und Felsarten.* At essentially the same time, Zirkel's rival at Heidelberg, H. Rosenbusch, was publishing a possibly even more influential work, *Die mikroskopische Physiographie der petrographisch wichtigen Mineralien.* Rosenbusch not only clearly elucidated the methods for

identifying rocks, but he greatly improved the mechanical equipment employed, and he introduced the rotating stage. Rosenbusch was a follower of Leonhard, as Zirkel was a protégé of Sorby, but both made great advances on the work of their predecessors. The revised works of the two great German leaders kept appearing for many years and their direct influence, which remained great for nearly half a century, is still felt today.

The names of the devotees of the subscience which Zirkel and Rosenbusch did so much to establish firmly are now legion, but W. C. Brøgger and J. P. Iddings were perhaps among the first to follow in their footprints. In the English-speaking world alone the later masters have included such workers as A. N. Winchell, C. S. Ross, F. E. Wright, A. Harker, F. H. Hatch, R. H. Rastall, A. Holmes, G. W. Tyrrell, A. F. Rogers, A. Johannsen, H. B. Milner, S. J. Shand, A. K. Wells, F. F. Grout, E. S. Larsen, N. L. Bowen, F. J. Turner, C. E. Tilley, R. C. Emmons, F. J. Pettijohn, and many others. The importance of the general subject, including its various ramifications, is suggested by the calibre of the scientists who have been attracted to it. The list of non-British foreign workers is equally impressive.

Professor Moorhouse's book *The Study of Rocks in Thin Section*, of course, has had a number of American predecessors. Among them may be mentioned A. Johannsen's *Rock Forming Minerals in Thin Section* first published in 1908 and revised in 1928. In 1933 *Thin Section Mineralogy* by A. F. Rogers and Paul F. Kerr became available to students, and there was published as recently as 1954 *Petrography* by the University of California experts H. Williams, F. J. Turner, and C. M. Gilbert. Moreover, *Sedimentary Rocks* by F. J. Pettijohn, also in the Harper Geoscience Series, during the last decade has become a standard work here and abroad, and it, too, covers some of the subjects considered in this book. But none of these works, old or relatively new, present for the student in simple style the basic information necessary for the study of all types of rock in thin section. Professor Moorhouse, however, develops in thirty relatively brief chapters an adequate synopsis of the almost encyclopedic petrographic information presently available. In addition to the Introduction, there are beginning chapters devoted to methodology in optical mineralogy, descriptions of minerals, and mineral identification tables. Chapter 5 discusses the petrography of igneous rocks in general terms and provides tables of classification. Chapters 6–10 are devoted to the volcanic and hypabyssal rocks, and Chapters 11–15 are concerned with rocks of plutonic type. Chapters 16 and 17 discuss respectively ultrabasic rocks and the lamprophyres.

The sedimentary rocks in thin section are described in Chapters 18–24 and the metamorphic rocks in Chapter 25. In addition, Chapters 26–29 are concerned sequentially with dynamic, thermal, and regional metamorphism, and with metasomatism. The final chapter discusses the petrography of the

ores. Most of the chapters are fully illustrated, there being more than 200 figures, mostly of composite type, and many of them based on sections prepared by the author and his associates.

We have stated that the study of rocks in thin section has been growing steadily in importance ever since the pioneering efforts of William Nicol. This is not surprising because it is increasingly clear that the results obtained from such studies are fundamental to the solution of the majority of problems involving basic geological philosophy. Moreover, the economic overtones of the subject have grown stronger as companies dealing with the geology of the fuels, as well as those concerned with ore deposits, devote more and more money and effort to the closely interrelated disciplines of petrography and petrology. It seems certain, therefore, that Professor Moorhouse's book will find an honored place in the reference libraries of commercial organizations, as well as in the classrooms and laboratories of our universities and colleges.

CAREY CRONEIS

Preface

The study of rocks in thin section is the most effective way of giving the undergraduate or graduate student a true realization of the mineralogical constitution of rocks. Not until he has studied rocks in this way does the student actually apprehend the significance of such rock names as greenstone, andesite, granite, or greywacke. Thin section study thus performs a very important educational function in giving body to the terminology of rocks. For the professional geologist petrography provides a most important check on field identifications. Many an attractive theory based upon ambiguous field relationships has foundered on petrographic evidence. Apart from this, petrography is an interesting and rewarding study in its own right and a field in which much useful research remains to be done.

This book has been planned with the purpose of providing in a single volume a brief review of the methods of optical mineralogy (with a minimum of optical theory), descriptions of the rock-forming minerals encountered in the more common rocks, identification tables to assist in the identification of these minerals, and descriptions of the common rock types.

The section on optical mineralogy is not intended as a substitute for the standard texts and references on this subject. Its object is to present as briefly and simply as possible the optical tests most frequently used in thin-section mineralogy.

Only the commoner rock-forming minerals are described in the mineralogical section. The minerals listed comprise over 99 per cent of the constituents of the common rocks, so that for most routine petrographic work no other source will be necessary. The study of some unusual rocks and research work will require reference to more detailed and comprehensive texts, such as Winchell (*Elements of Optical Mineralogy*, by A. N. Winchell and H. Winchell, Wiley, New York) and Larsen (*The Microscopic Determination of the Nonopaque Minerals*, by E. S. Larsen and H. Berman, *U.S. Geol. Survey Bull. 848*). A feature of the mineral descriptions, which should accelerate the process of running a mineral down from the tables, is the consecutive numbering of the mineral species. These numbers are given in the tables along with the mineral names and allow one to refer immediately to

the mineral description without having to look up the page number in the index.

The petrographic section of the book also has a number of novel features. It is divided into igneous, sedimentary, and metamorphic rocks in the conventional way. The grouping of the rocks into individual chapters is also conventional, except that volcanic and plutonic rocks have been separated from one another in recognition of the wide range of views concerning the origin of the plutonic rocks. This leads inevitably to a certain amount of repetition, a fact that is surely not without significance. The rock groups considered in each chapter are systematically discussed under the following headings: definitions, mineralogy, texture, alteration, varieties, petrogenesis, and economic geology. This rather rigid formula of description also leads to repetition, but it is believed that this is compensated by the greater ease in using the book in the laboratory. In the descriptions attention is paid particularly to the typical rocks; for unusual rock types the student is referred to Johannsen's monumental *Petrography*, to Pettijohn's *Sedimentary Rocks*, and to Harker's *Metamorphism*. More attention is paid to altered rocks than is usual in petrographic texts, as the practical geologist finds that more often than not the rocks with which he has to work are altered. The section on petrogenesis is included not to discuss this subject exhaustively but to bring out, as far as possible, the significance of the mineralogy, texture, and to some extent the field characteristics of the rocks. It is hoped that this will help the student to appreciate that petrogenetic theories, however abstract they may seem, are ultimately based upon the nature of rocks as he sees them in the field and laboratory. The sections on economic geology of rocks are necessarily brief and selective rather than comprehensive. They are intended simply as a starting point for thought, study, and research on the relationship between rock and mineral deposit. The chapter on the petrography of ores again is not intended as a descriptive chapter but simply as a series of pointers to guide the economic geologist studying the petrography of an ore deposit or the petrographer interested in the relationships of ore deposits to rocks.

No attempt has been made to document this textbook. To have acknowledged the source of every fact and opinion mentioned here and to have provided the appropriate reference for each would have inordinately extended and cluttered the text and would have been undesirable in what is essentially a laboratory manual. Despite this intentional omission the author is fully appreciative of these contributions and regrets that practical considerations prevent him from acknowledging his debt in individual instances.

A number of new features have been incorporated in the drawings of thin sections that accompany the text. Most of them have been drawn on a grid using a grating micrometer so as to reproduce the textures as accurately as

possible. In most of the drawings a standard pattern has been used for each mineral or mineral group, so that labeling of the individual diagrams is not necessary. In most instances, the pattern selected represents some cleavage or relief feature of the mineral. As many as possible of the common textural types of each major rock group have been included in the series of drawings. It is hoped that by this means the user may acquire an appreciation of the variety of textures of such common rock types as basalt, gabbro, andesite, and granite. Less emphasis has been placed on rare or unusual rocks. Among the rocks illustrated are most of Wards' *100 American Rocks*. They are indicated immediately after the name and location by a "W" with the number of the specimen in the Wards' series in parentheses, thus (W-1). The author is grateful to Wards for lending him a splendid set of thin sections for the preparation of these illustrations.

In conclusion, it is hoped that this text will be of use to the following persons:

1. The beginning student in petrography who requires optical mineralogy, mineral descriptions, determinative tables, and a petrographic manual.
2. The graduate student who is interested in petrography either for itself or as a tool in other lines of geological research.
3. The student of economic geology who is interested in the country rock of ore deposits and in its alteration.
4. The practicing or field geologist who in the course of his work encounters rocks of puzzling character or who for his own interest wishes to keep up the petrographic technique he developed while at a university.

A text of this sort is most valuable in the "tips" and tricks of the trade it can contribute to the beginner, thus assisting him in the identification of minerals and rocks. No one man can acquire or devise more than a fraction of the tricks that are known, so the writer will appreciate receiving further suggestions on this point from the users of this book. The attempt has been made to keep the text free of prejudices and biased opinions, but in a field as subjective as petrology and petrogenesis this is literally impossible.

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Contents

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Introduction

Petrography is the description and classification of rocks. Petrology embraces not only the systematic and descriptive aspects of rocks, but also the natural history and origin of rocks and rock masses. Lithology is a term sometimes applied to the identification of rocks in the field or megascopically.

The study of rocks involves many methods, the procedures followed depending on the nature of the rock, the purpose of the study, and the facilities and time available. It cannot be emphasized too often that the accurate mapping and description of the rock in the field is the basic starting point of the study of rocks. It is equally true that all conclusions or theories regarding the origin and relationship of rocks based upon laboratory investigations must be checked in the field. It is not my purpose to deal with this very important aspect of petrology in this book, but the elements of lithology are briefly summarized in the chapter on rock classification.

Following the field study and mapping of rocks, the next step in their study is the preparation and examination of thin sections. This procedure, which is the main topic of this book, provides us with precise information regarding the mineralogy of the rock, the proportions of the various minerals, and the texture—a feature that is as important as the mineralogy. In some instances the exact identification of the minerals may not be possible, and the thin-section examination must be supplemented by other methods of mineral identification, for example, accurate determination of indices of refraction, x-ray powder photographs, or suitable chemical tests. In certain types of investigation, it is often desirable also to determine the chemical composition of the rock or rocks being studied. This may be done in a number of ways. In

coarse-grained rocks of relatively simple mineralogy, precise determination of the minerals present and of their relative proportions may enable one to calculate the composition almost as accurately as a bulk chemical analysis will give it. On the other hand, if the rock contains glassy fractions, or portions so fine-grained as not to be identified readily, or strongly-zoned crystals, a chemical analysis is the only resource. New spectrochemical and x-ray techniques, now in various stages of development, will probably largely supersede conventional chemical analyses in the near future and, as methods become standardized, will undoubtedly provide more numerous analyses in routine petrological investigations.

In the study of sedimentary rocks, other special methods may be applied. The heavy minerals of sandstones may be concentrated and examined microscopically; the insoluble constituents of limestones may be studied similarly. The grain size of sandstones, siltstones, and shales may be determined by various methods, depending upon the degree of cementation and grain of the rock. In the following pages, only those methods will be discussed that directly involve the use of the microscope. Other methods are well described in standard textbooks and will not be considered here.