BOOK REVIEWS

PHYSICAL GEOCHEMISTRY, by F. GORDON SMITH, Addison-Wesley Publishing Company, Reading, Massachusetts, 1963, pp. 624+x.

Despite the bold title, the author of this book has limited himself, probably wisely, to those parts of physical geochemistry in which he has a special interest. As he notes in the introductory chapter, readers will find few analytical or descriptive data, and practically no discussion of processes that take place near the earth's surface. "The melting and crystallization of rocks, and formation of primary hypogene mineral deposits," are the subject matter of the book. Geochemists will welcome this detailed exposition of the work and speculation in these special fields which for many years have engaged the attention of Dr. Smith and his students at Toronto. Some of the author's forthright statements and efforts to draw broad generalizations from meager data will doubtless arouse controversy and criticism, as several of his papers have done heretofore, but controversy is a necessary ingredient of progress in this rapidly changing branch of geochemistry.

The first third of the book is devoted, I think unfortunately, to a rapid-fire review of basic concepts in physical chemistry. Crystal structure, bonding, solid solutions, crystal defects, polymorphism, thermodynamics of fluids, and the phase rule lead into a long, culminating chapter on theoretical phase diagrams for heterogeneous systems. The treatment is so condensed, so encyclopedic, with such scant discussion and so few illustrative examples, that it serves little purpose except possibly as a quick review for specialists. Students in particular will find their interest killed before the exciting part of the book gets under way. The most essential parts of this material could be better added as an appendix, and the rest could be handled by references to standard texts and recent literature.

The second part of the book begins with a traditional discussion of magmatic differentiation based on experimental work with dry silicate melts. Of most interest here is the careful demonstration that accessory minerals, if formed by a simple crystallization process, must appear late in the sequence of solid phases. There is only passing mention of the possible role of oxygen partial pressure in modifying the course of differentiation, and no treatment of the possible effects on differentiation of phase changes at high pressures. A brief supplementary chapter attempts to generalize from the few available data on silicate-oxide and silicate-sulfide systems, with particular reference to conditions necessary for liquid immiscibility.

Silicate-water systems are treated in great detail. The author makes a valiant attempt to pull together and organize into a coherent theoretical structure the abundant but spotty experimental data on mutual solubilities of silicates and aqueous solutions at magmatic temperatures and pressures. Considerable simplification is achieved by emphasizing solubility relations at constant specific volumes and along various postulated geothermal gradients. The discussion is aided by many novel and informative graphs, constructed by re-working well-known data from the literature. Values for the solubility of quartz are shown to fit an equation of the form

$$\log S = -a/T + b$$

where S is the solubility and a and b are constants for a given specific volume. By assuming that a similar expression holds for other solubility equilibria (and more generally for any equilibrium in which enthalpy change and entropy change can be assumed to remain approximately constant at constant specific volume), Smith is able to extrapolate the solubilities of several silicates and other insoluble compounds to high temperatures and pressures. Other empirical relationships applied to the data of Goranson, Tuttle and Bowen, and others, lead to diagrams for the melting behavior of various silicate-water systems and to a discussion of conditions necessary for retrograde boiling in a water-rich silicate melt. Smith shows that melts with reasonable ratios of silicates, water, and salts can be postulated to separate into "hydrosilicate" solutions, which may be precursors of pegmatites, and "hydrosaline" solutions, which are one likely source (but by no means the only source) of the hydrothermal fluids responsible for hypogene ore deposition.

Next the author turns his attention to the chemistry of typical hydrothermal systems involving chiefly water and metallic sulfides. The above equation for variation of equilibrium constants with temperature at constant specific volume enables Smith to guess at extrapolations to high temperature and pressure not only of sulfide solubilities, but also of the ionization constants of water, hydrogen sulfide, and several hydrosulfide complexes. Using recently published data on low-temperature solubilities of lead sulfide and silver sulfide in sulfur-rich solutions, he can then show that the solubilities of these compounds would be large at temperatures commonly postulated for hydrothermal ore deposition. One can object that some of the assumptions are pretty shaky and that failure to mention possible halogen complexes seems arbitrary, but the ordering of data from many sources into a not unreasonable theoretical treatment is impressive nonetheless. A brief chapter on systems that include silicates as well as sulfides and water containing an interests discussion of relations of ore deposits to various kinds of igneous rocks and to metamorphic processes.

Under the heading "Igneous and Metamorphic Rocks" Smith gives chiefly an orthodox treatment of the behavior of individual elements during igneous differentiation. Sedimentary and metamorphic processes are left to a few pages at the end. Interesting here is an attempt to marshal statistics to show that the ratio Na/K in sedimentary rocks is not far different from its value in igneous rocks.

In the final chapter Smith treats at length a subject to which he has made important contributions, the estimation of temperatures of igneous and ore-forming processes. Detail here extends even to specifications of recommended laboratory apparatus. Particularly interesting are the author's present views on two methods, decrepitation and measurement of thermoelectric potential of pyrite which were largely developed in his own laboratory and which have been severely criticized. Although he does not fully answer the objections that Kennedy was raised to the one, and Fischer and Hiller to the other, his discussion of the limitations of the methods is cautious and realistic.

A few pages of questions are included at the end of the book for the benefit of students. The bibliography contains over a thousand entries, but the author disclaims any intention of making it complete. The index is unusual in that it contains many literature references supplemental to those in the text; its major shortcoming is the lack of easy-to-find entries for some of the unusual terms that Smith favors, e.g. daltonide, berthollide, and geothermobar.

The author has strong biases, as most of us do, and the biases are not always made clear to the unwary reader. But the book is nevertheless a valuable addition to the literature of geochemistry, particularly valuable for its attempt to use concepts from contemporary physical chemistry to evaluate and organize geochemical data from many sources.

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PRINCIPLES OF SOIL MECHANICS, by RONALD F. SCOTT, Addison-Wesley Publishing Co., Reading, Massachusetts, 1963, 550 p., $12.50.

Professor Scott, of the California Institute of Technology, has written an extremely lucid analysis of a theoretically diffuse subject. As a textbook for a graduate course in soil mechanics, it assumes of the student a high and sustained level of technical competence. The author's concern for fundamentals is reflected by the stress he places on the physics of fine particles and the mineralogy of clays, which are the subject of Chapter 2. The discussion of clay mineralogy leans heavily on Grim's *Clay Mineralogy* (1953, McGraw-Hill) and therefore reflects the concepts and analytical techniques of a decade ago. With the exceptions of this work, Ross and Hendrick's report on the montmorillonite group (U. S. Geol. Surv. Prof. Paper 205B, 1944), and 2 articles in the proceedings of the National Conferences of Clays and Clay Minerals, the 33 references in the bibliography at the end of Chapter 2 are almost all drawn from the literature of engineering and physics. Whatever shortcomings the clay mineralogist may find in the mineralogy itself, the discussion is adequate for the purposes of the book.

However, geology has more than mineralogy to contribute to soil mechanics. The field relationship of soils—that is, soils as a 3-dimensional reality—is a fundamental matter which is not touched upon at all. A knowledge of the size, shape, stratigraphic relationship, and origin of soil masses should be the point of departure for all engineering work. Perhaps the author has avoided the subject because it is too large for the scope of the book and therefore more properly left to a companion course in geology. The reviewer fears, however, that assuming this preparation in the engineering student may be taking too much for granted.

One misses in this book not only consideration of the field relationships of soils but also the field application of soil mechanics to engineering. Because of its intense concern with theoretical fundamentals, the book makes the barest use of examples drawn from engineering practice. Soil mechanics is a pragmatic subject and it is risking much to separate it from everyday construction problems. The engineering student, just as much as the medical or law student, needs contact with reality via the casebook method.

For the geologist, equipped as he is with the necessary geological knowledge, the book is as fine an introduction as he will find to soil mechanics—an ancillary subject that is growing every day in importance.

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