out violating Sahlins's strictures, offers a quite different approach from Lévi-Straussian symbolism to the problems Sahlins sets.

The reservations, then, are that the book should have done even more than it did, that it should have taken us even further. Still it is a noteworthy achievement.

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Planetary Geology

The Geology of Mars. THOMAS A. MUTCH, RAYMOND E. ARVIDSON, JAMES W. HEAD, III, KENNETH L. JONES, and R. STEPHEN SAUNDERS. Princeton University Press, Princeton, N.J., 1977. x, 400 pp., illus. $35.

T. A. Mutch published the classic lunar stratigraphic study *The Geology of the Moon* in 1970, late enough to summarize all pre-Apollo knowledge but too early to reflect the discoveries of Apollo. Now Mutch and his associates have done the same with Mars, summarizing the pre-Viking results but going to press too soon to do more than include an appendix of Viking photos and results from the August 1976 preliminary Viking report. The authors' preface explains how this happened and predicts criticism for doing the right thing at the wrong time; and a reviewer is obliged to make the criticism. Does one really want to pay $35 for a book on Mars that, if it had been published six months or a year later, could have included actual measurements of martian soil chemistry, seismology, atmospheric composition, and so forth?

Having made that obligatory criticism, one can make a fair, if not totally convincing, argument that the book's excellent qualities override its timing. Mutch, Arvidson, Head, Jones, and Saunders together possess a significant fraction of this nation's expertise in interpreting spacecraft photos and geophysical data concerning terrestrial planets. There is no better-reproduced or better-explained collection of photographs of the martian landforms than that in this book. Furthermore, the book could well have been subtitled "A Text in Comparative Geology of the Planets." It includes splendid photographs and discussions of features and processes on the earth, the moon, and Mercury paralleling those on Mars. It thus should have a broader appeal to geoscientists than a mere review of pre-Viking knowledge of Mars. There is also a comprehensive review of the pre-Viking literature, with approximately 600 references. Significant findings about processes that shaped the planet Mars (and may have shaped earlier landforms of the earth)—such as cratering, volcanism, wind erosion, and the cutting of the mysterious arroyo-like channels—are described in detail.

One should remember that the Mariner 9 orbital photos and measurements, acquired in 1971–72 and here used as the primary data base, covered virtually the whole planet, with the resolution of the photographs nearly equaling that of most Viking orbital pictures. As a result, the basic outline of martian geological evolution developed from Mariner 9 data remains current. Viking has added evidence that there was once a more massive atmosphere (as hypothesized by Mutch *et al.*), that water exists in the soil, that iron minerals have oxidized to form the red color, that some seismic activity still occurs, and that, although the chemistry of the soil is peculiar, life did not evolve to a thriving state. This evidence outdates the book somewhat, but it does not require the revision of whole chapters. Some subjects are still quite controversial: the last sentence of the book concludes that martian volcanism "continued past 3 b.y. [billion years] ago, the age of lunar maria, perhaps extending close to the present." My own recent work, based on dividing known numbers of impact craters on volcanic flows by calculated crater production rates, supports this conclusion. Yet a paper recently published as a lead article in *Science* (24 December 1976) concludes just the opposite, that most martian volcanism occurred prior to 3.4 billion years ago and that "the last great volcanic construct is 2.5 billion years old." The section on the mysterious channels presents strong evidence (in my opinion) that many of them were formed by flowing water, indicating a dramatically different martian climate at some time in the past; but some planetary geologists, including a few Viking team members, attribute the channels to lava or wind action. The channels are currently an important puzzle, and study of them may lead to the discovery of general planetary climate oscillations. Very recent work by Ward, Burns, and Toon (not included in this book) suggests that these climate changes on Mars resulted from dynamic changes in martian obliquity, caused by volcanic changes in the planetary mass distribution. Geoscientists should consider the ramifications for the earth, whose climate has also varied.

Some question may remain about the use for this excellent review of martian and planetary geology. The preface indicates three goals: preparation of a martian atlas, compilation of planetary comparisons, and production of a textbook with references. The first goal is not truly met, since the book is not an atlas of maps or of geographically ordered photos, though it does include many geologically organized maps and photos. The second goal is well met. Although the book would make an excellent text, one might question whether the price and the heavy emphasis on Mars are conducive to use in existing courses. Nevertheless, the book is bound to become a classic reference on the pre-Viking knowledge of Mars and an invaluable historic document when the time comes to review how we learned about that planet. Any researchers concerned with terrestrial geology and climate history would benefit by considering the "textbook examples" of the processes that have been discovered to have taken place on Mars and are described here. Let us hope for an update in a year or two, with the final Viking data woven in.

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Magma Formation

Generation of Basaltic Magma. H. S. Yoder, Jr. National Academy of Sciences, Washington, D.C., 1976. xii, 266 pp., illus. Cloth, $8.25; paper, $5.50.

It is currently accepted that the earth's crust has evolved from magmas generated by partial melting in the mantle, and in the broadest sense the term "basaltic magma" covers the full range of mantle-derived silicate liquids. Since the recognition of different "primary" magmas by Bailey and his colleagues in the Scottish Tertiary province in the 1920's, the problem of the generation of basaltic magmas has underlain much petrologic research. The generation and extrusion of magma have come to be recognized as complex processes, the full understanding of which requires diverse contributions from geochemistry and geophysics. In this book, Yoder attempts to provide "a comprehensive summary and synthesis of current knowledge" in the field and

particularly "to bring to a focus the many problems amenable to theoretical and experimental investigation." The book covers the following major topics: the nature of the parental material and source environment, the thermal and mechanical requirements for melting, the physical chemistry of melting and crystallization, and the mechanisms of magma accumulation and extrusion.

The introduction is only marginally related to the rest of the book and conveys little of the history or of the interdisciplinary nature of the study of basalt genesis. Subsequent chapters, however, adequately represent the diversity of current research on the subject.

The section on the nature of the source material and environment gives a comprehensive summary of the major arguments on which current models of the outer few hundred kilometers of the earth's mantle are based and gives estimates of the depth ranges over which partial melting occurs. In a comparable manner, the discussion of the thermal and mechanical requirements for melting draws together the varied hypotheses put forward concerning the parameters that control melting. Although somewhat eclectic, the recital of hypotheses that need adequate testing is illuminating.

Experimental studies of the phase equilibria that govern the fusion and crystallization of basaltic magma dominate the central portion of the book. The clarity with which the fundamental parameters that control the major variability of basalt magmas are explained testifies to the success of this approach. The section is excellently balanced between review and synthesis. It reflects the author's research experience, and it represents the culmination of one aspect of traditional studies of magma genesis.

The discussion of the mechanisms of magma accumulation and intrusion and the mechanical and tectonic effects controlling the energetics and periodicity of magmatism catalogs a broad spectrum of ideas and experimental studies. Although the discussion is nondogmatic in describing a variety of possible mechanisms, it lacks critical assessment of the alternatives.

There is no discussion of research on the trace element and isotopic chemistry of basalts or of the thermodynamic analysis of magmatic processes, although major contributions to the understanding of basalt genesis have resulted from such work.

A final chapter accurately summarizes the ideas and conclusions discussed in the book.

Yoder has largely succeeded in his goals. His lack of dogma and his willingness to accept alternative working hypotheses stimulate the reader to appreciate the frailty of many of our basic tenets. The book thus primarily looks forward to new research rather than presents accepted assumptions as fact. Although there is an understandable lack of critical assessment of alternative hypotheses, the wide-ranging discussion makes the book valuable to both geochemists and geophysicists interested in the evolution of the crust-mantle system.

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