

the butt-end of the rod, and the female ferrule; or, rather, we have made a variety of butt-ends, some elegant and some crazy botched affairs, but all alike incomplete, and all awaiting the test of whether they will receive the male ferrule of fact. Some will no doubt prove too narrow to be united at all; others will be so broad that they would accommodate any conceivable partner, and the actually realized possibilities of the world will slop around inside them like a stick in a bucket. One—we can hope—will be just right [p. 160].

In summary, it is difficult to recommend this book except to patient specialists.

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## Southern African Geology

**Crustal Evolution of Southern Africa.** 3.8 Billion Years of Earth History. A. J. TANKARD, K. A. ERIKSSON, D. R. HUNTER, M. P. A. JACKSON, D. K. HOBDAI, and W. E. L. MINTER, with a contribution by S. C. Eriksson. Springer-Verlag, New York, 1982. xviii, 524 pp., illus. \$45.80.

Komatiite, Fig Tree Group, Bushveld Complex, Damara Province, Dwyka tillite, Karoo volcanics—these and numerous other names from southern Africa not only help to fill the geologic glossary, they represent major concepts in the understanding of planet Earth. Komatiite immediately makes one think of early crustal evolution, the Fig Tree Group of the development of life on Earth, the Bushveld Complex of metallogenesis par excellence, and the Damara Province of possible intracratonic orogenesis; the Dwyka tillite is virtually synonymous with climatic change; and the Karoo volcanics are on anyone's list of igneous rocks related to continental fragmentation. A. L. Du Toit's 1954 volume *Geology of South Africa* and L. C. King's 1962 volume *The Morphology of the Earth*, which is also based upon a southern African perspective, are classic contributions to the geologic literature. The new book by Tankard and his colleagues is the first complete geologic history of the southern part of the African continent to be published since the broad acceptance of the plate tectonics paradigm for at least the late Mesozoic and Cenozoic. With many earth scientists currently exploring the nature of earlier tectonic activity, as well as the history of life on Earth, the book is a timely contribution that will be of widespread interest. Unquestionably it should be on the shelves of every geologic library, and indeed probably on those

of every serious historian of the earth.

The authors divide the geologic history of southern Africa into five stages: Archean Crustal Development, Early Proterozoic Supracrustal Development, Proterozoic Orogenic Activity, The Gondwana Era, and After Gondwana. Spatially they consider the African continent south of approximately 18°S latitude to be composed of ten distinct tectonic provinces defined on the basis of such parameters as lithology, structure, metamorphism, and predominant radiometric age. Some of these provinces will be familiar to readers outside of southern Africa (Kaapvaal Province, Namaqua Province), others less so (Saldanian Province). Inevitably there are a large number of unfamiliar names for the outsider to absorb, but numerous clearly drafted maps and tables help to overcome this obstacle.

The six principal authors must have put a lot of effort into coordinating their contributions, because the discussions of such subjects as structural geology, petrology-geochemistry, and sedimentology-stratigraphy blend well into the account of the various temporal and spatial subdivisions, and the geologic problems, discussed. As is pointed out in the foreword by Brian F. Windley, an impressive attempt is made to separate a review of factual data from consideration of various interpretations of those data, and space is not wasted on unwarranted speculation.

It is no criticism of the volume to point out that scientists seeking detailed information on the state of knowledge of, say, the Pan-African belts or the Cape fold belt will want to follow up the references in the bibliography, which covers material into the earliest 1980's. The space devoted to the five stages of southern African crustal development is approximately proportional to the time intervals involved. Thus the late Precambrian Pan-African orogenic activity is described in just over 50 pages and the early Mesozoic Cape orogeny in one page. One can quibble with the weight of the treatment given to one topic or another, but any suggested alternative arrangement will probably merely reflect one's own special interests. This reviewer, for example, would like to have found more Gondwana-wide comparisons even though the book does by no means treat southern African geology in vacuo.

The strength of the volume lies in lucid description of a panoply of important and evolving geologic processes that occurred in one unique and important location through virtually the entire span of geologic time. It takes little foresight to

predict that this work on one part of a large continent will be carefully scanned for years to come in the formulation of hypotheses concerning the tectonic history of the earth as a whole.

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## Porphyry Copper Deposits

**Advances in Geology of the Porphyry Copper Deposits.** Southwestern North America. SPENCER R. TITLEY, Ed. University of Arizona Press, Tucson, 1982. xiv, 560 pp., illus. \$35.

Southwestern North America is one of the great copper provinces of the world and accounts for most of the copper production and reserves of the United States, the world's leading copper-producing country. The region attracted the attention of several generations of geologists, and much has been written about it, including the predecessor to this volume, *Geology of the Porphyry Copper Deposits, Southwestern North America*, published in 1966 and edited by Titley and C. L. Hicks. Nevertheless, discoveries of more deposits, accumulation of geological information, and advances in concepts of porphyry deposit geology make this volume a welcome, timely addition to the literature on this classic porphyry copper region.

The book is divided into two parts: Topics in Porphyry Copper Geology and Deposit Descriptions. There are chapters on grades and tonnages of deposits, geological settings, fluid and heat transport, fracture and dike patterns, style and timing of mineralization and alteration, hydrothermal alteration in silicate rocks, skarns, a rock geochemical study at Kalamazoo, the sulfur and copper in magmas and rocks and the petrology and chemistry of igneous rocks at Ray, leached cappings, geochemical prospecting, and 12 selected porphyry copper deposits and one district. Deposits have been included for which no previous reports have been published and for which substantial additions have been made to the information contained in earlier studies. Because the volume lacks descriptions of some of the most important porphyry copper deposits of the region, it should be used in conjunction with the 1966 volume and other papers.

The quality of papers and editing is generally high. Some papers, especially those by Titley, reflect many years of

work, compilation of data, and perceptive thought about porphyry copper deposits. In addition, Titley emphasizes to good effect what is not known about the deposits and how much of the record of them has been destroyed by late Tertiary Basin and Range structures, erosion, repeated strong supergene alteration, and intense hydrothermal masking of rock relationships and petrographic features of the temporally and genetically related porphyry intrusions. He stresses the importance of fracture-control of the economic hypogene sulfides in a variety of host rocks and places less emphasis on "disseminated" sulfides in intrusive rocks than had previously been placed. This emphasis on the crosscutting, epigenetic nature of the mineralization should help alleviate misconceptions held by some nonporphyry specialists working in "frontier areas," such as the Canadian Shield, about one of the most fundamental features of porphyry-style mineralization. I recommend the classification of joint sets, veins, faults, fault-veins, dikes, and fault-dikes presented in the volume by Heidrick, Rehrig, and Titley. Widespread use of their terms would permit more precise comparison of these important ore-related features in porphyry deposits in many parts of the world.

Einaudi presents a useful overview of skarns and a particularly good summary of the skarns at Bingham, Utah, and their relationship to the porphyry copper deposit and the lead-zinc-silver lode deposits. With limited data he also makes a valiant attempt to relate geological features to copper grades and tonnages. This approach, of course, will have to be pursued more vigorously in the future as higher copper grades are sought and at greater depths. Sphalerite is mentioned as occurring in many deposits, but especially in the peripheral parts of copper-bearing skarns. One cannot help but wonder how much zinc and other valuable metals, such as lead, silver, and even tungsten, at Twin Buttes has been mined but not extracted from the deposits. Perhaps improved knowledge of the distribution of such metals and of the techniques used to extract them could increase the supply of these commodities for industry.

Part 2 includes much basic information on deposits and their surrounding geology, but perhaps the most outstanding contributions are new ones on the important Pima district south of Tucson, Arizona. An overview of the geology of the district is followed by descriptions of the Twin Buttes, Sierrita-Esperanza, Mission, and San Xavier North deposits,

which makes for a reasonably complete, concise account of the district.

Titley and other contributors to this volume have helped direct future studies by pointing out what is still not known about the deposits in this region. But here, as well as in other important copper-producing regions, geologists have been preoccupied with the large economic deposits and have virtually ignored subeconomic and almost barren deposits. Little has been published about their abundance, distribution, basic features, and relationship to important economic deposits. When you see only part of the beast, how do you know that you have an elephant? Geologists must learn how to recognize the difference. Einaudi's attempt to relate geological features to grades and tons of copper metal is a step in the right direction for effective exploration for blind and higher-grade deposits.

This is a stimulating book on a fascinating subject. It will be of particular value to exploration geologists searching for porphyry copper deposits, but it is indispensable for any serious student of porphyry deposits. The binding, paper, editing, printing, illustrations, and price are excellent.

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## Collision Theory

**Atomic and Molecular Collision Theory.** Proceedings of an institute, Arezzo, Italy, Sept. 1980. FRANCO A. GIANTURCO, Ed. Plenum, New York, 1982. x, 506 pp., illus. \$59.50. NATO Advanced Study Institutes Series B, vol. 71.

Atomic and molecular collision theory is a relatively old field; most of the basic theory and simple models were developed in the early decades of this century. The field has, however, experienced an extraordinary productivity in recent years. There are several causes for this, especially the development of more specific and powerful experimental tools to complement the classic spectroscopy and provide more and more sensitive data and advances in computer science, which make increasingly complex systems amenable to computational attack. Most stimulating of all, however, has been the continuing development of new applications, in fields ranging from astrophysics to laser physics to surface science, which encourage atomic physicists to investigate new classes of problems.

This book consists of the lecture notes

from a NATO Advanced Study Institute that present collision theory from both a theoretical and an applied point of view. Most of the papers deal with formal aspects of collision theory, including electron and photon collisions with atoms and molecules, heavy particle collisions, and collisions under special circumstances. The remainder of the papers deal with applications to related fields. No experimental papers are included.

As always in a volume like this, the papers vary considerably in length, style, and quality. Most of the papers on theory stress the formalism used to describe atomic and molecular collisions and briefly explain the methods that have been used to attack a particular class of problems. The clarity of the exposition suffers, however, from the extraordinary complexity of notation employed. This problem is endemic to collision theory, especially as applied to multiparticle systems. Still, the authors would have done better to include more discussion of why each method is unique and when it might be applicable. Few examples or comparisons with experimental results are provided, which adds to the confusion. The reader is left with little sense of which methods are proving to be most successful.

Exceptions are Bardsley's chapter on recombination and Percival's on highly excited atoms. Bardsley's contains very little formalism but a wealth of "working rules" and examples, together with comparisons to experiment. Percival's discussion of classical theory and the correspondence principle contains a clear treatment of regions of validity.

The papers on applications, such as van Regemortel's on astrophysics and Levine's on chemical physics, present quite a different view of atomic and molecular collisions. Here one learns, for example, how information from atomic and molecular physics can be applied to the diagnosis of astrophysical plasmas.

For the specialist in atomic and molecular collision theory, the book is a reasonably compact and up-to-date review of methods. The extensive references compensate for the dearth of examples to a considerable extent. The papers on applications offer an opportunity to look at collision theory from a new perspective and may suggest new problems. For the nonspecialist, the formal chapters would be heavy going indeed, and of dubious usefulness. The papers on applications and the less formal papers on theory offer insight into the calculation of atomic and molecular collision pro-