rately and fully recorded at the time of discovery. (The archeological work of Mary Leakey is among the finest ever carried out.) Louis Leakey's contribution to paleontology cannot perhaps yet be fully assessed, but had it not been for him the prehistory of East Africa might remain uncovered to this day.

But there were other aspects to his work. He was an ardent and effective conservationist in Kenya, and was especially interested in the higher primates. Cole describes how he inspired Jane Goodall to undertake what was then an extraordinary research project on the shores of Lake Tanganyika, and Goodall was followed by two other intrepid women, Dian Fossey and Biruté Brindamour. Thanks to him, all three of the great apes have acquired worthy biographers, and the work he set in motion will continue for many years to come.

Some other aspects and views of Leakey the man and his work are presented in *Human Origins: Louis Leakey and the East African Evidence*, prepared as a tribute to Leakey. The volume includes biographical chapters by colleagues, such as J. Desmond Clark and Phillip Tobias, and a complete annotated bibliography of Leakey's writings by Shirley Coryndon, along with some valuable papers on hominids from East Rudolf by his son Richard and papers by various other authors on topics pertaining to the reconstruction of the environment of early man and of early hominid behavior in East Africa.

Louis Leakey was a fearless man, and in the modern landscape of institutional anonymity he stands out as a giant. He was interested in all of nature and was perennially young in ideas. He was a sensitive man, and often ahead of his time. Looking at the record of his life, I feel we should pay attention when he speaks. This quotation from his autobiography set me thinking:

> When I think back over the problem of my eagles and also of the serval cat and a baboon that I had as pets in my childhood days—and that eventually I had to house in large cages—it makes me sad. It makes me sadder still, however, and also very angry, when I think of the innumerable adult animals and birds deliberately caught and locked up for the so-called "pleasure" and "education" of thoughtless human beings. I appreciate that many people cannot afford to travel to far countries to see wildlife in nature's own setting, but surely there are today so many firstclass films, often in beautiful color, about almost every wild species in its natural habitat that the cruelty of keeping wild creatures in zoos should no longer be tolerated.

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Seismology and the Test Ban

Nuclear Explosions and Earthquakes. The Parted Veil. BRUCE A. BOLT. Freeman, San Francisco, 1976. xxiv, 310 pp., illus. $9.95. A Series of Books in Geology.

The solution of the technical problems involved in monitoring a treaty banning the testing of nuclear weapons has been a goal of research in the United States and a few other nations for about 15 years. A treaty banning testing in the atmosphere, in space, and underwater has been in effect since 1963 and has been honored by the United States, the Soviet Union, and the United Kingdom, who were signatories, though France and the People's Republic of China, who were not, have proceeded with testing. The overriding technical obstacle in the way of a ban on testing in the remaining environment, underground, has been the lack of reliable methods for detecting underground explosions and distinguishing them from the thousands of earthquakes that occur every year.

There is hardly an earthquake seismologist now active in the United States who has not participated in some aspect of our national research program, known as Project Vela-Uniform, to establish such methods. The present high level of development of seismology in this country owes very much to the resources made available by the Department of Defense for support of this program.

Bruce Bolt has written an informative and thorough account, with a minimum of technical jargon, of the detection problem and recent attempts to solve it. The book is intended for the nonspecialist, and Bolt has provided the necessary background for understanding the questions that arise and the methods used in seeking the answers. A large amount of material about the work of global-scale geophysicists, valuable to the general reader apart from any interest he might have in test monitoring, is summarized.

A useful history of nuclear explosions, including a chronology beginning with the Trinity test, 16 July 1945, is followed by a brief introduction to the physics and engineering of a nuclear explosive and the phenomenology of an underground explosion. This reviewer's experience with concerned laymen has demonstrated that the inclusion of this information is essential for them because it gives some assurance that the apparently incomprehensible chaos in the region surrounding a nuclear blast can, in fact, be described in terms of well-understood and predictable processes.

A "short course" in elementary seismology then leads into the heart of the book, a historical treatment of test-ban research. The major problems, the sources of the disagreements between the United States and the Soviet Union, the contributions of the research groups in various nations, and the recent status of detection and discrimination (telling a bomb from an earthquake) are discussed.

Some schemes for evasion of a surveillance system by a would-be violator of a treaty are analyzed briefly, but this discussion primarily reflects the viewpoint of weapons laboratory scientists as presented about five years ago. Though it is natural for the scientist working on detection to think of ways he could beat his own methods, evasion was not considered a subject for polite conversation in the earlier days of the research, and the matter has not been widely studied in the scientific community. For a painstaking analysis of the methods of evasion outlined by Bolt, the reader is referred to Jack F. Evernden's "Study of seismological evasion" in the February 1976 issue of the *Bulletin of the Seismological Society of America*. Evernden's conclusion is that the operator of the surveillance system has a far less complicated task than does the evader.

Bolt is a strong proponent of the use of nuclear explosives for such peaceful engineering projects as large-scale excavation of harbors and canals and stimulation of oil and gas flow in impervious formations. This reviewer has also strongly supported the view that it would be desirable that a treaty banning testing of nuclear weapons be drawn so as to permit the exploitation of this relatively inexpensive source of energy. Realization of the extreme difficulty of distinguishing between a "peaceful uses" shot and the test of a new weapon (perhaps only espionage would be effective) has lessened my conviction of the feasibility of ac-

commodating Plowshare-type projects under the provisions of a comprehensive test ban, however.

In addition, there is at present no proposal for peaceful applications for U.S. purposes that appears attractive. The Rio Blanco gas stimulation experiment (p. 189) seems to have been a failure as far as commercial development is concerned. The American excavation projects that have been proposed all involve environmental hazards that appear to be unacceptable, if not illegal. The control of earthquakes by relieving tectonic strain with explosion-generated motion (p. 209) should no longer be considered as a serious suggestion in view of the great uncertainties of the interaction of the dynamic stress field from the explosion with the ambient stress field and geologic structures. Fluid injection and withdrawal offer a much more promising approach, based on principles we understand better. It seems unfair to suggest (as the author does on p. 246) that some proponents of an extended treaty want to end Plowshare programs. Another interpretation is that they see these as incompatible with a test ban and choose to forgo them in the interest of achieving an end to nuclear weapons development.

The text is almost free of editorial and technical errors, and the few I noticed will be of concern more to the seismologist than to the general reader. More information on Soviet seismic arrays is available, in a RAND report published in June 1975, than the author suggests on p. 146. The problem of determining the depth of a shallow seismic source, discussed briefly on p. 151, is more difficult than the author implies, and recent results using techniques not discussed are promising. The statement, on p. 170, that "shallow-focus earthquakes are always followed by a sequence of aftershocks" is not true, as seismologists who have worked with earthquakes in the central United States are well aware.

The publication of this book is especially timely in view of the treaty between the United States and the Soviet Union limiting underground tests to yields smaller than 150 kilotons that was to have gone into effect on 31 March and that is being honored even though the negotiations are incomplete. The background provided by this book will be most useful to the reader who wants to consider the problems of test bans on the basis of the facts.

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Forecasting

Earthquake Prediction. TSUNEJI RIKITAKE. Elsevier, New York, 1976. xvi, 358 pp., illus. $37.95. Developments in Solid Earth Geophysics, 9.

Twenty years ago one would have kept a book on earthquake prediction on the same shelf with texts on astrology, ESP, and dowsing. Because of limited and sketchy data, lack of good understanding of earthquake mechanics, and relatively poor detection equipment, scientific prediction of earthquakes was impossible. All that has drastically changed. The seismic and other geophysical data available today are voluminous and quite accurate, the equipment to obtain the data is versatile and sensitive, and the mechanics of faults is much better understood.

The near accomplishment of earthquake prediction raises new challenges. It is now necessary to specify more precisely what is required of an earthquake prediction. If we characterize an earthquake by its location, time, and magnitude, it is necessary to predict all three with a certain accuracy. If uncertainties in predicted time, location, or magnitude are large, the significance of prediction is greatly reduced. The prospect of earthquake prediction raises also social, political, and economic questions. How can and how should society respond to an earthquake warning? How can we deal with the uncertainties of prediction? What degree of prediction accuracy is necessary to justify the evacuation of an area at risk?

Rikitake's book is therefore timely. It opens with a brief collection of legends about harbingers of earthquakes, a resume of historical developments in earthquake research, and a description of the Japanese, Soviet, U.S., and other national programs. These are followed by an extensive collection of examples of crustal motion and deformation, seismic activity, and geomagnetic and electrical variations detected in association with earthquakes. Special attention is paid to variations in seismic wave velocity preceding earthquakes and to their possible relation to dilatancy and fluid flow in the earth's crust. It is interesting to point out here that the work that led to the development of the dilatancy-diffusion hypothesis was international. In the 1920's, Bridgman at Harvard University discovered that the elastic moduli of rocks increase significantly with pressure, owing to crack closure. In 1948 M. Hayakawa in Japan suggested that the change of stress in the earth's crust should cause small changes in wave velocities, which he observed. Fifteen years later a Russian team repeatedly detected velocity changes preceding local earthquakes. This was followed by similar observations in the United States. At the same time laboratory studies of velocities in rocks and dilatancy at the Massachusetts Institute of Technology provided the basis for the explanation for the velocity changes.

The dilatancy-diffusion hypothesis highlights the otherwise empirical approach that has been taken to earthquake prediction. The final section of the book contains a prediction theory developed by the author that is almost entirely statistical in nature and makes no use of physical models for earthquakes or their precursors. In fact, the lack of physical models is probably the greatest weakness of the book. Reid's notion of elastic rebound, which opened the way in 1906 to an understanding of strain accumulation and release, is mentioned only once. There is no mention of work on faulting mechanics, such as that by Burridge, Walsh, Haskell, and many others. Friction, which is probably the most important physical quantity in earthquake faulting, is not even listed in the index. The lack of concern with these aspects of earthquakes is also reflected by inaccuracies in references to original work on, for example, velocities in dry and saturated rock.

The book falls short of putting earthquake prediction into a strong scientific framework with working hypotheses. It is, however, an invaluable collection and summary of past and current work on the prediction of earthquakes around the world. As such, it will be an important reference for earthquake students.

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Experimental Petrology

Composition and Petrology of the Earth's Mantle. A. E. RINGWOOD. McGraw-Hill, New York, 1975. xviii, 618 pp., illus. $29.95. McGraw-Hill International Series in the Earth and Planetary Sciences.

Experimental petrology addresses problems related to the origin of magmas and the evolution of the crust and upper mantle. High pressure petrology is a subdiscipline that concerns itself with phase assemblages that occur deeper in the mantle. Geologists and geophysicists