

ments, and he minimizes not the usual action operator but only its trace.

This trace action is real and gauge invariant, and it yields just the right quantum equations for both complex and quaternionic theories, but it cannot be fundamentally right. It is actually the action of a classical theory, for its variables obviously commute. In addition, it diverges even for a linear harmonic oscillator, let alone for a field theory. Physics still lacks a good concept of quantum dynamical law, one that is both mathematically meaningful and physically adequate. This is not a problem of the quaternionic theory alone.

Adler does cite a gauge-invariant quaternionic theory. Its imaginary operator I varies in spacetime and is then a natural Higgs field. But this theory does not account for color $SU(3)$, the one-handed neutrino and several other peculiarities of nature that seem to belong together. Adler quite reasonably shelves this theory. Indeed, the gaps in this theory led me to shelve the whole quaternionic project in the 1960s. Adler suggests a quaternionic route that might close these gaps.

Writing for advanced students and researchers in particle physics, the foundations of quantum physics or related mathematics, Adler systematically and thoroughly develops the quaternionic quantum theories, synthesizing the earlier studies and building on them. This monograph is the first on the subject and gives by far the fullest treatment ever published. It abounds in original results and sheds new light on the complex and real quantum theories as well. Physicists and mathematicians open to fundamental conceptual innovation should take this quaternionic voyage. They will truly see the world with new eyes.

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Radiogenic Isotope Geology

Alan P. Dickin

Cambridge U. P., New York, 1995.

452 pp. \$89.95 hc

ISBN 0-521-43151-4

It is a strange world in which the average graduate student in geology knows more about nuclear physics than does the average graduate student in physics. And yet that is our current world, at least at my school, the University of California at Berkeley. The explosive growth of nuclear techniques in the study of Earth has been phenomenal, with no end in sight. We wonder, what would Willard

Libby think today, in viewing this enormous field that is, in effect, an outgrowth of his original radiocarbon work? Perhaps he would respond as the beaver did when asked if he had built the Grand Cooley Dam: "No, I didn't. But it was based on my idea."

To get a sense of the vast expanse of this field all you need do is thumb through an excellent new text by Alan P. Dickin, *Radiogenic Isotope Geology*. Or look at his figure 1.1, which shows "some" geologically useful radionuclides, 22 of them, many well known to geologists but not to the average physicist.

Dickin's goals are laudable: to "concisely review the field," which he succeeds in doing in a terse 452 pages, and to give an impression of the "development of thought in the field," which he is somewhat less successful at doing. His unmentioned challenge is to improve on the already classic book in the field, *Principles of Isotope Geology*, by Gunter Faure (Wiley), first published in 1977 and then revised in 1986.

Dickin's book is a very welcome addition to the field, if only because it is up-to-date. Just in the fields that I know best—accelerator mass spectrometry and argon–argon dating—the developments of the past decade are important and exciting. Dickin's inclusion, for example, of step-heating diagrams will prove enormously valuable to any student attempting to read the current literature in Ar–Ar dating. But an encyclopedic text such as this cannot give a full introduction to any one of the many subjects. For such details the student must go to a more specialized book—for example, *Geochronology and Thermochronology by the Ar-40/Ar-39 Method*, by Ian McDougall and T. Mark Harrison (Oxford U. P., 1988)—or to the articles that are referenced at the end of each chapter.

A detailed comparison of Dickin's book with Faure's reveals the minor advantages and disadvantages of each. Dickin's discussion of the geomagnetic reversal time scale is similar to Faure's but better and more up-to-date. Faure's book has a somewhat better discussion of Ar–isotope correlation diagrams. Such comparisons can go on indefinitely. But the real praise for Dickin is that he has produced a book that is in the same class as Faure's and is a competitor for selection as a graduate text. (However, Faure's book has some simple exercises at the end of each chapter, with answers; Dickin's book has none.)

I certainly recommend *Radiogenic Isotope Geology* to any scientist who is interested in the field, particularly in recent developments. Like Faure's book it gives a solid foundation for someone trying to learn more about a

particular method of radiogenic analysis. A serious student should own both.

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Introduction to Nonlinear Science

Gregoire Nicolis

Cambridge U. P., New York, 1995.

254 pp. \$24.95 pb

ISBN 0-521-46782-9

The lecture notes of an enthusiastic and knowledgeable instructor often provide a royal road to the understanding of a new subject by a beginner. Many beginning graduate students in physics, chemistry and chemical engineering will find this to be the case with Gregoire Nicolis's *Introduction to Nonlinear Science*. This is not an intermediate or advanced textbook or treatise, of which there are a number of excellent ones in print; it is exactly what it purports to be, a first introduction that exposes the student to a great variety of topics. Nicolis pioneered many of the areas covered, particularly applications to chemical kinetics and chemical engineering reactor theory as well as certain probabilistic methods in chaos theory.

Nicolis presents a broad view of most aspects of nonlinear dynamics, including spatially extended systems, as well as statistical topics that other treatments tend to omit. He employs two important representative physical systems throughout the book to illustrate the various methods of nonlinear science, the first being convection in a layer of fluid heated from below and the second being reaction–diffusion models leading to chemical oscillations and symmetry-breaking pattern-formation equations.

After a concise derivation of the dynamics, he develops techniques appropriate to systems of a finite number of degrees of freedom. Among these are the use of phase-space methods, linear stability theory and local bifurcation analysis, including a very insightful derivation of normal forms, the use of multiple scales and stability criteria. He continues naturally with these approaches to spatially extended systems with an infinite number of degrees of freedom, including a very beautiful introduction to the complex Ginzburg–Landau equation and some other models of pattern formation. The author's interests are reflected in his masterly exposition of Turing patterns of chemical systems.

The final chapter deals with chaos—topics such as the Poincaré maps, logistic and circle maps, period doubling intermittency and probabilistic con-