self-consistent program are beside the point; they do not change the order of discovery.

The matter of Rutten raises another issue. On p. 130 it is asserted that Rutten lacked the training to follow up his early time scale, and this is presented as evidence that Rutten's scale was premature and not a serious part of the development of such scales. It is disturbing to find that the remark concerning Rutten's alleged lack of competence is "unattributed on request." In fact, remarks "unattributed on request" are scattered throughout the book, and in almost every case they are highly critical of the capacities and judgments of scientists involved in the story. Whether accurate or not, such statements are unacceptable in a work of historical scholarship. Reporting them reduces historical narrative to gossip, hearsay, and innuendo. In this case, we hear that the informants are paleomagnetists who worked with Rutten, and since there are six candidate names in the bibliography, suspicion falls on all of them, a disservice to those not culpable for disparaging remarks they do not wish to acknowledge.

This error of judgment aside, there is an issue of more general significance that bears on the allegation of priority for the Berkeley groups. At fault here is Glen's equivocal use of the term "program" in referring to the relevant research efforts. Philosopy of science journals are full of "solutions" to "problems" attacked by "teams" with "programs"—a style of analysis known as rational reconstructionism—in which one pieces together the logic of a sequence of discoveries and determines which research efforts (from a logical point of view) were crucial in attaining a result, whether or not the principals understood their position in the sequence at the time. But there is another and quite different sense of the term "research program," referring to the series of studies one carries out and records in laboratory records; and, finally, there is a third sense: the program one outlines in the "program proposal" to a funding agency, stating the larger context of the work and its justification.

Glen uses the term in all three ways, and it is often not clear from the context which sort of program he means. For instance, he speaks of the "young-rock dating program" at Berkeley, and the "geomagnetic time scale reversal program" at Menlo Park. But, as Glen's materials show, there was no "young-rock dating program," but a "rock dating program" in which young rocks were sometimes dated, not always willingly. Similarly, at Menlo Park there was not a "geomagnetic time scale reversal program" but a rock magnetics program with a reversal component, and a controversy, at times acrimonious, over the ownership of data, the use of facilities, and proper direction of research. That of all the rock dates at Berkeley the youngest ones were significant and that in the magnetics program the directionality data were overshadowed finally by the reversal data, were learned in retrospect by everyone, the thrust of Glen's narrative notwithstanding. In fact, Cox, Doell, and others had a "program," within a "program," which fits the analytic definition of a "program"—*caveat lector*. The reader must decide at each juncture which sense is meant.

Although the book is announced as intellectual history, it is not: the organizing intelligences are offstage, and although certainly not minor figures in the narrative are well in the background for the first 275 pages. Moreover, except in the beautifully detailed account of the study of magnetic self-reversal, we hear more of proposed research and final results than of the actual doing of the research. This is institutional rather than intellectual history. As such the book has real strengths. Glen shows how important it is that scientists in charge of academic and professional departments introduce their students to a broad range of fundamental problems. Verhoogen and others at Berkeley, John Jaeger at the Australian National University, and James Balsley at the U.S. Geological Survey emerge as men who had an eye for bright young scientists willing to take some chances, who steered them to fundamental, front-line topics and gave them support, money, time, encouragement, and protection—with stunning results. Glen's focus on the academic and professional setting of time scale research shows again and again a sustained interest in tests of the theory of continental drift at major university centers, from the 1950's on—a conclusion certainly at variance with the idea that continental drift died with Wegener in 1930.

In spite of its serious flaws, *The Road to Jaramillo* opens up an approach to earth science history that I hope others will follow—making careful note of Glen's failures as well as his successes. There are tantalizing leads here, and a mine of information for Glen himself, and many others, to exploit.

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A Framework for Archeology

Archaeology as Human Ecology. Method and Theory for a Contextual Approach. KARL W. BUTZER. Cambridge University Press, New York, 1982. xiv, 364 pp., illus. Cloth, $29.50; paper, $12.95.

Since the 1960's many archeologists have adopted an ecological approach to their discipline, but—particularly in Europe—the majority continue to think more as historians than as ecologists. By adopting an explicitly ecological framework and recasting the discipline within it, Karl Butzer presents non-ecologically minded archeologists with an alternative mental construct for the subject as a whole. And to those colleagues who already work within an ecological paradigm he offers a conspectus of the field that is valuable chiefly for its comprehensiveness.

Integral to Butzer's conception of archeology as human ecology is the assumption that systems theory provides an appropriate model for interpreting past relationships between culture and environment. However, he acknowledges that, although systems-theory concepts allow coherent hypotheses to be formulated, they tend to be too complex to be applied directly to the data base of archeology. They contribute to the ultimate goal of understanding the dynamics of past human ecosystems, but at the level of operational research some more practical approach to the data is needed. This is provided by the concept of archeological context, which Butzer defines (p. 4) as "a four-dimensional spatial-temporal matrix that comprises both a cultural environment and a noncultural environment and that can be applied to a single artifact or to a constellation of sites." Thus broadly defined, "contextual archeology" embraces such established subfields as geoarcheology, archeometry, archeobotany, zooarcheology, and spatial archeology.

Part 1 of the book consists of two introductory chapters, the second of which examines spatial and temporal variability in environmental systems and includes a useful six-order classification of scales of climatic variation ranging from a few to several million years' duration. A method of summarizing concepts and data in tabular form, with frequent supplementary diagrams, is introduced in this chapter and used effectively throughout the text. Both the tables and the diagrams add materially to the value of the book, especially for teaching purposes.

Six of the nine chapters that make up part 2 are devoted to aspects of geoarcheology. These range from landscape and stratigraphic context to site formation, modification, and destruction, and the treatment includes a consideration of human impacts on the landscape. The remaining chapters deal with archeometry, archeobotany, and zooarcheology. This apparent imbalance is partly a result of Butzer's predilection for and unrivaled experience in geoarcheology and partly an attempt to counterbalance the more highly developed subfields of archeometry and bioarcheology. This is justifiable in light of the present state of the discipline as a whole, but it results in the other subfields being dealt with in such a highly condensed fashion that some important topics—for example the potential contribution of ethnobotanical fieldwork to archeobotany—get little or no attention. Despite their brevity, however, these chapters are commendably up to date and supported by many recent references, as indeed is the entire book.

In the third and final part, entitled Synthesis, Butzer tackles the daunting task of integrating the approaches discussed in part 2. Three chapters are devoted to spatial integration. They deal with quantitative models of settlement patterns and resource use, principally gravity and central-place formulations derived from human geography, and resource-concentration models, including optimal foraging theory; with socioecological models of the dynamics of settlement systems, including the distinction between real and perceived environments; and with the empirical reconstruction of settlement patterns. These themes are examined with reference both to sedentary farmers and to mobile hunter-gatherers and pastoralists. The last two chapters are concerned with temporal change. In these Butzer analyzes the dynamics of human ecosystems in terms of cultural adaptation, which, he argues (p. 281), provides "an effective approach to the interactive human and nonhuman components" of such systems. He distinguishes fundamental evolutionary transformations of global significance, such as hominization, late Pleistocene cultural diversification, the origins of agriculture, and urbanization, from modifications of regional adaptive systems and from short-term adjustments to such phenomena as epidemics, famines, destructive wars, and dynastic changes. This approach permits diachronic analysis at varying spatial and temporal scales, and in the final chapter it is applied briefly to three examples: the transformational changes of Pleistocene hominization and of Holocene food production and the adaptive modifications that made possible the persistence of hydraulic cultivation for some five millennia in ancient Egypt and Mesopotamia.

As the subtitle implies, Butzer's central aim is to provide a comprehensive theoretical framework for archeology conceived as past human ecology. In this he succeeds. The outstanding merits of the book are its breadth of coverage, its logical structure of conceptual categories, and its synthesis of an extraordinarily wide range of data. Such comprehensiveness entails some superficiality, but this is mitigated by the inclusion of case studies and by a 37-page list of up-to-date references. Not all will accept Butzer's claim that the book proposes a new paradigm for the study of archeology, complementary to that of social archeology, but those of us who regret the persistence of pedagogical barriers that continue to separate the natural and social sciences, and who share Butzer's vision of archeology as human ecology, will warmly welcome this pioneering prospectus.

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Bat Ecology

Ecology of Bats. THOMAS H. KUNZ, Ed. Plenum, New York, 1982. xviii, 426 pp., illus. $49.50.

Bats are among the most ecologically diverse of all mammals. For example, the 850-odd species of Chiroptera exhibit a dietary diversity (insects, fruit, pollen, nectar, flowers, leaves, blood, fish and other vertebrates) that is unparalleled among mammalian orders. Researchers have recently begun to exploit this ecological diversity for comparative studies. The influence of environment (food, predators, shelter, and climate) has been detected in phenomena ranging from echolocation pulses to mating systems.

This volume's ten chapters, well organized and well indexed, constitute a broad sampling of current research interests that have not recently been reviewed from an ecological perspective. It is evident from them that bat ecology has come a long way from the days of species lists and anecdotes. More sophisticated study methods (including night viewing devices, radiotelemetry, and portable oscilloscopes with ultrasonic microphones) have made it possible to observe previously inaccessible aspects of bat life. Although many areas still suffer from a paucity of rigorous studies that frustrates meaningful synthesis, the field as a whole is becoming increasingly quantitative.

Among the more provocative contributions is Findley and Wilson's, in which they argue that multivariate analyses of bat morphology (for example of jaw, wing, and brain) generate predictions about behavior and community structure with an accuracy heretofore unappreciated. Another is Fenton's, contending that there is no convincing evidence for resource partitioning by insectivorous bats, despite opinions to the contrary held by many.

Notably thorough reviews of roosting and reproductive ecology are provided by Knuz and Racey, respectively. And Heithaus pulls together an especially broad literature to argue that the intricate mutualisms that characterize bat pollination and seed dispersal systems probably arose by preadaptation and "diffuse coevolution." ("Diffuse" coevolution is a term proposed by D. H. Janzen for situations in which the sequence of response and counter-response involves several species on both sides.)

Our understanding of most areas of bat ecology is based on a relatively few, intensive studies conducted within the past decade. In several cases, the key studies on the topic were done by the authors themselves. For example, major portions of McNab's chapter on physiological ecology and Erkert's on circadian rhythms are derived from their own excellent publications. Tuttle and Stevenson's data on gray bats are the most complete available on chiropteran growth and survival. A fascinating account of the curious ectoparasites of bats is drawn primarily from Marshall's own recent work.

Fleming cautions us that the generalizations that close out his chapter on the foraging behavior of fruit-eating bats are based on detailed case histories of only four species. Though the data are not in themselves sufficient to generate predictive patterns, it is interesting that so many of the findings are consistent with current theories of foraging and mating system evolution, theories for the most part inspired by studies of birds and nonvolant mammals.

This last exemplifies one of the most