with the exceptions of work on tectally mediated prey catching in frogs and on retinotectal plasticity. But investigations of the optic tectum have generated a tremendous amount of information on its anatomy and physiology in all vertebrate classes, so much information in fact that we have a far more detailed comparative picture of this structure than of any other in the nervous system. This information is presented in *Comparative Neurology of the Optic Tectum*, a compendium that begins with a chapter on tectal anatomy in lampreys by Kennedy and Rubinson and ends with three fine chapters on the mammalian superior colliculus by Huerta and Harting, Chalupa, and Stein.

The 20 contributions to the volume are arranged so that a chapter on tectal anatomy is followed by one or more chapters on tectal function (physiology and behavioral correlates) for each vertebrate class. In deference to the tectum's central role in many regeneration studies, two chapters on retinotectal plasticity in fish (by Sharma and Romeskie) and frogs (by Levine) are added.

With a few exceptions, the contributing authors have elected to present detailed, and fairly exhaustive, expositions of data amassed from previous tectal studies without much synthesis or speculation. Because of this, and because nearly all the contributions focus on a single vertebrate group, a truly comparative overview is missing from the book. (One notable exception is a chapter by Freeman and Norden on neurotransmitters in nonmammals.) It is a shame that one or more additional chapters were not added to summarize and compare the principles of tectal organization presented for the various vertebrates, because each section reveals common patterns of tectal organization, such as the greater response of the tectum to moving visual stimuli, and common unresolved issues, such as the nature of the interaction of the tectum with forebrain visual centers.

Early in the book, Bullock raises one such issue during his discussion of elasmobranchs: is the optic tectum part of the visual system or a center for multimodal integration? At one level, the answer is that it is both. Certainly any structure with a massive input from the retina and widespread visual activity is part of the visual system. But as the chapters in the volume progress it becomes clear that the tectum also receives highly ordered, multiple nonvisual sensory inputs in every vertebrate so far examined. The problem is more complex than this, however. At the root of Bullock's query is the question of what if anything these other sensory inputs contribute to the visual function of the tectum. Most investigations of the nonmammalian tectum implicitly assume that there is an interaction, or that at the least both visual and nonvisual maps layer onto a common "motor map" that provides the output of this structure. But Bullock states explicitly that there really is little evidence for this in sharks. And, in an excellent chapter, Huerta and Harting detail the vast morphological and physiological differences between the superficial and deep zones of the mammalian superior colliculus, differences that suggest strongly that in mammals the colliculus consists of two functionally independent systems, a purely visual area above and a multimodal (including visual) area below. Does such an organization exist in any nonmammals? Or is the segregated condition a mammalian specialization with a still unknown purpose?

There is no answer to this question, and it is worth exploring. For when investigating how the functional organization of different tectal zones varies across vertebrates and how the tectal functional organization may have evolved, one is also addressing a far more fundamental problem in comparative neuroanatomy: whether homologies can be established between subregions, and even between types of neurons, within homologous regions of the brain. Underlying many of the anatomical contributions to this volume is a feeling that the identification of such microhomologies is not only a desirable goal but a real possibility. One can detect the feeling most strongly in a chapter by Freeman and Norden on neurotransmitters in the tectum, in a chapter by Hunt and Brecha correlating morphological, biochemical, and physiological properties of avian tectal neurons, and in a chapter by Northcutt on reptilian tectal anatomy that compares the variation in lamination and cell type among reptiles and briefly discusses the problems of extending the comparison to other vertebrates. If neuronal homologies can be explored anywhere in a complex vertebrate brain region it will be in the tectum. A great deal of groundwork has already been laid in describing neuronal morphology, transmitter biochemistry, laminar arrangements, and the details of afferent terminations in a wide spectrum of vertebrates.

The contribution of Vanegas and his authors is that they present this groundwork in detail. This is a book one buys for raw information, rather than for a new synthesis. It is a book to have for reference rather than a book to read for the latest ideas. But its expansive treatment does present the type of information that might cause a reader to wonder if the optic tectum could be pressed into service as yet another model system: a model to explore neuronal homologies and the evolution of intranuclear organization.

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The Geology of Africa

The Geochronology and Evolution of Africa. L. CAHEN, N. J. SNELLING, J. DELHAL, and J. R. VAIL with the collaboration of M. Bonhomme and D. Ledent. Clarendon (Oxford University Press), New York, 1984. xiv, 512 pp., illus. $110.

In 1902, just six years after radioactivity was discovered, the New Zealand physicist Ernest Rutherford and his student Frederick Soddy, armed with their concept of the half-life, dated Canadian pitchblende at 700 million years old. In 1948 the visionary British geologist Arthur Holmes, working in Africa, first demonstrated the power of geochronology for systematic correlation of Precambrian crust.

Africa is a good place to decipher earth history. The Precambrian covers 87 percent of earth history, and more Precambrian crust is exposed in Africa than on any other continent. The authors of this book undertook an ambitious geochronologic survey encompassing the African continent, Madagascar, and the western Arabian shield. Their task was daunting. Mainland Africa has 47 recognized countries, ranging from Gambia (10,403 square kilometers) to Sudan (2,505,813 square kilometers). Below or next to little-deformed cratonic strata lie about 60 juxtaposed or crosscutting Precambrian tectonic provinces whose interiors and boundaries are thoroughly mangled by pervasive strain and regional metamorphism.

The book assumes familiarity with or provides references to techniques of age dating but begins with a chapter summarizing recent developments in methodology and interpretation. The authors illustrate the uses and pitfalls of discordant ages and discuss the scale of open and closed systems and many causes of daughter nuclide leakage. They go back

to the original isotopic measurements and recalculate the ages of samples using 1976 decay constants. Whole-rock isochrons and concordant ages are classified as ages, the remaining ages are classified as apparent ages. Isochrons are distinguished from less reliable regression lines by mean square of weighted deviates values.

Each of the following 20 chapters deals with a particular area. Each starts with an adequate geologic description and neatly drawn maps generally too small to show much geology or even all the places named in the text. The geochronology of each area is described by means of selected age data, whose reliability is assessed.

The authors compiled 502 isochron and concordia age clusters. Only 21 cover the 800 million years before 3000 million years ago, after which a virtually continuous Precambrian record is preserved in three long durations: 3000 to 2450 million years ago, 2275 to 1750 million years ago, and 1425 to 425 million years ago. Only the 3786-million-year-old Sand River gneisses in the Limpopo domain are definitely older than 3500 million years, but samples from southern Africa, central Sahara, northern Zaire, and Madagascar date to around 3500 million years ago. A truism of plate tectonics (which is favored by the authors for the Archean) is that no pre-Jurassic oceanic crust survives owing to Benioff subduction. Yet rocks composed of oceanic crust (greenstone belts) and of continental crust (granitoid gneisses) have coexisted in Africa since 3550 million years ago, becoming widespread between 3300 and 2500 million years ago. At least three ages for greenstone belts are recorded in Zimbabwe and Zaire.

Four major periods of Archean cratonization are recognized. Precambrian cratonic cover includes the 2700 million-year-old Francevillian of Gabon and the many southern African sequences displaying an almost unbroken record from the Pongola (3000 million years ago) to the Mulden (580 million years ago).

High-grade gneiss terranes (mobile belts), representing deeply eroded sections through orogenic belts, crisscross the continent. Supposedly discrete and widespread tectonic cycles were proposed by earlier workers on the basis of age clusters that we now know are not discrete or representative. Only the youngest cycle survives, and then only if the original 1964 definition of it is enlarged; the Pan-African cycle affected two-thirds of Africa in six ubiquitous pulses from 900 to 550 million years ago.

The last three chapters deal with Phanerozoic igneous activity and the succession of tectono-thermal events and present the authors' conclusions. The remarkable Phanerozoic stability of Africa is shown by the restriction of orogeny to narrow fringes in the north and south. There was extensive anorogenic igneous activity in the rest of Africa during the Phanerozoic. The authors' theme is that continuity was imposed on the development and movement of magma by older tectonic provinces, especially during the breakup of Gondwana.

Field geologists will doubtless scrutinize the sections of the book that deal with their areas of interest for errors of commission or omission. But this would be petty given the wide sweep of this authoritative and objective synthesis of about 1450 references, some of the most important of which are in French. The formerly dark continent and its radiometric clocks provide an illuminated showcase for most of our planetary history.

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Climate Dynamics

Ice Sheets and Climate. J. OERLEMANS and C. J. VAN DER VEEN. Reidel, Boston, 1984 (distributor, Kluwer Boston, Hingham, Mass.). xii, 217 pp., illus. $34.50.

In the past few decades considerable progress has been made in understanding the present and past climate of the earth. With this increased knowledge has come an awareness of the remarkably wide range of processes that play vital roles in climate and changes of climate.

In the book under review Oerlemans and van der Veen are concerned with the role of the cryosphere as a component of the climate system, acting on a time scale of 10^3 to 10^6 years. Their stated objective is to write a short book suitable for graduate students that bridges the gap between glaciology and climate research. This is a challenging task, not only because of the number of disciplines directly involved but because research is advancing rapidly on many fronts; in addition, in spite of advances, a number of fundamental questions remain open and practical numerical methods are not yet available to deal with some topics, such as the coupling of the thermodynamics to the flow field of an ice sheet.

The book is logically organized. After a brief chapter reviewing the traditional components of the climate system, the atmosphere and the oceans, the authors devote a chapter to a preliminary survey of the role of ice sheets in climate. This is followed by four chapters on the physics of ice sheets and modeling procedures, first leaving out thermodynamics and then including it. After a brief chapter on the physics of the response of the earth to varying ice loads, the authors devote two chapters to the response of continental ice sheets to the atmosphere-ocean environment.

After briefly reviewing the observational evidence of the Pleistocene glaciations, the authors discuss simulation modeling of the ice volume record and the stability of ice-age ice sheets. They then return to the present ice sheets, Greenland and Antarctica, drawing conclusions about each from the results of their modeling studies. In the final chapter they touch on "the carbon-dioxide problem" and difficulties of detecting long-term climate changes from brief time series of observations.

To a considerable extent, the book is, as the authors admit, an exposition of their (extensive) work on ice sheet modeling. The additional material included is apparently intended to provide the necessary background and supplementary knowledge to make their work reasonably comprehensible to the reader with some background in the natural sciences and mathematics. They have succeeded in bringing together considerable information about the physics of the cryosphere; the discussion is heavily, but not exclusively, slanted toward the point of view of the climate modeler. The method of presentation is quantitative and makes extensive use of very simple numerical models of one or more of the components of the climate system. Modeling is used both for purposes of demonstration of specific processes and as an investigatory tool.

The book gives some appearance of being hastily written; there are a number of typographical and grammatical errors. There are some confusions; for example, the authors refer to the crust as being separate from the lithosphere rather than part of it. More important, in view of their conclusion that bedrock adjustment to the varying ice load is one of the important processes involved in the Pleistocene glaciations, the chapter on bedrock adjustment is an inadequate presentation of the present knowledge of the subject. On the other hand, the material on the coupling of ice flow and thermo-