Copernicus "can hardly be blamed for not undertaking to investigate [the phenomena themselves, which] Ptolemy and Regiomontanus both considered to be settled" (p. 84); and so (iv) "comparison with modern computed positions (of the planets) is not really of interest . . . and give[s] a positively misleading idea of the contemporary judgment that is of real historical interest" (p. 457). Thus, though Swerdlow asserts that Copernicus's theories give better results than Ptolemy's did because the initial conditions were more accurate, some readers will be disappointed by his refusal to provide the comparisons with modern theory that have been traditional for this enterprise.

Although many readers will agree that this book contains "more [detail] than anyone wants to know," there can be little doubt that it will join Neugebauer's *History of Ancient Mathematical Astronomy* as one of the classics of the field.

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Earth History

Patterns of Change in Earth Evolution. H. D. HOLLAND and A. F. TRENDALL, Eds. Springer-Verlag, New York, 1984. x, 434 pp., illus. $22.50. Dahlem Workshop Reports. Physical, Chemical, and Earth Sciences Research Report 5. From a workshop, Berlin, May 1983.

This volume of results from an interdisciplinary conference amply documents the case that geological processes have changed significantly during the course of earth history and that the rates of change have fluctuated widely.

Though it is common knowledge that the earth's living inhabitants have changed with time, it is less well known, even among scientists, that the non-living world has changed also. In fact, life has had a significant effect on its physical and chemical environments. The most impressive example in earth history of organisms changing their environment is the oxygenation of the ocean and the atmosphere brought about by photosynthetic organisms approximately 2×10^9 years ago (during the Early Proterozoic). There is no longer much disagreement among earth scientists that the ocean and the atmosphere during the first half of earth history were anaerobic, in the sense that they contained too little oxygen to support aerobic metabolism. But the factors that made possible this significant impact of life on its environment are still subject to debate. The suggestion is made here by A. H. Knoll that the change was brought about by a great increase in the extent of stable, shallow-water, continental-shelf environments, which harbor particularly productive ecosystems. That the early earth probably lacked extensive continental land masses and the associated continental shelves is not yet well known, even to many earth scientists. Evidence for the growth in time of the extent of the continents is reviewed in several of the papers in this collection.

If the continents grew with time, did the masses of atmosphere and ocean grow also? Were the tectonic styles on the early earth markedly different from the now-familiar plate tectonics? What processes caused the growth and stabilization of continents? These questions are debated in the book. There is a consensus that earth accreted rapidly and therefore began its history with a hot, convecting interior. As a consequence, the volatiles of the ocean and the atmosphere were released from the interior of the earth at an early stage. The heat flow from the interior must also have been significantly higher when the earth was young, but how this high heat flow influenced global tectonics and the growth and development of the continents is not yet clear.

Other topics in earth history also receive attention. These include the impact on life, on the oceans and the atmosphere, and on climate of collisions with the earth by large extraterrestrial bodies, meteorites, or comets. Attention is given also to the accumulating evidence that significant and frequently rapid changes in the chemistry of the ocean (and presumably also of the atmosphere) took place during the most recent 600×10^6 years of earth history. Some of these changes may have been caused by biological innovation, but changing geography, a result of continental drift and plate tectonics, is the favored cause for most of the changes.

The book includes review papers, many of them exceptionally good, by individual authors, as well as four Group Reports presenting consensus views of current knowledge and questions for further study. The book presents a useful overview of recent advances in our understanding of earth history.

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Paleoclimatology

Milankovitch and Climate. Understanding the Response to Astronomical Forcing. A. BERGER, J. IMBRIE, J. HAYS, G. KUKLA, and B. SALTZMAN, Eds. Reidel, Boston, 1984 (distributor, Kluwer Boston, Hingham, Mass.). In two volumes. Vol. 1, xxxiv pp. + pp. 1–510, illus. Vol. 2, ix pp. + pp. 511–895, illus. The set, $117. NATO ASI Series C, vol. 126. From a workshop, Palisades, New York, Nov. 1982.

Palaeoclimatic Research and Models. A. GHAZI, Ed. Reidel, Boston, 1983 (distributor, Kluwer Boston, Hingham, Mass.). viii, 205 pp., illus. $34.50. From a workshop, Brussels, Dec. 1982.

Great strides have been made in quantitative paleoclimatology in the last 15 years. Every few years a book is published that summarizes another level in the development of the field. The most recent addition to this list is a two-volume set of about 50 papers from a conference on Milankovitch and climate.

The volumes address the role of orbitally induced insolation changes on the earth's past climates. The book is dedicated to an early champion of the theory—Serbian astronomer Milutin Milankovitch. Without explicitly saying so, the book is also a tribute to the most eloquent recent advocate of the Milankovitch effect—John Imbrie. As one of the leaders of the former CLIMAP project and the present SPECMAP project, and as a coauthor of a landmark paper, Imbrie has inspired a widespread search for evidence of an orbital effect on climate. The present book summarizes observational evidence and modeling results that bear on this relationship.

The observational part of the book mainly focuses on evidence of an orbital effect during the Pleistocene ice ages, although there is a valuable section on evidence of pre- Pleistocene cyclicity. In both cases, there seem to be cycles, cycles everywhere. There are several papers on rhythmic bedding in rocks spanning the last 200 million years. The sedimentary couplets have a characteristic time scale of tens of thousands of years, the same period as Milankovitch cycles. Further evidence from Pleistocene sections indicates that there was an orbital influence on lake levels, wind-blown dust variations, ocean currents, and the African-Asian monsoon. A contribution from the SPECMAP group (a consortium of scientists from Brown University, Lamont-Doherty Geological Observatory, and Oregon State University) indicates that orbital insolation changes account for as much as 85 percent of the variance in global ice volume