# Book Review

Frozen Earth: Explaining the Ice Ages by R. V. Fodor. Enslow Publishers, Hillside, N.J. 07205, 1981. 64 pages, $7.95.

Reviewed by Charles W. Burnham

Several times during the last million years glaciers and ice sheets have covered some 30% of the earth's land surface. The most recent of these ice ages ended rather abruptly between 6,000 and 10,000 years ago. Spectacular mountain cirques, deep valleys and fjords, countless deposits of debris in moraines, sand and gravel in ice contact regimes and outwash plains, thick sequences of silt and clay deposited on long-vanished glacial lake bottoms, and square mile upon square mile of glacial till all attest to the ubiquitous impact of Pleistocene ice advances over much of the northern North American and European landscapes. That ice sheets and glaciers were really responsible for these features has been generally accepted for a century and a half; before Louis Agassiz expounded his glacial theories in 1837 the scientific world held the prevailing view that glacial deposits were the work of floods or in some cases represented debris from melting icebergs. Those ideas were at least not inconsistent with Biblical teachings.

After rather rapid acceptance of the idea of ice ages - assisted in part by the discovery of the Greenland and Antarctic ice sheets, and by Agassiz's observations in New England - the geological responses to repeated advances and retreats of ice sheets of continental dimensions became well documented and quite clearly understood. Such is not the case, however, for the causes of ice ages. Major climate fluctuations clearly must be responsible for recurring advances and retreats of continental ice sheets, but what brings about such fluctuations?

Many theories have been put forward, but the one for which convincing scientific evidence has emerged during the past ten years - the "astronomical" theory - asserts that climate responds to changes in the amount of radiant energy reaching the earth from the sun brought about by (1) cyclic variations in the ellipticity of the earth's orbit around the sun with frequency of about 100,000 years, (2) cyclic precession of the earth's axis of rotation with frequency of about 22,000 years, and (3) oscillations in the degree of axial tilt between 22° and 25° with frequency of about 41,000 years.

In 1971 the National Science Foundation organized project CLIMAP, whose objective was to study climate changes on the earth over the past 700,000 years, spanning the bulk of the Pleistocene Epoch and including several distinct ice ages. In 1976 this group published a landmark paper (Hays, J. D., J. Imbrie, and N. J. Shackleton, Variations in the earth's orbit: Pacemaker of the Ice Ages, Science 194, 1121-1132, 1976) that ascertained climate variations during the Pleistocene from study of cores of sea-floor sediments and correlation of these with variations in the earth's orbital parameters. Soon afterward, Imbrie and his daughter published a book documenting the CLIMAP discoveries in the fuller context of the history of ideas about glaciology and ice ages (Imbrie, J., and K. P. Imbrie, Ice Ages: Solving the Mystery, Enslow Publishers, 1979). Frozen Earth is based entirely on that book, and has been written, according to the author, to present "these recent findings about ice ages in a form accessible to students."

This book is short and contains practically no technical language. Its 60 pages of text will be easily digested by inquisitive high school students in merely a few hours. It begins with a primer on glaciers and ice sheets, and outlines a brief history of the science of glacial geolo-

gy. Then it lays out some of the theories of the causes of ice ages (sun spots, volcanoes, lower atmospheric $CO_2$ content), and moves quickly to an explanation of earth orbital variations. It outlines the history of this "astronomical" theory and the nature of the geological evidence that was recently found to support it, primarily from studies of cores of oceanic sediments. Finally there is brief discussion of ice ages much older than Pleistocene, and comment about future climate changes. The observation that ice ages are not uniformly distributed throughout geologic time, as one might anticipate if their explanation were to lie wholly with variations in insolation, is dealt with in two pages setting out the additional requirement that land masses must exist at high latitudes. A very cursory introduction to plate tectonic theory and its explanations of motions of continents through time provide the rationale for concentration of ice ages into very limited periods of Earth history. A brief bibliography includes 15 references; interestingly six additional references at a more highly technical level are included only in the author's preface.

In only 60 pages Dr. Fodor has created a rather well-written but simplistic overview of today's ideas about Pleistocene climatic fluctuations and the consequent advances and retreats of continental ice sheets. The book will whet the minds of young (middle school, early high school) inquiring students. But, unfortunately, the simplifications have been, in some cases, overdone. Oxygen isotope measurements, which have been key ingredients in unravelling the mystery, are not suitably explained but are referred to as "examinations" of "the types of oxygen atoms present in seafloor fossils" (p. 47). Reversals of the Earth's magnetic field are only alluded to in one sentence dealing with the critical development of a Pleistocene time scale: "They (Hays & Opdyke of Columbia Univ.) combined a new understanding of the magnetic properties of seafloor material with knowledge about the magnetic field of the earth" (p. 50). Regarding the ice age climate: "For ice to have grown and covered great portions of the earth's surface, the climate of the earth must have been much colder than it is today" (p.25). How much colder we're not told, nor are we informed of the results of CLIMAP modeling of surface temperatures and ice extent for the Wisconsin ice age maximum 18,000 years ago.

Oversimplification and brevity normally have their virtues, but not in Dr. Fodor's highly dogmatic last few paragraphs on future climate. He speaks of the anticipated world-wide warming due to fossil-fuel combustion and the attendant increases in atmospheric $CO_2$ content as an "extension of our present interglacial time... marked by temperatures climbing like they never have before" (p. 58, underline mine). It seems to me that uncertainty about future climate, even given that $CO_2$ levels in the atmosphere are likely to double within the next century, is sufficiently great that a more equivocal approach would have been of greater service to young students likely to read this book. They will learn nothing of current attempts to understand more fully the climatic implications of ocean/atmosphere coupling and oceanic heat transport, to predict future climate with general circulation models, or to predict the effect of temperature changes on the extent of our major ice sheets. A final paragraph (p. 60) that, with no elaboration, says"... temperatures will rise 4 to 5 degrees Fahrenheit..." and "much of our present ice sheets will melt and raise the sea level" is not scientifically credible.

College students and upper-level high school students with some facility with science will get more satisfaction and sense of understanding from the longer but equally readable Ice Ages, Solving the Mystery, by Imbrie and Imbrie, which, after all, provided the impetus for Fodor's short, overly simplified version.

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