Letters

Earth's Early Atmosphere

J. F. Kasting and T. P. Ackerman (Reports, 12 Dec., p. 1383) present results of yet another computer-generated model for the evolution of the earth's atmosphere. The work indicates that, given certain starting assumptions, a dense CO_2 atmosphere could have coexisted with the oceans early in earth history. They conclude (i) that this result can be accomplished "without violating any known constraints on the planet's subsequent evolution" and (ii) that it precludes "the possibility of an oxygenic prebiotic atmosphere caused by photodissociation of water vapor followed by escape of hydrogen to space." These conclusions deserve comment.

There are at least two constraints that appear to have been left out of the model and presumably violated: (i) the development of a Precambrian ocean isotopically lighter in hydrogen than the mantle source rock from which it was presumed to have outgassed and (ii) the development and maintenance of some sort of atmospheric protection against the higher-than-present fluxes of solar ultraviolet radiation (necessary to mediate the origin of nucleic acids and allow a continuity in the evolution of life, especially photosynthetic life). The former demands a loss of photodissociated ocean water hydrogen to space. The latter can be best accomplished by means of a minimal ozone screen, something which the former could provide with the oxygen left over after hydrogen loss.

Changes in the ozone screen have been important in evaluating the radiation effects of nuclear winter or bolide impact scenarios on the oceanic plankton and to our own survival. The radiation factor should be at least as important in studies of the early earth—even more so in view of the higher ultraviolet fluxes involved. Computer-generated models could be designed explicitly to require that whatever photochemical changes take place in the early atmosphere over time, they be accomplished in such a way that the potentially lethal ultraviolet flux at the earth's surface is maintained at or below some value which would permit life to originate, proliferate, and diversify. This boundary condition may be considered on a par with such traditionally incorporated model requirements as ocean water temperatures above freezing but below boiling or initial silicate weathering rates rapid enough that carbonates can conveniently remove sufficient CO_2 in the time required to prevent a runaway greenhouse. If in the end all such computer models prove unstable, then the starting assumptions may need to be reconsidered. For example, early outgassing might be combined with the input of volatiles from cometary sources.

KENNETH M. TOWE
Department of Paleobiology, Smithsonian Institution, Washington, DC 20560

Response: Towe raises two objections to our model of a dense, CO_2 early atmosphere. The first is that the deuterium-to-hydrogen ratio in the present ocean is higher than in typical mantle materials (*1*). This is taken to imply the loss of large quantities of water, presumably by photodissociation in the atmosphere followed by escape of hydrogen to space. Preferential escape of the lighter isotope could account for the observed deuterium enrichment. According to Towe our model does not explain this phenomenon because the primitive stratosphere is predicted to be dry and, hence, the hydrogen escape rate from this process should have been low. However, we have not precluded the possibility that substantial quantities of hydrogen were lost by other mechanisms. One plausible example would be photostimulated oxidation of iron in the oceans (*2*) followed by escape of H_2. Furthermore, we specifically limited our model to the time period after the accretionary process had slowed down, that is, subsequent to the first 100 million years or so of Earth's history. During the accretion period itself a steam atmosphere is expected (*3*), and hydrogen should have been lost rapidly by the mechanism that Towe envisions.

The second point that Towe raises—the perceived requirement that the primitive earth possessed an ozone screen to protect early organisms from solar ultraviolet (UV) radiation—is a matter of opinion rather than of fact. For that matter it is an opinion that is not, to our knowledge, widely held among paleobotanists. An alternative viewpoint is presented in the discussion of the early evolution of life by Schopf *et al.* (*4*). Prokaryotic organisms are known to be more resistant to UV radiation than are eukaryotes. This observation is consistent with their having evolved in an earlier, higher UV environment. The proliferation and diversification of oceanic plankton between 2.5 and 1.5 billion years ago may have been related to a decrease in biologically harmful UV radiation during that time. Before the establishment of an ozone screen organisms may have protected themselves from irradiation by living under a protective layer of water, or soil, or the bodies of other organisms. Thus, along with many other workers, we believe that life could have evolved under a high UV flux. The absence of O_2 (and hence ozone) from the early atmosphere is furthermore often considered to have been essential in order for life to have originated in the first place (*5*). This latter requirement may be more fundamental than the one that Towe has suggested, in which case our model is in good accord with evolutionary constraints.

J. F. KASTING
T. P. ACKERMAN
Space Science Division, NASA Ames Research Center, Moffett Field, CA 94035

REFERENCES

1. M. Schidlowski, J. M. Hayes, I. R. Kaplan, in *Earth's Earliest Biosphere: Its Origin and Evolution*, J. W. Schopf, Ed. (Princeton Univ. Press, Princeton, NJ, 1983), chap. 7.
2. P. S. Braterman, A. G. Cairns-Smith, R. W. Sloper, *Nature (London)* **303**, 163 (1983).
3. T. Matsui and Y. Abe, *ibid.* **319**, 303 (1986).
4. J. W. Schopf, J. M. Hayes, M. R. Walter, in *Earth's Earliest Biosphere: Its Origin and Evolution*, J. W. Schopf, Ed. (Princeton Univ. Press, Princeton, NJ, 1983), chap. 15.
5. S. Chang, D. DesMarais, R. Mack, S. L. Miller, G. E. Strathearn, in: *ibid.*, chap. 4.

Novelty of "Supply-Side Ecology"

It is heartening to learn from Roger Lewin's 3 October article (Research News, p. 25) that intertidal ecologists and theoreticians are recognizing the importance of recruitment processes. Lewin writes that "[i]nterest in the potentially broad impact of the supply of new members to community dynamics has been developing . . . for at least half a dozen years. . . ." Without disputing the main points of the article, I feel compelled to point out that, even outside fishery science (where recruitment studies are the stock and trade), studies of larval abundance and settlement have been a mainstream endeavor ever since delay of metamorphosis was discovered over a half-century ago (*1, 2*) and T. C. Nelson (*3*) began correlating recruitment levels of oysters with abundances of larvae and their predators. Following the early thinking of Thorson (*4*), Wilson (*2*) and others, many British, Scandinavian, and Russian ecologists have consistently discussed the role of larval supply since the 1950s. Relative newcomers to the hoary field have boldly suggested that larval supply may influence populations of intertidal barnacles, even though literally dozens of papers have already been published on barnacle recruitment, including some classics of empirical fieldwork (*5*). A major assumption of one of the new models is that "[t]he rate of settlement per unit of unoccupied space is assumed to be determined by factors outside of the local system"