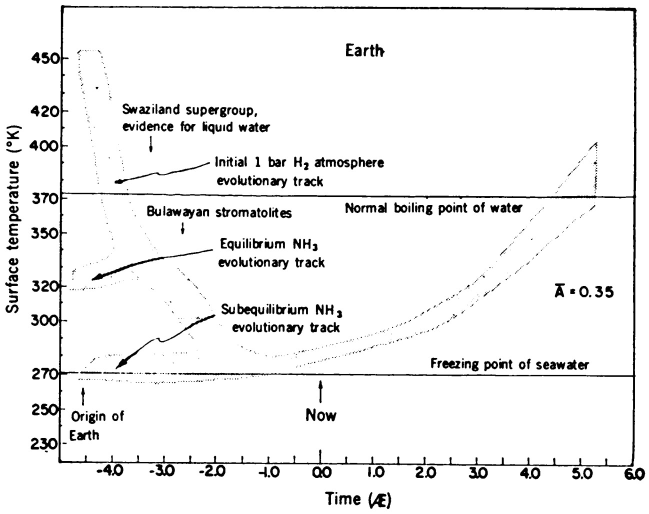
Earth's temperature: Life in a greenhouse



Thermal history of earth. Three branches at left correspond to the three possible beginnings.

Sagan and Mullen/Science

The temperature of a planet that has no significant internal heat source depends on the difference between the heat it gets from the sun and the heat it reradiates or reflects away. Thus the trapping of heat by any atmosphere the planet might have, the so-called greenhouse effect, becomes important. In fact, as new models for the temperature history of the earth and Mars published last week indicate, very small amounts of certain gases can mean the difference between life and death.

The work was done by Carl Sagan of Cornell University and George Mullen, now of Mansfield State College in Mansfield, Pa. It appears in the July 7 SCIENCE.

Historical models are needed because changes in the sun preclude the possibility that the thermal regimes of the planets have remained constant over aeons of time (one aeon is defined as a billion years). Astronomers believe that during geologic time the sun's brightness has increased by about 40 percent.

In past aeons, when the sun was not so bright, one would expect the planets were cooler than they are now. In fact, when Sagan and Mullen calculate backwards using the present composition of the earth's atmosphere, they arrive at the freezing point of seawater less than 2.3 aeons ago. However, there is evidence that life was present 3.2 aeons ago, and many paleobiologists believe life started 4 or 4.5 aeons ago. Life more or less implies liquid water. Furthermore there is stratigraphic evidence for liquid water 3.2 aeons ago. All in all, Sagan and Mullen conclude, the global mean temperature of the earth must have been between the freezing and boiling points of seawater, 270 to 370 degrees K., during most of its history.

To provide such temperatures at a time when the sun was less luminous than now requires a more efficient greenhouse effect than now operates. That means the presence of some atmospheric component not now present. After considering a number of possibilities, Sagan and Mullen suggest ammonia. A very small amount of ammonia, a few parts per million in the middle Precambrian atmosphere, would have done the job.

Sagan and Mullen present three possible scenarios for the evolution of the terrestrial atmosphere and temperature regime. All of them call for a greenhouse dominated by ammonia and water vapor in the early stages, which gradually evolves to the present water and carbon dioxide greenhouse as photodissociation and other chemical reactions do away with the ammonia.

On the first case, which the two authors do not recommend highly, the earth starts out with an atmosphere dominated by hydrogen and with temperatures in excess of the boiling point of water. The hydrogen escapes into space and the temperature drops rapidly until, about 3.5 aeons ago, the water-ammonia greenhouse takes over. In the other two cases, the earth starts out in the ammonia-water stage; the difference is whether the amount of ammonia starts out in equilibrium between the processes for producing it and the processes for destroying it or whether the ammonia starts in a subequilibrium amount.

Whatever the past has been, Sagan and Mullen see disaster in the earth's future. As the sun continues to brighten, earth's atmosphere will enter a runaway greenhouse stage. In about another 3 to 4.5 aeons the earth will have an atmosphere of steam with a pressure 300 times the present atmosphere.

There's hope, however, for any people that may survive then, and it lies on Mars. Being a smaller planet than earth, Mars has had more trouble holding heavy gases in its atmosphere and has therefore evolved faster. It went through a period in the first aeon of its existence when temperatures were near the freezing point of seawater, and life might have originated. Then it evolved rapidly to its present condition of aridity and severe temperature variations characterized by a very inefficient greenhouse effect. In the future, however, the same conditions that produce a runaway greenhouse on earth will produce clement conditions on Mars, and Sagan and Mullen suggest the survivors may wish to emigrate. □

A new class of astronomical objects

The astronomical universe consists of a rich variety of objects. Most of them are associated with each other in galaxies. Between the galaxies is mostly empty space, containing a few very important exceptional objects.

The first of these to be discovered were the quasars, objects that look like stars but have the energy output of galaxies and appear to lead an independent existence in intergalactic space. Observations of the quasars have raised cosmological questions of the first importance.

Now there appears to be a second exceptional class. The best name for these so far is compact extragalactic nonthermal sources, and the claim for their being "a new class of astronomical objects" is made in the July 1 ASTROPHYSICAL JOURNAL LETTERS by P. A. Strittmatter, K. Serkowski and R. Carswell of the University of Arizona, W. A. Stein of the University of California at San Diego and the University of Minnesota and K. M. Merrill and E. M. Burbidge of the San Diego campus.

The new class has four basic characteristics: rapid variations in the intensity of the output at radio, infrared and visual wavelengths; concentration of most of their energy emission in the infrared; absence of discrete lines in the spectra, and strong and rapidly varying polarization at visual and radio wavelengths. Five of these objects have so far been extensively studied: BL Lacertae, OJ 287, ON 231, ON 325 and PKS 1514—24.

The new class may be astrophysically related to the quasars, but how is not yet clear. The lack of spectral lines means that their distance is so far unknown, but if they are at the same distances as quasars are supposed to be, one of them, OJ 287, would be among the most luminous objects in the universe.