H. D. Holland (Princeton) proposed that reactions of the type chlorite + calcite + CO_2 = dolomite + kaolinite + quartz + water have exerted a considerable buffering effect on atmospheric CO_2 during much of geologic time. But he suggested that before the evolution of land plants the CO_2 content of the atmosphere was approximately 10 times greater than at present, and that the *p*H of ocean water was approximately one half of a *p*H unit lower. W. T. Holser (Chevron Oil Field Research Co.), after noting the deficiency of salt and gypsum deposits in the Precambrian, pointed out the difference between the ratios of S^{32} to S^{34} of late Precambrian evaporites and organic shales as evidence of activity of sulfate-reducing bacteria at that time. He presented the secular variation of ratios of S^{32} to S^{34} in evaporites, showing pronounced variations that he attributed to non-steady withdrawal and supply of isotopically light sulfides with respect to the oceanic reservoir. L. G. Sillén (Swedish Royal Institute of Technology) proposed an equilibrium model for the oceans based on free exchange between atmosphere, ocean and crust, and dominance of silicate equilibria in controlling oceanic *p*H and atmospheric CO_2. He used the nine-component system CO_2-H_2-O-CaO-MgO-Al_2O_3-K_2O-Na_2O-HCl-SiO_2 to present probable phase relations and emphasized equilibrium models as the most important first approximation of this complex system. P. K. Weyl (State University of New York, Stony Brook) hypothesized an oceanic density gradient layer (thermocline) at a depth near 100 meters in which life may have originated and evolved. This layer would have been protected from ultraviolet radiation fed by convective cells from the sea surface and the low rate of diffusion in the layer would have led to an early accumulation of free oxygen. G. Nicholls (University of Manchester, United Kingdom) sought to infer evolutionary changes in the composition of seawater by following a chain of calculations from terrestrial abundances of trace elements to the abundance of sodium in Precambrian sediments, which seem to be richer in sodium than later rocks. He explained the richness of nitrogen as the result of lack of chemical "winnowing" during sedimentation in the early Precambrian.

The last morning was devoted to questions related to the origin of life. C. Ponnamperuma (NASA Research Center, Ames, California) described a scheme for synthesis of organic compounds from H, C, N, and O; reviewed energy sources, ultraviolet being by far the most important; and attempted to develop criteria for biogenic origin of organic compounds. J. Oró (University of Houston) discussed the evolution of self-replicating proto-DNA and similar molecules from primitive organic compounds in the early Precambrian. He argued for the need for estimates of maximum and minimum permissible concentrations of necessary building materials, such as sulfur and phosphorus. L. Margulis (Boston University) distinguished between evolution of procaryotic and eucaryotic cells and emphasized the importance of free oxygen in the atmosphere as a precondition for the evolution of eucaryotic organisms, which probably took place later in the Precambrian. A. R. Palmer (State University of New York, Stony Brook) summarized worldwide distribution of Early Cambrian faunas and concluded that shelled representatives of the major phyla and of many minor groups within the phyla all appeared within about 5 million years, but significantly later than the first records of metazoans without shells.

Discussion of papers was spirited and it appeared that there was no general agreement on the types of models to be used for the evolution of the earth's crust or for the evolution of the oceans or atmospheres. Equilibrium models vied with complex feedback mechanisms for support. The rock record was invoked to support many models but our current ways of looking at it seem not to provoke convergence to a unique solution. There was more general agreement that much of the Precambrian rock record showed no great differences from later rock sections in gross aspect. It seems that the general earth surface system, including the presence of primitive life, was established by 3.5 billion years ago, leaving only the first billion years of the earth's history for many significant events to have taken place. In the absence of any rock record of that first billion years, it may be that organic chemical investigations of the first steps in the formation of prebiogenic compounds and then the evolution of the first cell will prove to be the best guides to the nature of the physical and chemical environment of the earliest stage of earth history.

RAYMOND SIEVER
Department of Geological Sciences,
Harvard University,
Cambridge, Massachusetts 02138