Conference on Early Mars, Houston, Texas, 1997 April 24–27

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The Antarctic meteorite Allan Hills 84001 may be at the center of a revolution in our thinking about the origin of life on Earth, Mars and perhaps elsewhere. This is not because of the attention given by non-scientists to last summer's paper on this meteorite, but because it has forced a reexamination of the importance of microbes in the eco-system, the nature of the smallest possible life forms, the nature of organic materials and structures that led to the origins of life and the temperature regime at which life originated.

A major theme of the Conference on Early Mars: Geologic and Hydrologic Evolution, Physical and Chemical Environments, and the Implications for Life, concerned early planetary environments and their compatibility for life. Early conditions on Mars and Earth were quite different from now. Accretionary heating produced magma oceans and core formation, impact and other processes wreaked havoc, and the atmospheres probably underwent several episodes of change. The change in the atmosphere of the Earth from mildly reducing to oxidizing can be followed in the rock and soil record. The geological record on Earth is highly fragmentary, and Paul Hoffman pointed out that Mars probably retains the better record of its early history. All these processes were discussed in review papers by Paul Hoffman, Heinrich Holland, Ann Vickery and Gerald Schubert.

The evidence for major changes in the surface environment of Mars are the Valley Networks and denuded craters in the highlands that indicate considerable water and/or ice flow over the early surface of the planet. Perhaps the water was in the form of lakes, rivers and glaciers that were part of an active water cycle on a warm wet surface of Mars as argued by Tim Parker, Alan Howard and Bruce Jakovsky. Ways to remove such an ancient atmosphere are not difficult to envisage, although creating such an atmosphere might have been difficult. Perhaps the planet was always cold and dry, much like now, with episodic excursions of water over the surface triggered by volcanoes or by impact heating. Such a scenario was favored by Robert Haberle, Michael Carr and James Kasting. Stephen Clifford described a whole martian hydrogeology while the complex history of C, H, N, O, P and S in the atmosphere, hydrosystem and soil was described by Benton Clark, Christopher Chyba, Laura Griffith and James Gooding. Whether the surface was cold and dry (with short-lived aqueous events) or wet and warm (with long-term lakes and rivers) went unresolved. Heinrich Holland suggested that since photogeologic evidence is not leading to a consensus, we should set the issue aside pending better remote sensing data of the sort Roger Clark described, wherein spectra are used to define high-resolution compositional maps, and sample return and manned missions to Mars. The numerous upcoming spacecraft missions to Mars were briefly reviewed at the meeting by Wendy Calvin. Confirmation or exclusion of massive evaporite deposits may be possible with these missions and may help test the models of an early warm, wet Mars. However, the idea that life might have evolved on Mars in highly localized environments created by episodic outbursts of water and energy struck a familiar chord with those interested in life on Earth.

Ribonucleic acid-typing has caused a revolution in microbiology, and this was described by Anna-Louis Reysenback. The "tree of life" no longer has three major branches culminating in plants, animals and fungi, with lowly bacteria somewhere near the trunk, but the tree now consists of bacteria, archae and eucaryotes with plants, animals and fungi at the outermost twigs of one of the minor branches. Placed near the juncture of the branches, as best can be judged, is a variety of bacteria that are adapted to high temperatures—the thermophiles. Several authors were enlisted to describe the bacteria adapted to these "extreme environments." Beverly Pierson described some of the diversity, Carol Litchfield stressed that many bacteria can survive remarkably high salinity levels, while Todd Stevens described subsurface conditions and suggested that some bacteria could survive current martian subsurface conditions. E. Imre Friedmann described bacteria that live inside rock, some actually digesting the rocks. Suddenly it seemed that—contrary to the views of almost a century that life formed on the surface of the planet—life may have begun in environments closely resembling submarine volcanic vents ("smokers"). The discussion also included fossil bacteria, the problems and opportunities being reviewed by Jack Farmer. One day of the meeting was devoted to examining these ideas and the fascinating chemistry involved in providing the high energy required to fight the entropy opposing the formation of life. As Sherwood Chang pointed out, it was clearly a complex process, involving the construction of membranes to isolate the system from the environment, setting up a process for metabolism and discovering a means of replication. Our views on the origin of life on Earth and the conditions under which it formed have evolved enormously in the last 25 years and no doubt will evolve similarly in the next 25.

Enormous amounts of data were presented at the meeting, mostly elaborating on these central themes, and there were nearly 60 posters. It is an exciting and challenging business, not least of all because it is so highly multidisciplinary. A stream of heroic session chairmen struggled to introduce each speaker and topic to an audience mostly unfamiliar with each other and each other's work. Good chairmen were there. Benton Clark placed an overhead on the projector entitled "Evidence against life on Mars" and skillfully facilitated over an hour of productive discussion.

A debate on the final day, about whether ALH 84001 harbors remnants of martian life, did not resolve the issues, and several of the brave participants expressed discomfort with the debate format, arguing that it promotes polarizing the argument instead of dispassionate (or less passionate) analysis. A major theme that emerged from the four "con" speakers was that ALH 84001 was contaminated with terrestrial carbonates and organics. The four "pro" speakers refuted this with evidence of a relative lack of those materials on the surface crust. Perhaps because of the polarization of the debate, little attention was paid to the question of whether the 20 nm structures could represent not fully functioning microbes but important non-living prebiotic structures, such as membrane-defined structures, on the road to life.

Isotopic data for the martian meteorites were used by Robert Haberle to argue for the loss of an early atmosphere, and Michael Drake and Allan Trieman showed how bulk compositions of the martian meteorites are feeding ideas about a magma ocean and core formation and the composition of the highlands. But the idea that the carbonates in Allan Hills 84001 might be of high-temperature origin and that this would point to the importance of localized hot spots triggering hydrothermal processes on Mars was not really discussed. It should not surprise us that many experts on Mars seem hesitant to infer much about Mars from the SNC meteorites. After all, it is only a few years since meteorite experts came to agreement on this, and there are still doubters. Emil Jagoutz is to be praised for daring to argue, in his poster, that SNCs are not martian. All too often our community comes to a premature consensus, and Allan Hills 84001 was considered a diogenite for more years than it has been considered martian. It is important when discussing meteorite data with experts in other fields to stress the strengths and weakness of our conclusions. Workshops like this one are essential to the process, especially when so well planned and executed.

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