Publications of the Exobiology Program for 1989

A Special Bibliography

The George Washington University
Washington, D.C.

and

NASA Office of Space Science and Applications
Washington, D.C.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>COSMIC EVOLUTION OF BIOGENIC COMPOUNDS</td>
<td>4</td>
</tr>
<tr>
<td>PREBIOTIC EVOLUTION</td>
<td>12</td>
</tr>
<tr>
<td>EARLY EVOLUTION OF LIFE</td>
<td>24</td>
</tr>
<tr>
<td>EVOLUTION OF ADVANCED LIFE</td>
<td>34</td>
</tr>
<tr>
<td>SOLAR SYSTEM EXPLORATION</td>
<td>36</td>
</tr>
<tr>
<td>SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE (SETI)</td>
<td>44</td>
</tr>
<tr>
<td>PLANETARY PROTECTION</td>
<td>48</td>
</tr>
<tr>
<td>GENERAL</td>
<td>50</td>
</tr>
<tr>
<td>ADDENDUM</td>
<td>52</td>
</tr>
<tr>
<td>APPENDIX: Principal Investigators</td>
<td>56</td>
</tr>
</tbody>
</table>
INTRODUCTION

The Exobiology Program, within the Office of Space Science and Applications of the National Aeronautics and Space Administration, is an integrated program designed to investigate those processes that may have been responsible for or related to the origin, evolution, and distribution of life in the universe.

This report contains a listing of 1989 publications resulting from research supported by the Exobiology Program. Our intent in compiling this report is twofold: We want to provide the scientific community with an annual publication listing (as we have done since 1975) of current NASA-supported research in this field, and we hope to stimulate the exchange of information and ideas among scientists working in the different areas of the program.

Research supported by the Exobiology Program is explored in the areas of Cosmic Evolution of Biogenic Compounds, Prebiotic Evolution, Early Evolution of Life, and Evolution of Advanced Life. Pre-mission and pre-project activities supporting these areas are supported in the areas of Solar System Exploration and Search for Extraterrestrial Intelligence. The Planetary Protection subject area is included here because of its direct relevance to the Exobiology Program.

EACH AREA IS DEFINED AS FOLLOWS:

**COSMIC EVOLUTION OF BIOGENIC COMPOUNDS** focuses on the history of the biogenic elements (C,H,N,O,P,S) and their compounds in the galaxy and the early solar system. This includes: (1) tracing the physical and chemical pathways taken by the biogenic elements and their compounds from their origins in stars to their incorporation in the pre-planetary bodies; (2) determining the kinds of measurements that can be made on the biogenic elements and compounds in the galaxy and solar system and prebiotic evolution and origin of life; and (3) determining the ways in which the physical and chemical properties of the biogenic elements and compounds may have influenced the course of events during the formation of the solar system and the component bodies.

**PREBIOTIC EVOLUTION** involves research and analysis in two major areas: (1) the consequences of planetary evolution on the physical environment of the Earth and planets, and (2) the evolution of molecules and molecular systems under the constraints imposed by the physical environment and the appearance, a posteriori, of living systems on Earth. It also assesses the importance of the physical-chemical processes associated with the dynamic development of planetary surfaces.

**EARLY EVOLUTION OF LIFE** focuses on the nature of the most primitive organisms, determining the environment in which they evolved, and the way in which they influenced that environment. Investigations are executed through the use of the molecular record in living organisms and the geological record in rocks. These records are used to determine when and in what setting life first appeared; to determine the characteristics of the first successful living organisms; to understand the phylogeny and physiology of microorganisms that inhabit hydrothermal areas now thought to be analogs of primitive environments; to determine the original nature of biotic energy transduction, membrane function, and information processing through study of extant microbes; and to elucidate the physical, chemical, and biotic forces operating on microbial evolution.
EVOLUTION OF ADVANCED LIFE examines the influence of astrophysical, stellar and solar system events on the evolution of advanced life on Earth. Research in this area attempts to understand possible evolutionary pathways for advanced life and to develop a program plan for a paleontological data base.

SOLAR SYSTEM EXPLORATION focuses on providing specific information on the elemental and chemical composition, mainly with respect to gases and volatiles, of the atmospheres and surfaces of solar system bodies, including planets and their satellites, comets, asteroids, meteorites, and dust in space. Improved methods, instrumentation, and experiments will be developed for in situ chemical analyses of the volatile species associated with the bodies to be investigated.

SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE (SETI) involves the search for extraterrestrial intelligent life by detecting signals in the electromagnetic spectrum. Principal emphasis has been on technology development for the microwave observing project.

PLANETARY PROTECTION focuses on environmental protection of planets of biological interest from potentially harmful contamination from terrestrial sources during future exploration, based on explicit guidelines established for each planet and for each type of mission. It also focuses on protection of the Earth from potential hazards posed by returned sample missions.

This bibliography is divided into the areas noted above. Within each research area, references are listed alphabetically by author. Authors who are Principal Investigators are identified by an asterisk. In addition, current addresses for all Principal Investigators are given in the Appendix.

We wish to thank all the participants in the Exobiology Program for their cooperation in responding to our request for a listing of their 1989 publications. We also wish to thank Janice Wallace-Robinson and F. Ronald Dutcher for their editorial and technical assistance and Audrey Brown and Stephen Szibler for their technical assistance.

John D. Rummel
Exobiology Program Manager
March, 1991
COSMIC EVOLUTION OF BIOGENIC COMPOUNDS

*In situ* investigations.


Allamandola*, L.J.; Bregman; J.D.; Sandford, S.A.; Tielens, A.G.G.M.; Witteborn, F.C.; Wooden, D.H.; Rank, D.
The discovery of a new infrared emission feature at 1905 wavenumbers (5.25 microns) in the spectrum of BD + 30° 3639 and its relation to the polycyclic aromatic hydrocarbon model.


Allamandola*, L.J.; Tielens, A.G.G.M.


Allamandola*, L.J.; Tielens, A.G.G.M.; Barker, J.R.


Thermal evolution of Comet P/Tempel 1: Representing the group of targets for the CRAF and CNSR missions.


Bar-Nun, A.; Kleinfeld, I. (Owen, T. = P.I.)

On the temperature and gas composition in the region of comet formation.


Blake*, D.; Fleming, R.H.; Bunch*, T.E.

Identification and characterization of a carbonaceous, titanium containing interplanetary dust particle (Abstract).


Blake*, D.F.

Analytical electron microscopy of biogenic and inorganic carbonates (Abstract).


The infrared emission bands. II. A spatial and spectral study of the Orion Bar.


The 3.4 micron emission in comets.

Brownlee, D.; Bunch*, T.; Chang*, S.; Kerridge*, J.; Wolfe, J.
Cosmic dust collection.

Chang*, S.
Studies of samples returned from a comet nucleus by the Rosetta Mission (Abstract).

Tielens, A.G.G.M.; Rank, D.M.; de Muizon, M.
Airborne observations of the infrared emission bands.

Allamandola*, L.J.; Wooden, D.H.; de Muizon, M.
The infrared emission bands. III. Southern IRAS sources.

Allamandola*, L.J.
Airborne observations of the infrared emission bands.

Cronin*, J.R.
Amino acids and bolide impacts.

Cronin*, J.R.
Analysis of organic compounds in returned comet nucleus samples.
In: *Workshop on Analysis of Returned Comet Nucleus Samples, Milpitas, CA, January 16-18, 1989*, p. 16-17. (GWU 11404)

Cronin*, J.R.
Origin of organic compounds in carbonaceous chondrites (Abstract).

Cronin*, J.R.
Origin of organic compounds in carbonaceous chondrites.
*Advances in Space Research* 9(2): 59-64, 1989. (GWU 11405)

DeFrees*, D.J.; McLean, A.D.
A priori predictions of the rotational constants for HC$_3$N, HC$_{13}$N, C$_5$O.
DeFrees*, D.J.; Miller, M.D.
The effect of ionization on the infrared absorption spectra of PAHs: A preliminary report.

Freund, F.; Batlo, F.; Freund, M.M. (Bunch, T.E. = P.I.)
Dissociation and recombination of positive holes in minerals.
In: *Spectroscopic Characterization of Minerals and Their Surfaces* (Coyne, L.M.,
310-329, 1989. (GWU 11598)

Spatial variations of the 3 micron emission features within UV-excited nebulae:
Photochemical evolution of interstellar polycyclic aromatic hydrocarbons.

Gibson*, E.K., Jr.; Carr, R.H.
Laser microprobe-quadrupole mass spectrometer system for the analysis of gases and
volatiles from geologic materials.
In: *New Frontiers in Stable Isotopic Research: Laser Probes, Ion Probes, and Small-
Sample Analysis* (Shanks, W.C., III, Criss, R.E., Eds.). Denver, CO: U.S. Geological
Survey, p. 35-49, 1989. (GWU 11474)

Gibson*, E.K., Jr.; Hartmetz, C.P.; Blanford, G.E.
Analysis of interplanetary dust particles for volatiles and simple molecules (Abstract).

Grady, M.M.; Gibson*, E.K., Jr.; Wright, I.P.; Pillinger, C.T.
The formation of weathering products on the LEW 85320 ordinary chondrite: Evidence
from carbon and oxygen stable isotope compositions and implications for carbonates in
SNC meteorites.

Hartmetz, C.P.; Blanford, G.E.; Gibson*, E.K., Jr.
*In situ* analysis of volatile elements and molecules in carbonaceous chondrites (Abstract).

Hartmetz, C.P.; Gibson*, E.K., Jr.
*In situ* determination of volatiles in CM2 chondrites (Abstract).
*Meteoritics* 24: 275, 1989. (GWU 11472)

Hartmetz, C.P.; Gibson*, E.K., Jr.; Socki, R.A.
Total carbon and sulfur abundances in Antarctic carbonaceous chondrites, ordinary
chondrites, and eucrites (Abstract).

Herbst, E.; DeFrees*, D.J.; Koch, W.
Can interstellar H₂S be formed via gas-phase reactions? Calculations concerning the rates
of the ternary and radiative association reactions between HS⁺ and H₂.
(GWU 11411)
Herbst, E.; Winnewisser, G.; Yamada, K.M.T.; DeFrees*, D.J.; McLean, A.D.
*Ab initio* determination of mode coupling in HSSH: The torsional splitting in the first excited S-S stretching state.
*Journal of Chemical Physics* 91(10): 5905-5909, 1989. (GWU 11413)

Irvine*, W.M.
Microwave spectroscopy of astrophysical molecules.
*Highlights of Astronomy* 8: 339-343, 1989. (GWU 11633)

Irvine*, W.M.
Observational astrochemistry: Recent results.
*Advances in Space Research* 9(2): 3-12, 1989. (GWU 9005)

Observations of some oxygen-containing and sulfur-containing organic molecules in cold dark clouds.

Irvine*, W.M.; Knacke, R.F.
The chemistry of interstellar gas and grains.

Knacke, R.F.; Kim, Y.H.; Irvine*, W.M.
An upper limit to the acetylene abundance toward BN in the Orion molecular cloud.

Koch, W.; Liu, B.; DeFrees*, D.J.
Structure of the 2-norbomyl cation.
*Journal of American Chemical Society* 111: 1527-1528, 1989. (GWU 11644)

Koch, W.; Liu, B.; DeFrees*, D.J.; Sunko, D.E.; Vancik, H.
Experimental and theoretical IR spectra of the 2-norborynl cation.

Koch, W.; Liu, B.; Scheiner, A.C.; DeFrees*, D.J.
Adaptation and vectorization of the Gaussian 86 quantum chemical program for the IBM 3090 with vector facility.

Krishna-Swamy, K.S.; Sandford, S.A.; Allamandola*, L.J.; Witteborn, F.C.; Bregman, J.D.
The nature of cometary dust as determined from infrared observations.
Krishna-Swamy, K.S.; Sandford, S.A.; Allamandola*, L.J.; Witteborn, F.C.; Bregman, J.D.
Infrared emission from comets.

Lumme, K.; Peltoniemi, J.I.; Irvine*, W.M.
Derivation of an average single particle phase function for the lunar regolith (Abstract).

Madden, S.C.; Irvine*, W.M.; Matthews, H.E.; Friberg, P.; Swade, D.A.
A survey of cyclopropenylidene (C₃H₂) in galactic sources.

Minh, Y.C.; Irvine*, W.M.; Ziurys, L.M.
Detection of interstellar hydrogen sulfide in cold, dark clouds.

Spatial variations of the 3 μm emission features within nebulae.

Muinonen, K.; Lumme, K.; Irvine*, W.M.
Statistical photoclinometry and surface topography of atmosphereless bodies (Abstract).

Peltoniemi, J.I.; Lumme, K.; Muinonen, K.; Irvine*, W.M.
Scattering of light by stochastically rough particles.

Sandford, S.A. (Allamandola, L.J. = P.I.)
Interstellar dust in collected interplanetary dust particles.

Sandford, S.A.; Bradley, J.P. (Allamandola, L.J. = P.I.)
Interplanetary dust particles collected in the stratosphere: Observations of atmospheric heating and constraints on their interrelationships and sources.
Icarus 82: 146-166, 1989. (GWU 11591)

Schutte, W.; Greenberg, M. (Allamandola, L.J. = P.I.)
The evolution of organic mantles on interstellar grains.

Theoretical studies of the infrared emission from circumstellar dust shells: The infrared characteristics of circumstellar silicates and the mass-loss rate of oxygen-rich late-type giants.
Schwartz, P.R.; Snell, R.L.; Schloerb, F.P. (Irvine, W.M. = P.I.)
1300 micron continuum and C^{18}O line mapping of giant molecular cloud cores. II. W3,
NGC 2264, NGC 63341, RHO Ophiuchi and S140.

Tielens, A.G.G.M. (Allamandola, L.J. = P.I.)
Dust in dense clouds.
Kluwer, p. 239-262, 1989. (GWU 11385)

Tielens, A.G.G.M.; Allamandola*, L.J. (Eds.)
*Interstellar Dust: Contributed Papers*. Moffett Field, CA: NASA, Ames Research Center,

Van Der Zwet, G.P.; Allamandola*, L.J.; Baas, F.; Greenberg, J.M.
Infrared spectrum of the complex of formaldehyde with carbon dioxide in argon and
nitrogen matrices.

Witteborn, F.C.; Sandford, S.A.; Bregman, J.D.; Allamandola*, L.J.; Cohen, M.;
Wooden, D.
Spectral structure near the 11.3 micron emission feature.
(GWU 11590)

Witteborn, F.C.; Sandford, S.A.; Bregman, J.D.; Allamandola*, L.J.; Cohen, M.;
Wooden, D.H.; Graps, A.L.
New emission features in the 11-13 micron region and their relationship to polycyclic
aromatic hydrocarbons.

Yonover, R.N.; Sinton, J.M.; Sommer, M.A.; Gibson*, E.K.
C-O-H ratios in silicate melt inclusions in basalts from the Galapagos Spreading Center
near 95°W: A laser decrepitation mass spectrometry study.

Ziurys, L.M.; Friberg, P.; Irvine*, W.M.
Interstellar SiO as a tracer of high-temperature chemistry.

Ziurys, L.M.; Snell, R.L.; Dickman, R.L. (Irvine, W.M. = P.I.)
Shock chemistry in the molecular clouds associated with SNR IC 443.
Armangue, G.; Mills, T.; Oro*, J.
Non-enzymatic oligomerization of dAMP and GTP and the condensation effects played by GTP (Abstract).

Arrehnious*, G.; Bachman, J.; Gedulin, B.; Hui, S.; Paplawsky, W.
Anion selective minerals as concentrators and catalysts for RNA precursor components (Abstract).

Chyba, C.; Sagan*, C.
The pre- and post-accretion irradiation history of cometary ices.

Chyba, C.F.; Sagan*, C.; Brookshaw, L.; Thomas, P.J.
Impact delivery of prebiotic organics to early Earth (Abstract).

Chyba, C.F.; Sagan*, C.; Mumma, M.J.
The heliocentric evolution of cometary infrared spectra: Results from an organic grain model.
*Icarus* 79: 362-381, 1989. (GWU 11317)

Coyne*, L.M.; Banin, A.; Carle*, G.; Orenberg, J.; Scattergood*, T.
Use of near infrared correlation spectroscopy for quantitation of surface iron, absorbed water and stored electronic energy in a suite of Mars soil analog materials (Abstract).

Coyne*, L.M.; Bishop, J.; Howard, L.; Banin, A.
Use of near infrared correlation spectroscopy to characterize and quantify surface water in variably Ca/Fe exchanged montmorillonite clays (Abstract).
In: *Program and Abstracts, California Catalysis Society Spring Meeting*, Stanford University, Palo Alto, CA, April 6-7, 1989, 2 p. (GWU 10167)

Coyne*, L.M.; Bishop, J.L.; Scattergood*, T.; Banin, A.; Carle*, G.; Orenberg, J.
Near-infrared correlation spectroscopy: Quantifying iron and surface water in a series of variably cation-exchanged montmorillonite clays.

Coyne*, L.M.; Costanzo, P.M.; Theng, B.K.G.
Luminescence and ESR studies of relationships between O*-centres and structural iron in natural and synthetically hydrated kaolinites.

Coyne*, L.M.; McKeever, S.W.S.
Spectroscopic characterization of minerals and their surfaces.
Coyne*, L.M.; McKeever, S.W.S.; Blake*, D.F. (Eds.)

Deamer*, D.W.

Deamer*, D.W.; Harang, E.A.; Seleznev, S.A.

Deamer*, D.W.; Pashley, R.M.
Amphiphilic components of the Murchison carbonaceous chondrite: Surface properties and membrane formation.

Ertem, G.; Agarwal, V.; Ferris*, J.P.
The binding and clay mineral catalysis of the formation of oligomers of 5'-AMP in aqueous solution (Abstract).

Ertem, G.; Ferris*, J.P.; Holm, N.G.
Adsorption of mono- and polynucleotides on iron oxide hydroxide polymorphs (Abstract).

Ordovician paleosols at Arisaig, Nova Scotia, and the evolution of the atmosphere.

Ferris*, J.P.; Ertem, G.; Agarwal, V.
Mineral catalysis of the formation of dimers of 5'-AMP in aqueous solution: The possible role of montmorillonite clays in the prebiotic synthesis of RNA.

Ferris*, J.P.; Ertem, G.; Agarwal, V.K.
The adsorption of nucleotides and polynucleotides on montmorillonite clay.

Ferris*, J.P.; Ertem, G.; Kamaluddin; Agarwal, V.; Hua, L.L.
Mineral catalysis of the formation of the phosphodiester bond in aqueous solution: The possible role of montmorillonite clays.

N-cyanoimidazole and diimidazole imine: Water-soluble condensing agents for the formation of the phosphodiester bond.
Ferris*, J.P.; Ishikawa, Y.; Rahman, K.
Photolysis of ammonia in the presence of acetylene. A plausible explanation for the formation of HCN and chromophores on Jupiter (Abstract).

Ferris*, J.P.; Kamaluddin
Oligomerization reactions of deoxyribonucleotides on montmorillonite clay: The effect of mononucleotide structure on phosphodiester bond formation.

RNA oligomer synthesis on mineral surfaces: Structural factors which influence oligomer formation on montmorillonite (Abstract).

Ferris*, J.P.; McCain, P.J.; Mendoza-Gomez, C.X.; Briggs, R.; Schutte, W.; Greenberg, J.M.; Ertem, G.
Photochemical reactions on interstellar grains (Abstract).

Finney, S.A., Lt.; Tonks, W.B.; Melosh*, H.J.
Statistical evolution of impact ejecta from the Earth: Implications for transfer to other solar system bodies (Abstract).

Fox*, S.W.
The changing face of natural selection.

Fox*, S.W.
From non-random molecular structure to life and mind.
*Journal of Molecular Structure (Theochem)* 199: 183-188, 1989. (GWU 11456)

Fox*, S.W.
Selfsequencing of amino acids: Prebiotic source of biological information (Abstract).

Molecular structure of an A-DNA decamer d(ACCGGCGGCT).

Greenberg, J.M.; Zhao, N.; Hage, J. (Ferris, J.P. = P.I.)
Chemical evolution of interstellar dust, comets and the origins of life.
*Annales de Physique* 14: 103-131, 1989. (GWU 11448)

Guillemin, J.C.; Ferris*, J.P.
Photochemical cycloaddition of cyanoacetylene and dicyanoacetylene (Abstract).
Harada, K.; Orgel*, L.
Oligomerization of 5'-deoxy-5'-nucleosideacetic acid derivatives (Abstract).

Holland*, H.D.; Feakes, C.R.
Paleosols and their relevance to precambrian atmospheric composition: A discussion.
*Journal of Geology* 97: 761-762, 1989. (GWU 11483)

Holland*, H.D.; Feakes, C.R.; Zbinden, E.A.
The Flin Flon paleosol and the composition of the atmosphere 1.8 BYBP.

Honda, Y.; Navarro-González, R.; Ponnampерума*, C.
Chemical yields of biologically important compounds from electric discharges (Abstract).

Honda, Y.; Navarro-González, R.; Ponnamperuma*, C.
A quantitative assay of biologically important compounds in simulated primitive Earth experiments.

Johnson, G.A.; Máñquez, C.; Middleditch, B.S.; Zlatkis, A.; Oró*, J.
Aliphatic hydrocarbons obtained from iron carbides: Possible stellar and meteoritic implications (Abstract).

Kanavarioti*, A.; Bernasconi, C.F.; Doodokyan, D.L.; Alberas, D.
Magnesium ion catalyzed P-N bond hydrolysis in imidazolide-activated nucleotides. Relevance to template-directed synthesis of polynucleotides (Abstract).

Kanavarioti*, A.; Bernasconi, C.F.; Doodokyan, D.L.; Alberas, D.J.
Magnesium ion catalyzed P-N bond hydrolysis in imidazolide-activated nucleotides. Relevance to template-directed synthesis of polynucleotides.
*Journal of the American Chemical Society* 111: 7247-7257, 1989. (GWU 11492)

Kanavarioti*, A.; Chang*, S.
Limiting concentrations of activated mononucleotides necessary for template-directed oligonucleotide elongation (Abstract).

Kerridge*, J.F.
deuterium enrichments and synthesis of meteoritic organic matter (Abstract).

Kerridge*, J.F.
Interstellar molecules in meteorites.

Kerridge*, J.F.
Synthesis of meteoritic organic matter in an asteroid (Abstract).
Kerridge*, J.F.; Mariner, R.; Flores, J.; Chang*, S.

Khare*, B.N.; Sagan*, C.; Thompson, W.R.; Flynn, L.; Morrison, M.A.

Khare*, B.N.; Thompson, W.R.; Chyba, C.F.; Arakawa, E.T.; Sagan*, C.
Organic solids produced from simple C/H/O/N ices by charged particles: Applications to the outer solar system.

Khare*, B.N.; Thompson, W.R.; Murray, B.G.J.P.T.; Chyba, C.F.; Sagan*, C.

Kobayashi, K.; Hare, P.E.; Ponnamperuma*, C.
Analysis of sugars in the products of spark discharge in simulated primitive atmospheres by GC-MS. (Japanese)

Kuma, K.; Paplawsky, W.; Gedulin, B.; Arrhenius*, G.
Mixed-valence hydroxides as bioorganic host minerals.

Lacey*, J.C., Jr.; Staves, M.P.
Did an ancestor of both 5S ribosomal RNA and transfer RNA function as a universal translator? (Abstract)

Lacey*, J.C., Jr.; Thomas, R.D.; Staves, M.P.; Minic, V.; Watkins, C.L.
Purine monoribonucleotides may preferentially catalyze the synthesis of L-amino acid peptides (Abstract).

Lazcano, A.; Gariglio, J.; Orozco, E.; Oro*, J.
On the early evolution of reverse-transcriptase (Abstract).

Lazcano, A.; Llaca, V.; Fox*, G.E.; Oro*, J.
A classification of RNA polymerases based on their evolutionary relatedness (Abstract).

Levine*, J.S.
Planetary atmospheres.
MacElroy*, R.D.; Morowitz, H.; Pohorille, A.
Ion transport mechanisms and prebiotic membranes (Abstract).

Mar, A.; Oró*, J.
Synthesis of the coenzymes, ADPG, GDPG, and CDP-ethanolamine under primitive Earth conditions (Abstract).

McDonald, J.J.; Rein*, R.
Molecular modeling of calmodulin: A comparison with crystallographic data (Abstract).
Abstract of paper presented at the Sanibel Symposia, St. Augustine, FL, April 1-8, 1989, 1 p. (GWU 11562)

McDonald, J.J.; Rein*, R.
Molecular modeling of calmodulin: A comparison with crystallographic data (Abstract).

Mendis, D.A.; Arrhenius*, G.
Electrodynamic control in planetesimal accretion.

Molecular and mass spectroscopic analysis of isotopically labeled organic residues.

Michelangeli, D.V.; Allen, M.; Yung*, Y.L.
El Chichon volcanic aerosols: Impact of radiative, thermal, and chemical perturbations.

Miller*, S.L.; Bada, J.L.; Friedmann, N.
What was the role of submarine hot springs in the origin of life? (Abstract)

The γ-irradiation of aqueous hydrogen cyanide in the presence of ferrocyanide or ferricyanide: Implications to prebiotic chemistry.

Clay-mediated decarboxylation of acetic acid. The role of radiation heterogeneous catalysis in prebiotic chemistry (Abstract).
Oberbeck, V.R.; Fogleman, G. (Carle, G.C. = P.I.)
Effect of the late heavy bombardment of the terrestrial planets on chemical evolution on Earth and Mars (Abstract).

Oberbeck, V.R.; Fogleman, G. (Carle, G.C. = P.I.)
Estimates of the maximum time required to originate life.

Oberbeck, V.R.; Fogleman, G. (Carle, G.C. = P.I.)
Impacts and the origin of life.

Oberbeck, V.R.; McKay*, C.P.; Scattergood*, T.W.; Carle*, G.C.; Valentin*, J.R.
The role of cometary particle coalescence in chemical evolution.

Orgel*, L.E.
Abiogenic synthesis of polynucleotides (Abstract).

Orgel*, L.E.
The origin of polynucleotide-directed protein synthesis.
*Journal of Molecular Evolution* 29: 465-474, 1989. (GWU 11535)

Orgel*, L.E.
Was RNA the first genetic polymer?

Oró*, J.
Chemical evolution: A solar system perspective (Abstract).

Oró*, J.; Mills, T.
Chemical evolution of primitive solar system bodies.
*Advances in Space Research* 9(2): 105-120, 1989. (GWU 11543)

Peyser, J.R.; Ferris*, J.P.
Synthesis of deoxynucleotide dimers: A starting point for prebiotic studies (Abstract).

Pohorille, A.; MacElroy*, R.D.
Ions in aqueous solutions and at water interfaces: Supercomputer simulation tests of basic theories.
Ponnamperruma*, C.
Experimental studies in the origin of life.

Rein*, R.; McDonald, J.
Use of theoretical and experimental approaches in modeling macromolecular complexes (Abstract).
Abstract of paper presented at the Workshop on High-Field NMR and Biological Applications,
Pacific Northwest Laboratory, Richland, WA, September 8-9, 1989, 2 p. (GWU 11566)

Rein*, R.; Shibata, M.; McDonald, J.; McCourt, M.; Zielinski, T.
Study of nucleic acids and protein structure and function by methods of computational chemistry
(Abstract).
Abstract of paper presented at 8th Annual Conference of the Molecular Graphics Society, St.

Scattergood*, T.W.; McKay*, C.P.; Borucki, W.J.; Giver, L.P.; Van Ghyseghem, H.;
Parris, J.E.; Miller*, S.L.
Production of organic compounds in plasmas: A comparison among electric sparks, laser-induced
plasmas, and UV light.
Icarus 81: 413-428, 1989. (GWU 11528)

Schwartz, A.W. (Orgel, L.E. = P.I.)
Models for the origins of RNA molecules (Abstract).

Schwartz, A.W. (Orgel, L.E. = P.I.)
Nucleic acid analogues and the origins of replication.
Advances in Space Research 9(6): 77-81, 1989. (GWU 12001)

Schwartz, A.W.; Bakker, C.G. (Orgel, L.E. = P.I.)
Was adenine the first purine?
Science 245: 1102-1104, 1989. (GWU 10463)

Shen, C.; Lazcano, A.; Oró*, J.
On the prebiological significance of the catalytic activity of histidyl-histidine (Abstract).

Shen, C.; Yang, L.; Miller*, S.L.; Oro*, J.
The prebiotic synthesis of histidine and histidyl-histidine (Abstract).

Shia, R.-L.; Yung*, Y.L.; Allen, M.; Zurek, R.W.; Crisp, D.
Sensitivity study of advection and diffusion coefficients in a two-dimensional stratospheric model
using excess carbon 14 data.

Shibata, M.; Rein*, R.
A computer modeling study of acetylcholine receptor-ligand interactions.
In: Computer Assisted Modeling of Receptor-Ligand Interactions: Theoretical Aspects and
Staves, M.P.; Lacey*, J.C., Jr.
On the probability of a common origin for tRNA and 5S rRNA.

Stribling, R.; Miller*, S.L.
Attempted non-enzymatic template-directed polymerizations of uridine and uridine analogs on polyadenosine: Implications for the nature of the first genetic material (Abstract).

Su, Y.-L.; Honda, Y.; Hare, P.E.; Ponnamperuma*, C.
Search of peptide-like materials in electric discharge experiments (Abstract).

Thompson, W.R.; Sagan*, C.
Atmospheric formation of organic heteropolymers from N₂+CH₄: Structural suggestions for amino acid and oligomer precursors (Abstract).

Tohidi, M.; Orgel*, L.E.
Some acyclic analogues of nucleotides and their template-directed reactions.

Tonks, W.B.; Melosh*, H.J.
Mass exchange among the terrestrial planets: Implications for life exchange between Earth and Mars (Abstract).
Eos 70: 1173, 1989. (GWU 11527)

Visscher, J.; van der Woerd, R.; Bakker, C.G.; Schwartz, A.W. (Orgel, L.E. = P.I.)
Oligomerization of deoxynucleoside-bisphosphate dimers: Template and linkage specificity.
Origins of Life and Evolution of the Biosphere 19: 3-6, 1989. (GWU 11996)

Wade, R.C.; Powers, J.V.; Ponnamperuma*, C.

Weber*, A.L.
Glyceraldehyde as a source of energy and matter for the origin of life (Abstract).

Weber*, A.L.
Model of early self-replication based on covalent complementarity for a copolymer of glycerate-3-phosphate and glycerol-3-phosphate.

Weber*, A.L.
Thermal synthesis and hydrolysis of polyglyceric acid.

Wen, J.-S.; Pinto, J.P.; Yung*, Y.L.
Photochemistry of CO and H₂O: Analysis of laboratory experiments and applications to the prebiotic Earth's atmosphere.
Comment on "Study on the liquid-vapor interface of water. I. Simulation results of thermodynamic properties and orientational structure."
Journal of Chemical Physics 90(9): 5211-5213, 1989. (GWU 11428)

Interaction of a sodium ion with the water liquid-vapor interface.


Instruments and analyses.
In: Ninth College Park Colloquium on Chemical Evolution, College Park, MD, October 29-31, 1989, p. 35-36. (GWU 11554)
EARLY EVOLUTION OF LIFE
Evolution of the MSP multigene family in the nematode Caenorhabditis elegans (Abstract).
Worm Breeders Gazette 11: 45-46, 1989. (GWU 11454)

Beier, J.A.; Hayes*, J.M.
Geochemical and isotopic evidence for paleoredox conditions during deposition of the Devonian-Mississippian New Albany Shale, southern Indiana.

A new model for atmospheric oxygen over Phanerozoic time.

Boreham, C.J.; Fookes, C.J.R.; Popp, B.N.; Hayes*, J.M.

Buchanan*, B.B.; Hartman, H.; Syvanen, M.
Evolutionary history of chloroplast thioredoxins f and m (Abstract).
Plant Physiology 89(4, Suppl.): 174, 1989. (GWU 11395)

Byerly, G.R.; Lowe*, D.R.; Kroner, A.
A complex and prolonged magmatic evolution for the Barbermon Greenstone Belt, South Africa (Abstract).
Eos 70: 1391, 1989. (GWU 11510)

Canfield, D.E. (DeVincenzi, D.L. = P.I.)
Reactive iron in marine sediments.

Canfield, D.E. (DeVincenzi, D.L. = P.I.)
Sulfate reduction and oxic respiration in marine sediments: Implications for organic carbon preservation in euxinic environments.

D’Antoni-D’Amelio, E.; Cohen, Y.; Des Marais*, D.J.

Deamer*, D.; Mikhailov, A.I.; Selezev, S.A.
How the first cells appeared. (Russian)
Priroda 10: 3-9, 1989. (GWU 11407)

Sr isotopic variations in Upper Proterozoic carbonates from Svalbard and East Greenland.
Des Marais*, D.J.
Stable carbon and sulfur isotopes as records of the early biosphere (Abstract).

Des Marais*, D.J.; Cohen, Y.; Nguyen, H.; Cheatham, M.; Cheatham, T.; Munoz, E.
Carbon isotopic trends in the hypersaline ponds and microbial mats at Guerrero Negro, Baja California Sur, Mexico: Implications for Precambrian stromatolites.

Enzien, M.; McKhann, H.I.; Margulis*, L.
*Biological Bulletin* 177: 110-129, 1989. (GWU 11619)

Freeman, K.H.; Ricci, M.P.; Studley, S.A.; Hayes*, J.M.
Isotope ratio monitoring gas chromatography mass spectrometry (IRM-GCMS) (Abstract).

Friedmann*, E.I.
What is an extreme environment? (Abstract)
In: *Abstracts, Fifth International Symposium on Microbial Ecology*, Kyoto, Japan, 1989, p. 56. (GWU 11469)

Friedmann*, E.I.; Friedmann, R.O.
Microbial trace fossils in Antarctica and the search for evidence of early life on Mars (Abstract).

Friedmann*, E.I.; Koriem, A.M.
Life on Mars: How it disappeared (If it was ever there).

Friedmann*, E.I.; Meyer, M.A.; Friedmann, R.O.; Kappen, L.
Antarctic microorganisms: Optimal temperature for species may be lethal for the community (Abstract).
In: *Abstracts, 9th International Symposium on Environmental Biogeochemistry*, Moscow, USSR, September 4-8, 1989, No. 175. (GWU 11468)

Friedmann*, E.I.; Meyer, M.A.; Friedmann, R.O.; Kappen, L.
Antarctic microorganisms: Optimal temperature for species may be lethal for the community (Abstract).

Gelwicks, J.T.; Risatti, J.B.; Hayes*, J.M.
Carbon isotope effects associated with autotrophic acetogenesis.
*Organic Geochemistry* 14(4): 441-446, 1989. (GWU 11313)


Haselman, T.; Camp, D.G.; Fox*, G.E. Phylogenetic evidence for tertiary interactions in 16S-like ribosomal RNA. *Nucleic Acids Research* 17(6): 2215-2221, 1989. (GWU 11450)


Johnston, C.G.; Vestal, J.R. (Friedmann, E.I. = P.I.)  
Distribution of inorganic species in two Antarctic cryptoendolithic microbial communities.  

Kasting*, J.F.  
Carbon oxidation state in the early atmosphere: CO$_2$ or CO? (Abstract)  

Kasting*, J.F.  
Long-term stability of the Earth's climate.  

Kasting*, J.F.; Toon, O.B.  
Climate evolution on the terrestrial planets.  

Kasting*, J.F.; Zahnle, K.J.; Pinto, J.P.; Young, A.T.  

Kasting*, J.F.; Zahnle, K.J.; Pinto, J.P.; Young, A.T.  
Sulfur, ultraviolet radiation, and the early evolution of life.  

Knoll*, A.H.  
Evolution and extinction in the marine realm: Some constraints imposed by phytoplankton.  

Knoll*, A.H.  
The paleomicrobiological information in proterozoic rocks.  

Knoll*, A.H.; Bauld, J.  
The evolution of ecological tolerance in prokaryotes.  

Knoll*, A.H.; Butterfield, N.J.  
New window on Proterozoic life.  

Knoll*, A.H.; Swett, K.; Burkhardt, E.  
Paleoenvironmental distribution of microfossils and stromatolites in the Upper Proterozoic Backlundtoppen Formation, Spitsbergen.  
Kretsinger*, R.H.; Moncrief, N.D.
Evolution of calcium modulated proteins.
*Virginia Explorer* 5(5): 7-9, 1989. (GWU 11629)

Kröner, A.; Byerly, G.R.; Lowe*, D.R.
Precise single zircon evaporation ages documenting = 200 Ma of Archean greenstone evolution in the Barberton Belt of South Africa (Abstract).
*Eos* 70: 1404, 1989. (GWU 11509)

Kuhn, W.R.; Walker*, J.C.G.; Marshall, H.G.
The effect on Earth’s surface temperature from variations in rotation rate, continent formation, solar luminosity, and carbon dioxide.

Lang, F.; Hochstein*, L.I.
Are Archaebacteria appropriate models for studying the early evolution of life? The enzyme nitrate reductase as a case in point (Abstract).

Lowe*, D.R.
The geological record of life 3500 Ma ago: Coping with the rigors of a young Earth during late accretion (Abstract).

Lowe*, D.R.; Byerly, G.R.; Asaro*, F.; Kyte, F.J.
Geological and geochemical record of 3400-million-year-old terrestrial meteorite impacts.

Madigan, M.T.; Takigiku, R.; Lee, R.G.; Gest, H.; Hayes*, J.M.

Mancinelli*, R.L.
Nitrogen cycling in microbial mats beneath an Antarctic perenially ice-covered lake.

Mancinelli*, R.L.
The role of nitrogen in the evolution of life (Abstract).

Margulis*, L.; Guerrero, R.
From planetary atmospheres to microbial communities: A stroll through space and time.

Margulis*, L.; Lovelock, J.E.
Gaia and geognosy.
Margulis*, L.; Nealson, K.H.
Symbiosis as the source of evolutionary innovation.

Meyer, M.A.; Friedmann*, E.I.; Kappen, L.; Nienow, J.A.; Sun, H.J.
Long term production in the Antarctic cryptoendolithic microbial ecosystem (Abstract).

Navarro-González, R.; Ponnamperuma*, C.
El mecanismo de la bioluminiscencia bacteriana. (Spanish)
*Revista de la Sociedad Química de México* 33(2): 54-60, 1989. (GWU 11558)

Noll, K.M. (Woese, C.R. = P.I.)
Chromosome map of thermophilic archaeabacterium *Thermococcus celer*.
*Journal of Bacteriology* 171(12): 6720-6725, 1989. (GWU 11583)

Different isotope compositions of C₃₂ DPEP and C₃₂ etioporphyrin III in oil shale.
*Naturwissenschaften* 76: 419-421, 1989. (GWU 11278)

Olsen, G.J.; Woese*, C.R.
A brief note concerning archaeabacterial phylogeny.
*Canadian Journal of Microbiology* 35: 119-123, 1989. (GWU 11582)

Osawa, S.; Jukes*, T.H.
Codon reassignment (codon capture) in evolution.
*Journal of Molecular Evolution* 28: 271-278, 1989. (GWU 11486)

Evolution of the mitochondrial genetic code. I. Origin of AGR serine and stop codons in metazoan mitochondria.
*Journal of Molecular Evolution* 29: 202-207, 1989. (GWU 11488)

Evolution of the mitochondrial genetic code. II. Reassignment of codon AUA from isoleucine to methionine.
*Journal of Molecular Evolution* 29: 373-380, 1989. (GWU 11489)

Palmisano, A.C.; Cronin, S.E.; D'Amelio, E.D.; Munoz, E.; Des Marais*, D.J.
Distribution and survival of lipophilic pigments in a laminated microbial mat community near Guerrero Negro, Mexico.

Palmisano, A.C.; Summons, R.E.; Cronin, S.E.; Des Marais*, D.J.
Lipophilic pigments from cyanobacterial (blue-green algal) and diatom mats in Hamelin Pool, Shark Bay, Western Australia.
Palmisano, A.C.; Wharton*, R.A., Jr.; Cronin, S.E.; Des Marais*, D.J.
Lipophilic pigments from the benthos of a perennially ice-covered Antarctic Lake.
*Hydrobiologia* 178: 73-80, 1989. (GWU 11419)

Pande, C.; Lanyi*, J.K.; Callender, R.H.
Effects of various anions on the Raman spectrum of halorhodopsin.

Persechini, A.; Moncrief, N.D.; Kretsinger*, R.H.
The EF-hand family of calcium-modulated proteins.

The post-Paleozoic chronology and mechanism of $^{13}$C depletion in primary marine organic matter.

Rau, G.H.; Takahashi, T.; Des Marais*, D.J.
Latitudinal variations in plankton $^{8}$I3C: Implications for CO$_2$ and productivity in past oceans.

Rothschild, L.J. (Des Marais, D.J. = P.I.)
Protozoa, Protista, Protocista: What's in a name?

Rothschild, L.J.; Mancinelli*, R.L.
Microbial mats as a model system for the early evolution of carbon metabolism (Abstract).

Sagan, D.; Margulis*, L. (Eds.)

Schopf*, J.W.
Diversification and extinction in the Proterozoic biosphere (Abstract).

Sleep, N.H.; Zahnle, K.J.; Kasting*, J.F.; Morowitz, H.J.
Annihilation of ecosystems by large asteroid impacts on the early Earth.

Stan-Lotter, H.; Hochstein*, L.I.
A comparison of an ATPase from the archaeobacterium *Halobacterium saccharovorum* with the F$_1$ moiety from the *Escherichia coli* ATP synthase.

Electrophoresis and isoelectric focusing of whole cell and membrane proteins from the extremely halophilic archaeabacteria.

Swett, K.; Knoll*, A.H.
Marine pisolites from Upper Proterozoic carbonates of East Greenland and Spitsbergen.
*Sedimentology* 36: 75-93, 1989. (GWU 11503)
Transfer of *Halobacterium denitrificans* (Tomlinson, Jahnke, and Hochstein) to the genus *Haloferax* as *Haloferax denitrificans* comb nov.  

Trost, J.T.; Blankenship*, R.E.  
Isolation of a photoactive photosynthetic reaction center-core antenna complex from *Heliobacillus mobilis*.  
*Biochemistry* 28: 9898-9904, 1989. (GWU 11394)

5S ribosomal ribonucleic acid sequences in *Bacteroides* and *Fusobacterium*: Evolutionary relationships within these genera and among eubacteria in general.  

Váró, G.; Lanyi*, J.K.  
Photoreactions of bacteriorhodopsin at acid pH.  

Veizer, J.; Hoefs, J.; Lowe*, D.R.; Thurston, P.C.  
Geochemistry of Precambrian carbonates: II. Archean greenstone belts and Archean sea water.  

Veizer, J.; Hoefs, J.; Ridler, R.H.; Jensen, L.S.; Lowe*, D.R.  
Geochemistry of Precambrian carbonates: I. Archean hydrothermal systems.  

Vestal, J.R. (Friedmann, E.I. = P.I.)  
The metabolism of the Antarctic cryptoendolithic microbiota (Abstract).  

Vestal, J.R.; White, D.C. (Friedmann, E.I. = P.I.)  
Lipid analysis in microbial ecology: Quantitative approaches to the study of microbial communities.  

Weisburg, W.G.; Giovannoni, S.J.; Woese*, C.R.  
The *Deinococcus-Thermus* phylum and the effect of rRNA composition on phylogenetic tree construction.  
*Systematic and Applied Microbiology* 11: 128-134, 1989. (GWU 11314)

Wisotzkey, J.D.; Jurtshuk, P., Jr.; Fox*, G.E.  
Comparative 16S rRNA analysis on thermophilic and psychrophilic *Bacillus* species (Abstract).  
Woese*, C.R.
Archaeabacteria and the nature of their evolution.

Woese*, C.R.; Gutell, R.R.
Evidence for several higher order structural elements in ribosomal RNA.
Proceedings of the National Academy of Sciences, USA 86: 3119-3122, 1989. (GWU 10304)

Transient spectroscopy of bacterial rhodopsins with an optical multichannel analyzer.
1. Comparison of the photocycles of bacteriorhodopsin and halorhodopsin.
Biochemistry 28(12): 5165-5172, 1989. (GWU 11662)

Zimányi, L.; Lanyi*, J.K.
Halorhodopsin: A light-driven active chloride transport system.

Zimányi, L.; Lanyi*, J.K.
Low-temperature photoreactions of halorhodopsin. 2. Description of the photocycle and its intermediates.

Zimányi, L.; Lanyi*, J.K.
Transient spectroscopy of bacterial rhodopsins with an optical multichannel analyzer. 2. Effects of anions on the halorhodopsin photocycle.
Biochemistry 28(12): 5172-5178, 1989. (GWU 11661)

Zimányi, L.; Ormos, P.; Lanyi*, J.K.
Low-temperature photoreactions of halorhodopsin. 1. Detection of conformational substates of the chromoprotein.
EVOLUTION OF ADVANCED LIFE
Billingham*, J.
The evolution of complex life.

Briggs*, J.C.
The historic biogeography of India: Isolation or contact?

Jablonski, D. (Raup, D.M. = P.I.)
The biology of mass extinction: A palaeontological view.
Philosophical Transactions of the Royal Society of London B 325: 357-368, 1989. (GWU 11561)

Raup*, D.M.
The case for extraterrestrial causes of extinction.

Roughgarden*, J.
The structure and assembly of communities.

Roughgarden*, J.; May, R.M.; Levin, S.A. (Eds.)
(GWU 8950)

Sepkoski*, J.J., Jr.
Extinction events in the fossil record: An overview (Abstract).

Sepkoski*, J.J., Jr.
The importance of extinction resistance in onshore-offshore changes in faunal dominance during
evolutionary radiations (Abstract).

Sepkoski*, J.J., Jr.
Periodicity in extinction and the problem of catastrophism in the history of life.

The evolutionary dynamics of plants and animals: A comparative approach (Abstract).
SOLAR SYSTEM EXPLORATION
Becker, J.F.; Yaldaei, R.; McKay*, C.P.
Stable isotope laser spectroscopy (Abstract).

Observational exobiology.

Benz, W.; Cameron, A.G.W.; Melosh*, H.J.
The origin of the Moon and the single-impact hypothesis III.

Berry, W.; Duke, M.; Tarter*, J.
Observational and experimental opportunities in Earth orbit.

Chyba, C.F.; Squyres, S.W.; Sagan*, C.
Depth to unoxidized material in the Martian regolith (Abstract).

de Bergh, C.; Lutz, B.L.; Owen*, T.; Maillard, J.-P.
Measurements of the D/H ratio in planetary atmospheres by ground based infrared spectroscopy.

DeVincenzeni*, D.L.
Life in the universe: Space exploration opportunities (Abstract).

Fogleman, G.; Huntington, J.L.; Carle*, G.C.
Collection of cosmic dust in Earth orbit for exobiological analysis (Abstract).

Fogleman, G.; Huntington, J.L.; Carle*, G.C.; Nuth, J.A.

Fogleman, G.; Huntington, J.L.; Schwartz, D.E.; Fonda, M.L. (Eds.)
Fogleman, G.; Huntington, J.L.; Schwartz, D.E.; Fonda, M.L. (Eds.)
Gas-Grain Simulation Facility: Fundamental Studies of Particle Formation and Interactions.

Gautier, D.; Owen*, T.
The composition of outer planet atmospheres.

The search for and identification of amino acids, nucleobases and nucleosides in samples returned from Mars (Abstract).

Gehrke, C.W.; Ponnamperuma*, C.; Zumwalt, R.; Stalling, D.
The role of a lunar-based chemical biology/medical analysis laboratory (LBCAL) on the moon.
In: Ninth College Park Colloquium on Chemical Evolution, College Park, MD, October 29-31, 1989, p. 7-9. (GWU 11551)

Gibson*, E.K., Jr.
Analytical requirements of a lunar base.
Paper presented at the Lunar-Based Chemical Analysis Laboratory Colloquium, University of Maryland, College Park, MD, October 30-31, 1989.

Gibson*, E.K., Jr.
Soil development in polar deserts: Implications for Exobiology and future Mars missions (Abstract).

Gooding, J.L. (McKay, C.P. = P.I.)
Mineralogical sinks for biogenic elements on Mars (Abstract).

Gooding, J.L.; Carr, M.H.; McKay*, C.P.
The case for planetary sample return missions. 2. History of Mars.
Eos 70(31): 745-750, 1989. (GWU 11517)

Houdashelt, M.L.; Bustin, R.; Gibson*, E.K.
Hydrogen extraction from lunar soil: Methods applicable to a lunar processing facility (Abstract).

Huntington, J.L.; Fogleman, G. (Carle, G.C. = P.I.)
On performing exobiology experiments on an Earth-orbital platform with the gas-grain simulation facility (Abstract).
Irvine*, W.M.; Lumme, K.; Zhukov, B.S.
Disk-integrated photometry of Phobos from the Phobos 2 spacecraft.

Kanavarioti*, A.; Mancinelli*, R.L.
Chemical evolution and the preservation of organic compounds on Mars (Abstract).

Klein*, H.P.
The Viking Biology results (Abstract).

Klingler, J.M.; Mancinelli*, R.L.; White, M.R.
Biological nitrogen fixation under primordial Martian partial pressures of dinitrogen.

Klingler, J.M.; Mancinelli*, R.L.; White, M.R.
Ecological considerations for possible Martian biota (Abstract).

Levine*, J.S.
Venus' atmosphere.

Levine*, J.S.; McKay*, C.P.
A search for biogenic trace gases in the atmosphere of Mars (Abstract).

Levine*, J.S.; Rinsland, C.P.; Charmeides, W.L.; Boston, P.J.; Cofer, W.R., III; Brimblecombe, P.
Trace gases in the atmosphere of Mars: An indicator of microbial life.

Mancinelli*, R.L.
The nitrogen cycle on Mars (Abstract).

Mancinelli*, R.L.
Peroxides and the survivability of microorganisms on the surface of Mars.

McKay*, C.P.; Borucki, W.R.; Kojiri*, D.R.; Church, F.
Shock production of organics during cometary impact (Abstract).
McKay*, C.P.; Davis, W.L.

McKay*, C.P.; Pollack, J.B.; Courtin, R.
The thermal structure of Titan's atmosphere.

McKay*, C.P.; Stoker, C.R.
The early environment and its evolution on Mars: Implications for life.

Melosh*, H.J.; Kipp, M.E.
Giant impact theory of the moon's origin: First 3-D hydrocode results (Abstract).

Melosh*, H.J.; Vickery, A.M.
Impact erosion of the primordial atmosphere of Mars.

Meyer, T.R.; McKay*, C.P.
The resources of Mars for human settlement.

Moses*, J.I.; Allen, M.; Yung*, Y.L.
Neptune's visual albedo variations over a solar cycle: A pre-Voyager look at ion-induced nucleation and cloud formation in Neptune's troposphere.

Nedell, S.S.; McKay*, C.P.
Are there carbonate deposits in the Valles Marineris, Mars? (Abstract)

Oberbeck, V.R. (Carle, G.C. = P.I.)
Sampling stratospheric aerosols with impactors.

Oberbeck, V.R.; Fogleman, G. (Carle, G.C. = P.I.)
On the possibility of life on early Mars (Abstract).

SAGE II aerosol validation: Selected altitude measurements, including particle micromeasurements.

Oberbeck, V.R.; O'Hara, D.; Carle*, G.C.
Oró*, J.; Mills, T.

Owen*, T.; Gautier, D.
Titan: Some new results.
*Advances in Space Research* 9(2): 73-78, 1989. (GWU 11546)

Rothschild, L.J.; Des Marais*, D.
Stable carbon isotope fractionation in the search for life on early Mars.
*Advances in Space Research* 9(6): 159-165, 1989. (GWU 11421)

Snetsinger, K.; Verma, S.; Carle*, G.
The study of Titan from an exobiological perspective.

Schwartz, D.E.; Mancinelli*, R.L.
Bio-markers and the search for extinct life on Mars.

Crystal properties as bio-markers: A potential MRSR experiment (Abstract).

Schwartz, D.E.; Mancinelli*, R.L.; O'Hara, B.J.
Viking and Mars Rover exobiology (Abstract).
In: *Exobiology and Future Mars Missions* (McKay, C.P., Davis, W.L., Eds.) Moffett Field, CA:

Simonelli, D.P.; Pollack, J.B.; McKay*, C.P.; Reynolds, R.T.; Summers, A.L.
The carbon budget in the outer solar nebula.

Gamble, E.; McKay*, C.P.
Mars Rover Sample Return: A sample collection and analysis strategy for exobiology (Abstract).
In: *Exobiology and Future Mars Missions* (McKay, C.P., Davis, W.L., Eds.) Moffett Field, CA:

Production and fate of hydrocarbons, nitriles, and heteropolymers on Titan (Abstract).

Thompson, W.R.; Sagan*, C.
Photometric properties and classification of small jovian cloud features.

Triton: Stratospheric molecules and organic sediments.
Tsou*, P.; Aubert, J.; Brownlee, D.; Hrubesh, L.; Williams, J.; Albee, A.
Effectiveness of intact capture media (Abstract).

Tsou*, P.; Bradley, J.G.; Brownlee, D.E.; Albee, A.L.
Nondestructive cosmic dust positioning and velocity sensor (Abstract).

Valentin*, J.R.
Multiplex gas chromatography: An alternative concept for gas chromatographic analysis of planetary atmospheres.

Valentin*, J.R.; Hall, K.W.
Mechanical modulation for multiplex gas chromatographic analyses at subatmospheric pressures.

Vickery, A.M.; Melosh*, H.J.
Atmospheric erosion by impacts: Evidence for an early, dense atmosphere on Mars (Abstract).
*Eos* 70: 1172, 1989. (GWU 11526)

SAGE II aerosol data validation based on retrieved aerosol model size distribution from SAGE II aerosol measurements.

The Antarctic Dry Valley Lakes: Relevance to Mars (Abstract).

Early Martian environments: The Antarctic and other terrestrial analogs.

Wharton*, R.A., Jr.; Simmons, G.M., Jr.; McKay*, C.P.
Perennially ice-covered Lake Hoare, Antarctica: Physical environment, biology and sedimentation.
*Hydrobiologia* 172: 305-320, 1989. (GWU 10136)

Zent, A.P.; McKay*, C.P.; Pollack, J.B.; Cruikshank, D.P.
Grain metamorphism in polar nitrogen ice on Triton.
SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE (SETI)
Betz*, A.L.; Borieko, R.T.
Reversed far-infrared line emission from OH in Orion.

Billingham*, J.; Tarter*, J.
Detection of the Earth with the SETI microwave observing system assumed to be operating out in the galaxy.
Paper presented at the 40th Congress of the International Astronautical Federation, Malaga, Spain, October 7-12, 1989, 8 p. (IAF Paper 89-647) (GWU 11574)

Boreiko, R.T.; Betz*, A.L.
Heterodyne spectroscopy of the $J = 22-21$ CO line in Orion.

Boreiko, R.T.; Betz*, A.L.; Zmuidzinas, J.
Heterodyne spectroscopy of the $J = 17-16$ CO line in Orion.

VLSI processors for signal detection in SETI.

Gulkis*, S.
Analysis of a crossed bragg cell acousto-optical spectrometer for SETI.

Gulkis*, S.; Klein*, M.J.; Olsen, E.T.; Garyantes, M.F.; Wilck, H.C.; Deich, W.T.S.; Brady, R.B.; Burns, D.J.
Status of the NASA SETI Sky Survey Observing Project.

Heidmann, J.; Biraud, F.; Tarter*, J.
Pulsar-aided SETI experimental observations.
Paper presented at the 40th Congress of the International Astronautical Federation, Malaga, Spain, October 7-13, 1989, 7 p. (IAF Paper 89-642) (GWU 11631)

Klein*, M.J.; Brin, G.D.
CETI.

Klein*, M.J.; Gulkis*, S.; Olsen, E.T.; Renzetti, N.A.
The NASA SETI Sky Survey: Recent developments.

Kuiper, T.B.H.; Brin, G.D. (Klein, M.J. = P.I.)
Resource letter ETC-1: Extraterrestrial civilization.
Miller, A.; Jelinsky, P.; Bowyer*, S.; Welsh, B.Y.
Small blaze angle gratings with various surface treatments for use in the extreme ultraviolet.

Seeger, C.L.; Martin, A.R. (Eds.)
SETI: The search for extraterrestrial intelligence.

Tarter*, J.
Bridges from new worlds.

Tarter*, J.
Radio frequency interference at Jodrell Bank Observatory within the protected 21 cm band.

Tarter*, J.
SETI: The farthest frontier.

Zmuidzinas, J.; Betz*, A.L.; Boreiko, R.T.
A corner-reflector mixer mount for far infrared wavelengths.
PLANETARY PROTECTION
DeVincenzi*, D.L.
Proposed planetary protection guidelines for sample return missions (Abstract).

DeVincenzi*, D.L.; Klein*, H.P.
Planetary protection issues for sample return missions.

McKay*, C.P.; Davis, W.L.
Planetary protection issues in advance of human exploration of Mars.

Rummel*, J.D.
Planetary protection policy overview and application to future missions.
GENERAL
(NASA-SP-500) (GWU 11603)

Klein*, H.P.
Biology and the space sciences.
In: *Exobiology in Earth Orbit* (DeFrees, D., Brownlee, D., Tarter, J., Usher, D., Irvine, W.,
(NASA-SP-500) (GWU 11600)

Oró*, J. (Ed.)
Life Sciences and Space Research XXIII (1): Exobiology Science and Primitive Solar System
Bodies.

Schwartz, A.W.; Dose, K.; Raup*, D.M.; Klein*, H.P.; DeVincenzi*, D.L. (Eds.)
Life Sciences and Space Research XXIII (2): Planetary Biology and Origins of Life.
ADDENDUM
These publications were inadvertently omitted from the 1988 Bibliography.


Yung*, Y.L.; Drew, W.A.; Pinto, J.P.; Friedl, R.R.
Estimation of the reaction rate for the formation of CH₃O from H + H₂CO: Implications for chemistry in the solar system.
PRINCIPAL INVESTIGATORS

Louis J. Allamandola  
NASA, Ames Research Center  
Mail Stop 245-6  
Code SSA  
Moffett Field, CA 94035

Gustaf Arrhenius  
Scripps Institution of Oceanography  
Mail Code A-020  
University of California, San Diego  
La Jolla, CA 92093

Frank Asaro  
Lawrence Berkeley Laboratory  
University of California  
Berkeley, CA 94720

Peter Backus  
NASA, Ames Research Center  
Mail Stop 229-8  
Moffett Field, CA 94035

Albert Betz  
Space Sciences Laboratory  
University of California  
Berkeley, CA 94720

John Billingham  
NASA, Ames Research Center  
Mail Stop 236-3  
Code SL  
Moffett Field, CA 94035

Robert E. Blankenship  
Center for the Study of Early Events in Photosynthesis  
Arizona State University  
Tempe, AZ 85287

Stuart Bowyer  
Department of Astronomy  
Space Sciences Laboratory  
University of California  
Berkeley, CA 94720

John C. Briggs  
Department of Marine Sciences  
University of South Florida  
140 Seventh Avenue South  
St. Petersburg, FL 33701

Bob Buchanan  
College of Natural Resources  
Department of Plant Biology  
University of California  
Berkeley, CA 94720

Theodore Bunch  
NASA, Ames Research Center  
Mail Stop 239-4  
Code SSX  
Moffett Field, CA 94035

Glenn Carle  
NASA, Ames Research Center  
Mail Stop 239-12  
Code SSS  
Moffett Field, CA 94035

Sherwood Chang  
NASA, Ames Research Center  
Mail Stop 239-4  
Code SSX  
Moffett Field, CA 94035

Lelia M. Coyne  
Department of Chemistry  
San Jose State University  
San Jose, CA 95192

John R. Cronin  
Department of Chemistry  
Arizona State University  
Tempe, AZ 85287

David Deamer  
Department of Zoology  
University of California  
Davis, CA 95616
PRINCIPAL INVESTIGATORS

Douglas J. DeFrees
Molecular Research Institute
845 Page Mill Road
Palo Alto, CA 94304

David J. Des Marais
NASA, Ames Research Center
Mail Stop 239-4
Code SSX
Moffett Field, CA 94035

Donald L. DeVincenzi
NASA, Ames Research Center
Mail Stop 245-1
Code SS
Moffett Field, CA 94035

Robert S. Dixon
Ohio State University Radio Observatory
2015 Neil Avenue
Columbus, OH 43210

Samuel Epstein
Division of Geological and Planetary Sciences
California Institute of Technology
Pasadena, CA 91125

James P. Ferris
Department of Chemistry
School of Science
Rensselaer Polytechnic Institute
Troy, NY 12180

George E. Fox
Department of Biochemical and Biophysical Sciences
University of Houston
4800 Calhoun Road
Houston, TX 77004

Sidney W. Fox
Department of Electrical Engineering
College of Engineering and Technology
Southern Illinois University
Carbondale, IL 62907

E. Imre Friedmann
Department of Biological Science
Florida State University
320 Conrads Building
Tallahassee, FL 32306

Everett K. Gibson, Jr.
NASA, Johnson Space Center
SN4/Experimental Planetology Branch
Solar System Exploration Division
Space and Life Sciences Directorate
Houston, TX 77058

Samuel Gulkis
California Institute of Technology
NASA, Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109

Martha Hanner
California Institute of Technology
NASA, Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109

John M. Hayes
Department of Chemistry and Geology
Geology Building
Indiana University
Bloomington, IN 47405

Lawrence I. Hochstein
NASA, Ames Research Center
Mail Stop 239-4
Code SSX
Moffett Field, CA 94035

Heinrich D. Holland
Department of Earth and Planetary Sciences
Hoffman Laboratory
Harvard University
20 Oxford Street
Cambridge, MA 02138
PRINCIPAL INVESTIGATORS

William M. Irvine
Five College Radio Astronomy Observatory
University of Massachusetts
619 Lederle Graduate Research Center
Amherst, MA 01003

Linda Jahnke
NASA, Ames Research Center
Mail Stop 239-4
Code SSX
Moffett Field, CA 94035

Thomas H. Jukes
Space Science Laboratory
University of California
6701 San Pablo Avenue
Oakland, CA 94608

Anastassia Kanavariotti
Department of Chemistry
University of California
Santa Cruz, CA 95064

James F. Kasting
Department of Geological Sciences
503 Deike Building
Pennsylvania State University
University Park, PA 16802

John F. Kerridge
Institute of Geophysics and Planetary Physics
University of California
405 Hilgard Hall
Los Angeles, CA 90024

Bishun N. Khare
Laboratory for Planetary Studies
Center for Radiophysics and Space Research
Cornell University
Space Sciences Building
Ithaca, NY 14853

Michael J. Klein
California Institute of Technology
NASA, Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109

Andrew H. Knoll
Botanical Museum of Harvard University
26 Oxford Street
Cambridge, MA 02138

Robert Kretsinger
Department of Biology
University of Virginia
Charlottesville, VA 22901

James C. Lacey, Jr.
Department of Biochemistry
Room 520 CHSB
University of Alabama
Birmingham, AL 35294

Janos K. Lanyi
Department of Physiology and Biophysics
California College of Medicine
University of California
Irvine, CA 92717

Joel S. Levine
NASA, Langley Research Center
Atmospheric Sciences Division
Hampton, VA 23665

Donald Lowe
Department of Geology
Stanford University
Stanford, CA 94305

Robert D. MacElroy
NASA, Ames Research Center
Mail Stop 239-4
Code SL
Moffett Field, CA 94035
PRINCIPAL INVESTIGATORS

Rocco Mancinelli  
NASA, Ames Research Center  
Mail Stop 239-12  
Moffett Field, CA 94035

Lynn Margulis  
Botany Department  
Morrill Science Center  
University of Massachusetts  
Amherst, MA 01003

Christopher P. McKay  
NASA, Ames Research Center  
Mail Stop 245-3  
Code SST  
Moffett Field, CA 94035

H.J. Melosh  
Department of Planetary Sciences  
University of Arizona  
Tucson, AZ 85721

Stanley L. Miller  
Department of Chemistry, B-017  
University of California, San Diego  
La Jolla, CA 92093

Bernard M. Oliver  
NASA, Ames Research Center  
Mail Stop 229-8  
Code SI  
Moffett Field, CA 94035

Leslie E. Orgel  
The Salk Institute for Biological Studies  
P.O. Box 85800  
San Diego, CA 92138

John Oró  
Department of Biochemical and Biophysical Sciences  
University of Houston  
Houston, TX 77004

Tobias Owen  
Department of Earth and Space Sciences  
State University of New York  
Stony Brook, NY 11794

Allen Peterson  
Department of Electrical Engineering  
Stanford University  
Stanford, CA 94305

Cyril Ponnamperuma  
Laboratory of Chemical Evolution  
Department of Chemistry and Biochemistry  
University of Maryland  
College Park, MD 20742

David M. Raup  
Department of Geophysical Sciences  
University of Chicago  
5734 South Ellis Avenue  
Chicago, IL 60637

Robert Rein  
Roswell Park Memorial Institute  
New York State Department of Health  
666 Elm Street  
Buffalo, NY 14263

Alexander Rich  
Department of Biology  
Massachusetts Institute of Technology  
Cambridge, MA 02139

Jonathan Roughgarden  
Department of Biological Sciences  
Stanford University  
Stanford, CA 94305

John D. Rummel  
Program Manager, Exobiology  
NASA Headquarters  
Code SBR  
Washington, D.C. 20546
PRINCIPAL INVESTIGATORS

Carl Sagan
Center for Radiophysics and Space Research
Laboratory for Planetary Studies
Space Sciences Building
Cornell University
Ithaca, NY 14853

Thomas Scattergood
State University of New York
Stony Brook, NY 11794

J. William Schopf
Department of Earth and Space Sciences
3806 Geology Building
University of California
Los Angeles, CA 90024

J. John Sepkoski, Jr.
Department of Geophysical Sciences
University of Chicago
5734 South Ellis Avenue
Chicago, IL 60637

Jill Tarter
SETI Institute
Los Altos, CA 94022

Peter Tsou
California Institute of Technology
NASA, Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109

David Usher
Department of Chemistry
Baker Laboratory
Cornell University
Ithaca, NY 14853

Jose R. Valentin
NASA, Ames Research Center
Mail Stop 239-12
Code SSS
Moffett Field, CA 94035

James C.G. Walker
Department of Atmospheric and Oceanic Science
Space Physics Research Laboratory
Space Research Building
University of Michigan
Ann Arbor, MI 48109

Arthur L. Weber
The Salk Institute for Biological Studies
P.O. Box 85800
San Diego, CA 92138

Robert A. Wharton, Jr.
NASA Headquarters
Code SBR
Washington, DC 20546

Fritz Woeller
NASA, Ames Research Center
Mail Stop 239-12
Moffett Field, CA 94035

Carl R. Woese
Department of Microbiology
131 Burrill Hall
University of Illinois
407 South Goodwin Avenue
Urbana, IL 61801

George U. Yuen
Department of Chemistry
Arizona State University
Tempe, AZ 85287

Yuk Ling Yung
Division of Geology and Planetary Sciences, 170-25
California Institute of Technology
Pasadena, CA 91125
List of 1989 publications resulting from research pursued under the auspices of NASA's Exobiology Program.