

LITERATURE CITED (CHAPTERS 1-10)

- Abe, Y.: 1986, Early evolution of the terrestrial planets: Accretion, atmosphere formation, and thermal history, Ph.D. Dissertation, University of Tokyo, Tokyo.
- Abelson, P. H.: 1957, Organic constituents of fossils, *Geol. Soc. America Memoir* **67**, 87-92.
- Achenbach-Richter, L., Gupta, R., Stetter, K. O. and Woese, C. R.: 1987, Were the original eubacteria thermophiles?, *Syst. Appl. Microbiol.* **9**, 34-39.
- Agarwal, V. K., Schutte, W., Greenberg, J. M., Ferris, J. P., Briggs, R., Connor, S., Van De Bult, C. P. E. M. and Baas, F.: 1985, Photochemical reactions in interstellar grains, photolysis of CO, NH₃ and H₂O, *Origins Life Evol. Biosphere* **16**, 21-40.
- Ahern, J. J. and Klibanov, A. M.: 1985, The mechanism of irreversible enzyme inactivation at 100°C, *Science* **228**, 1280-1284.
- Ahern, J. J. and Klibanov, A. M.: 1986, Why do enzymes irreversibly inactivate at high temperatures?, in *Protein Structure, Folding and Design: GENEX-UCLA Symposium Vol. 39* (ed. D. L. Oxender), Allan R. Liss, New York, pp. 283-289.
- Airey, P. L. and Dainton, F. S.: 1966, Photochemistry of aqueous solutions of Fe(II), I. Photoelectron detachment from ferrous and ferrocyanide ions, *Proc. Roy. Soc.* **A291**, 340.
- Akermark, B., Ecklund-Westlin, U., Baeckström, P. and Löf, R.: 1980, Photochemical, metal-promoted reduction of carbon dioxide and formaldehyde in aqueous solution, *Acta Chemica Scandinavica*, ser B. **34**, 27-30.
- Albaiges, J., Borbón, J. and Walker, W., II: 1985, Petroleum isoprenoid hydrocarbons derived from catagenetic degradation of Archaeobacterial lipids, *Org. Geochem.* **8**, 293-297.
- Albarrán, G., Collins, K. E. and Collins, C. H.: 1987, Formation of organic products in self-radiolyzed calcium carbonate, *J. Molec. Evol.* **25**, 12-14.
- Albers, T.: 1989, Mutational effects on protein stability, *Ann. Rev. Biochem.* **58**, 765-798.
- Allaart, J. H.: 1976, The pre-3760 m.y. old supracrustal rocks of the Isua area, Central West Greenland, and associated occurrence of quartz-banded iron-stone, in *The Early History of the Earth* (ed. B. F. Windley), John Wiley & Sons, London, 177-189.
- Allamandola, L. J., Sandford, S. A. and Valero, G. J.: 1988, Photochemical and thermal evolution of interstellar/precometary ice analogs, *Icarus* **76**, 225-252.
- Allen, W. V. and Ponnampertuma, C.: 1967, A possible prebiotic synthesis of monocarboxylic acids, *Curr. Mod. Biol.* **1**, 24-28.
- Alt, J. C. and Anderson, T. F.: 1991, Mineralogy and isotopic composition of sulfur in layer 3 gabbros from the Indian Ocean, Hole 735B, *Proc. Ocean Drilling Program, Scientific Results* **118**, 113-125.
- Alt, J. C. and Honnorez, J.: 1984, Alteration of the upper oceanic crust, DSDP site 417: mineralogy and chemistry, *Contrib. Mineral. Petrol.* **87**, 149-169.
- Alt, J. C., Anderson, T. F. and Bonnell, L.: 1989, The geochemistry of sulfur in a 1.3 km section of hydrothermally altered oceanic crust, DSDP Hole 504B, *Geochim. Cosmochim. Acta* **53**, 1011-1023.

- Alt, J. C., Honnorez, J., Laverne, C. and Emmermann, R.: 1986a, Hydrothermal alteration of a 1 km section through the upper oceanic crust, Deep Sea Drilling Project Hole 504B: mineralogy, chemistry, and evolution of seawater-basalt interactions, *J. Geophys. Res.* **91**, 10,309-10,335.
- Alt, J. C., Muehlenbachs, K. and Honnorez, J.: 1986b, An oxygen isotopic profile through the upper kilometer of oceanic crust, DSDP Hole 504B, *Earth Planet. Sci. Lett.* **80**, 217-229.
- Alvarez, J., Crovetto, R. and Fernandez-Prini, R.: 1988, The dissolution of N₂ and H₂ in water from room temperature to 640K, *Ber. Bunsenges. Phys. Chem.* **92**, 935-940.
- Anders, E.: 1989, Pre-biotic organic matter from comets and asteroids, *Nature* **342**, 255-257.
- Anders, E., Hayatsu, R. and Studier, M. H.: 1974, Interstellar molecules: Origin by catalytic reactions on grain surfaces?, *Astrophys. J.* **192**, L101-L105.
- Anderson, R. B.: 1956, The thermodynamics of the hydrogenation of carbon monoxide and related reactions, in *Catalysis, Vol. 4, Hydrocarbon Synthesis Hydrogenation and Cyclization* (ed. P. H. Emmett), Reinhold, New York, pp. 1-27; Catalysts for the Fischer-Tropsch synthesis, pp. 29-255; Kinetics and reaction mechanism of the Fischer-Tropsch synthesis, pp. 257-371.
- Anderson, R. N., Langseth, M. G. and Sclater, J. G.: 1977, The mechanisms of heat transfer through the floor of the Indian Ocean, *J. Geophys. Res.* **82**, 3391-3409.
- Antal, M. J., Jr., Brittain, A., DeAlmerda, C., Ramayya, S. and Roy, J. C.: 1987, Heterolysis and homolysis in supercritical water, in *Supercritical Fluids - ACS Symposium Series 329* (ed. M. J. Comstock), American Chemical Society, Washington, p. 77-86.
- Antal, M. J., Jr., Mok, W. S. L., Roy, J. C. and T-Raissi, A.: 1985, Pyrolytic sources of hydrocarbons from biomass, *J. Appl. Anal. Pyrol.* **8**, 291-303.
- Appel, P. W. U.: 1979, Stratabound copper sulfides in a banded iron-formation and in basaltic tuffs in the early Precambrian Isua supracrustal belt, West Greenland, *Econ. Geol.* **74**, 45-52.
- Armstrong, F. A. J., Williams, P. M. and Strickland, J. D. M.: 1966, Photooxidation of organic matter in seawater by ultra-violet radiation, analytical and other applications, *Nature* **211**, 481-483.
- Arrhenius, G.: 1986, Dysoxic environments as models for primordial mineralisation, in *Clay Minerals and the Origin of Life* (eds. A. G. Cairns-Smith and H. Hartman), Cambridge University Press, Cambridge, pp. 97-104.
- Arrhenius, G.: 1990, Sources and geochemical evolution of cyanide and formaldehyde, Fourth Symp. on Chemical Evolution and the Origin and Evolution of Life, *NASA Ames Research Center, Moffett Field, CA. Reprint.*
- Arrhenius, G., Bachman, J., Gedulin, B., Hui, S. and Paplawsky, W.: 1989, Anion selective minerals as concentrators and catalysts for RNA precursor components, *Origins Life Evol. Biosphere* **19**, 235.
- Ashworth, M. R. F.: 1971, *Analytical Methods for Organic Cyano Groups*, Pergamon Press, Oxford.
- Asinger, F.: 1968, *Paraffins Chemistry and Technology* (translated B. J. Hazzard; ed. H. M. E. Steiner), Pergamon Press, Oxford.

- Aswad, D.: 1990, Formation of isoaspartate in human growth hormone and bovine brain calmodulin, *Ann. New York Acad. Sci.* **613**, 26-36.
- Bada, J. L., Zhao, M. and Miller, S. L.: 1991, Alanine stability in aqueous solutions at 250°C (abs.), *Geol. Soc. Amer. Abstr. & Prog.* **23**, A25.
- Ball, B. and Rickard, R. S.: 1976, The chemistry of pyrite flotation and depression, in *Flotation*, A.M. Gaudin Memorial Volume (ed. M. C. Fuerstenau), Vol. 1, American Inst. Mining, Metall. Petrol. Engrs., pp. 458-484.
- Ballard, R. D.: 1983, *Exploring Our Living Planet*, National Geographic Society, Washington, D.C.
- Banks, D. A.: 1985, A fossil hydrothermal worm assemblage from the Tynagh lead-zinc deposit in Ireland, *Nature* **313**, 128-131.
- Bar-Nun, A. and Shaviv, A.: 1975, Dynamics of the chemical evolution of Earth's primitive atmosphere, *Icarus* **24**, 197-210.
- Bar-Nun, A., Bar-Nun, N., Bauer, S. H. and Sagan, C.: 1970, Shock synthesis of amino acids in simulated primitive environments, *Science* **168**, 470-473.
- Barnes, H. L. (Ed.): 1979, *Geochemistry of Hydrothermal Ore Deposits*, Second Ed., John Wiley & Sons, New York, 798 pp.
- Barnes, H. L.: 1987, in *Hydrothermal Experimental Techniques* (eds. G. C. Ulmer and H. L. Barnes), John Wiley & Sons, New York, pp. 507-514.
- Baronnet, A.: 1972, Growth mechanisms and polytypism in synthetic hydroxyl-bearing phlogopite, *Amer. Mineral.* **57**, 1272-1293.
- Baronnet, A.: 1980, Polytypism in micas, A survey with emphasis on the crystal growth aspect, *Current Topics in Materials Science* **5**, 447-549.
- Baross, J. A.: 1991, The origin and early evolution of life in the subsurface crustal environments of submarine hydrothermal vents: An assessment (abs.), *Geol. Soc. Amer. Abstr. & Prog.* **23**, A19.
- Baross, J. A. and Deming, J. W.: 1983, Growth of 'black smoker' bacteria at temperatures of at least 250°C, *Nature* **303**, 423-426.
- Baross, J. A. and Hoffman, S. E.: 1985, Submarine hydrothermal vents and associated gradient environments as sites for the origin and evolution of life, *Origins Life Evol. Biosphere* **15**, 327-345.
- Barrer, R. M.: 1978, *Zeolites and Clay Minerals as Sorbents and Molecular Sieves*, Academic Press, London, New York, San Francisco, 497 pp.
- Barrett, T. J. and Jambor, J. L. (Eds.): 1988, Seafloor hydrothermal mineralization, *Can. Mineral.* **26**, 429-888.
- Basiuk, V. A., Gromovoy, T. Y., Glukhoy, A. M. and Golovaty, V. G.: 1991, Chemical transformations of proteinogenic amino acids during their sublimation in the presence of silica, *Origins Life Evol. Biosphere* **21**, 129-144.
- Becker, K., Sakai, H., Adamson, A. C., Alexandrovich, J., Alt, J. C., Anderson, R. N., Bideau, D., Gable, R., Herzig, P. M., Houghton, S., Ishizuka, H., Kawahata, H., Kinoshita, H., Langset, M. G., Lovell, M. A., Malpas, J., Masuda, H., Merrill, R. B., Morin, R. H., Mottl, M. J., Pariso, J.

- E., Pezard, P., Phillips, J., Sparks, J. and Uhlig, S.: 1989, Drilling deep into young oceanic crust, Hole 504B, Costa Rica Rift, *Rev. Geophys.* **27**, 79-102.
- Becker, R. S., Hong, K. and Hong, J. H.: 1974, Hot hydrogen atom reactions of interest in molecular evolution and interstellar chemistry, *J. Molec. Evol.* **4**, 157-172.
- Belkin, S., Wirsén, C. O. and Jannasch, H. W.: 1986, A new sulfur-reducing, extremely thermophilic eubacterium from a submarine thermal vent, *Appl. Environ. Microbiol.* **51**, 1180-1185.
- Belloc, H.: 1970, The microbe. *In Complete verse*, Gerald Duckworth, London, 246 pp.
- Benz, W., Slattery, W. and Cameron, A. G. W.: 1987, The origin of the moon and the single impact hypothesis II, *Icarus* **66**, 515-535.
- Berkowitz, N. and Calderon, J.: 1990, Extraction of oil sand bitumens with supercritical water, *Fuel Proc. Techn.* **25**, 33-44.
- Bernal, J. D.: 1951, *The Physical Basis of Life*, Routledge and Kegan Paul, London.
- Berndt, M. E. and Seyfried, W. E.: 1990, Boron, bromine, and other trace elements as clues to the fate of chlorine in mid-ocean ridge vent systems, *Geochim. Cosmochim. Acta* **54**, 2235-2246.
- Berndt, M. E., Seyfried, W. E. and Beck, J. W.: 1988, Hydrothermal alteration processes at mid-ocean ridges: Experimental and theoretical constraints from Ca and Sr exchange reactions and Sr isotopic ratios, *J. Geophys. Res.* **93**, 4573-4583.
- Berndt, M. E., Seyfried, W. E. and Janecky, D. R.: 1989, Plagioclase and epidote buffering of cation ratios in mid-ocean ridge hydrothermal fluids: Experimental results in and near the supercritical region, *Geochim. Cosmochim. Acta* **53**, 2283-2300.
- Berner, R. A.: 1967, Thermodynamic stability of sedimentary iron sulfides, *Amer. J. Sci.* **265**, 773-785.
- Bernhardt, G., Ludemann, H.-D., Jaenicke, R., König, H. and Stetter, K. O.: 1984, Biomolecules are unstable under "black smoker" conditions, *Naturwissenschaften* **71**, 583-586.
- Bernhauer, K.: 1929, Reaktionen zwischen Zuckerarten und deren Abbau Produkten mit stickstoffhaltigen Substanzen, *Z. Physiol. Chem.* **183**, 67-73.
- Bickle, M. J.: 1986, Implications of melting for stabilization of the lithosphere and heat loss in the Archaean, *Earth Planet. Sci. Lett.* **80**, 314-324.
- Biggerstaff, D. R.: 1986, The thermodynamic properties of aqueous solution of argon, ethylene, and xenon up to 720K and 34 MPa, Ph.D. Thesis, University of Delaware.
- Bird, D. K., Manning, C. E. and Rose, N. M.: 1988, Hydrothermal alteration of Tertiary layered gabbros, East Greenland, *Amer. J. Sci.* **288**, 405-457.
- Bird, D. K., Rogers, R. D. and Manning, C. E.: 1986, Mineralized fracture systems of the Skaergaard intrusion, East Greenland, *Meddelelser om Grønland, Geoscience* **16**, 68p.
- Bischoff, J. L. and Pitzer, K. S.: 1989, Liquid-vapor relations for the system NaCl-H₂O: Summary of the P-T-x surface from 300° to 500°C, *Amer. J. Sci.* **289**, 217-248.
- Bischoff, J. L. and Rosenbauer, R. J.: 1983, A note on the chemistry of seawater in the range 350°-500°C, *Geochim. Cosmochim. Acta* **47**, 139-144.
- Bischoff, J. L. and Rosenbauer, R. J.: 1984, The critical point and two-phase boundary of sea water, 200-500°C, *Earth Planet. Sci. Lett.* **68**, 172-180.

- Bischoff, J. L. and Rosenbauer, R. J.: 1987, Phase separation in seafloor geothermal systems: an experimental study of the effects on metal transport, *Amer. J. Sci.* **287**, 953-978.
- Bischoff, J. L. and Rosenbauer, R. J.: 1988, Liquid-vapor relations in the critical region of the system NaCl-H₂O from 380 to 415°C: A refined determination of the critical point and two-phase boundary of seawater, *Geochim. Cosmochim. Acta* **52**, 2121-2126.
- Bischoff, J. L. and Seyfried, W. E.: 1978, Hydrothermal chemistry of seawater from 25° to 350°C, *Amer. J. Sci.* **278**, 838-860.
- Bither, T. A., Bouchard, R. J., Cloud, W. H., Donahue, P. C. and Siemons, W. J.: 1968, Transition metal pyrite dichalcogenides, high-pressure synthesis and correlation of properties, *Inorg. Chem.* **87**, 2208-2220.
- Blair, J. S. and Braham, J. M.: 1924, Preparation of guanidinium salts from calcium cyanamide, *Ind. Eng. Chem.* **16**, 848-852.
- Blumer, M.: 1975, Curtisite, idrialite and pendletonite, polycyclic aromatic hydrocarbon minerals: Their composition and origin, *Chem. Geol.* **16**, 245-256.
- Blumer, M.: 1976, Polycyclic aromatic compounds in nature, *Sci. Amer.* **234**, 34-45.
- Boak, J. L. and Dymek, R. F.: 1982, Metamorphism of the ca. 3800 Ma supracrustal rocks at Isua, West Greenland: implications for early Archean crustal evolution, *Earth Planet. Sci. Lett.* **59**, 155-176.
- Böhlke, J. K., Honnorez, J., Honnorez-Guerstein, B.-M., Muehlenbachs, K. and Petersen, N.: 1981, Heterogeneous alteration of the upper oceanic crust: Correlation of rock chemistry, magnetic properties, and O isotope ratios with alteration patterns in basalts from site 396B, DSDP, *J. Geophys. Res.* **86**, 7935-7950.
- Bohon, R. L. and Claussen, W. F.: 1957, The solubility of aromatic hydrocarbons in water, *J. Amer. Chem. Soc.* **73**, 1571-1578.
- Bonatti, E., Simmons, E. C., Bregar, D., Hamlyn, P. R. and Lawrence, J.: 1983, Ultramafic rock/sea water interaction in the oceanic crust: Mg-silicate (sepiolite), deposit from the Indian Ocean floor, *Earth Planet. Sci. Lett.* **62**, 229-238.
- Borowska, Z. and Mauzerall, D.: 1987, Efficient near ultraviolet induced formation of hydrogen by ferrous hydroxide, *Origins Life Evol. Biosphere* **17**, 251-259.
- Boss, A. P.: 1990, 3D solar nebula models: implications for Earth origin, in *Origin of the Earth* (eds. H. E. Newson and J. H. Jones), Oxford University Press, New York, pp. 3-15.
- Bowers, T. S.: 1989, Stable isotope signatures of water-rock interaction in mid-ocean ridge hydrothermal systems: sulfur, oxygen, and hydrogen, *J. Geophys. Res.* **94**, 5775-5786.
- Bowers, T. S. and Taylor, H. P., Jr.: 1985, An integrated chemical and stable-isotope model of the origin of mid-ocean ridge hot springs, *J. Geophys. Res.* **90**, 12,583-12,606.
- Bowers, T. S., Campbell, A. C., Measures, C. I., Spivak, A. J., Khadem, M. and Edmond, J. M.: 1988, Chemical controls on the composition of vent fluids at 13 - 11°N and 21°N, East Pacific Rise, *J. Geophys. Res.* **93**, 4522-4536.
- Bowers, T. S., Von Damm, K. L. and Edmond, J. M.: 1985, Chemical evolution of mid-ocean ridge hot springs, *Geochim. Cosmochim. Acta* **49**, 2239-2252.

- Boyce, A. J., Coleman, M. L. and Russell, M. J.: 1983, Formation of fossil hydrothermal chimneys and mounds from Silvermines, Ireland, *Nature* **306**, 545-550.
- Bragger, J. M., Daniel, R. M., Coolbear, T. and Morgan, H. W.: 1989, Very stable enzymes from extremely thermophilic archaeobacteria and eubacteria, *Appl. Microbiol. Biotechnol.* **31**, 556-561.
- Brandts, J. F.: 1967, Heat effects on proteins and enzymes, in *Thermobiology* (ed. A. H. Rose), Academic Press, New York, pp. 25-72.
- Braterman, P. S. and Cairns-Smith, A. G.: 1987, Iron photo-precipitation and the genesis of the banded iron-formations, in *Precambrian Banded Iron-Formations* (eds. P. W. Uitterdijk Appel and G. L. LaBerge), Theophrastus Publications, S.A., pp. 215-245.
- Braterman, P. S., Cairns-Smith, A. G. and Sloper, R. W.: 1983, Photo-oxidation of hydrated Fe^{2+} - significance for banded iron formations, *Nature* **303**, 163-164.
- Brault, M. and Simoneit, B. R. T.: 1988, Steroid and triterpenoid distributions in Bransfield Strait sediments: Hydrothermally-enhanced diagenetic transformations, in *Advances in Organic Geochemistry 1987*, *Org. Geochem.* **13**, 697-705.
- Brault, M. and Simoneit, B. R. T.: 1989, Trace petroliferous organic matter associated with hydrothermal minerals from the Mid-Atlantic Ridge at the Trans-Atlantic Geotraverse 26°N site, *J. Geophys. Res.* **94**, 9791-9798.
- Brault, M., Simoneit, B. R. T., Marty, J. C. and Saliot, A.: 1985, Les hydrocarbures dans le système hydrothermal de la ride Est-Pacifique, à 13°N, *C.R. Acad. Sci. Paris* **301**, II, 807-812.
- Brault, M., Simoneit, B. R. T., Marty, J. C. and Saliot, A.: 1988, Hydrocarbons in waters and particulate material from hydrothermal environments at the East Pacific Rise, 13°N, *Org. Geochem.* **12**, 209-219.
- Brault, M., Simoneit, B. R. T. and Saliot, A.: 1989, Trace petroliferous organic matter associated with massive hydrothermal sulfides from the East Pacific Rise at 13°N and 21°N, *Ocean. Acta* **12**, 405-415.
- Briggs, R., Ertem, G., Ferris, J. P., Greenberg, J. M., McCain, P., Mendoza-Gomez, C. and Schutte, W.: 1992, Comet Halley as an aggregate of interstellar dust and further evidence for the photochemical formation of organics in the interstellar medium, *Origins Life Evol. Biosphere*, in press.
- Brikowski, T. and Norton, D.: 1989, Influence of magma chamber geometry on hydrothermal activity at mid-ocean ridges, *Earth Planet. Sci. Lett.* **93**, 241-255.
- Brimhall, G. H. and Crerar, D. A.: 1987, Chapt. 8, Ore Fluids: Magmatic or Supergene, in *Reviews in Mineralogy, Vol. 17, Thermodynamic Modeling of Geological Materials: Minerals, Fluids and Melts* (eds. I. S. E. Carmichael and H. P. Eugster), Mineralogical Society of America, Washington, D.C., pp. 235-321.
- Britton, H. T. S.: 1925, Hydrogen and oxygen electrode titrations of some dibasic acids and of dextrose, *J. Chem. Soc.* **127**, 1896-1917.
- Brock, T. D.: 1978, *Thermophilic Microorganisms and Life at High Temperatures*, Springer Verlag, New York.

- Brunmuller, F., Stecher, K., Kroener, M. and Schneider, R.: 1986, Reaction products of hydrogen cyanide, German Patent DE 3,443,462, 28 May 1986, *Chem. Abstr.* **105**, 135933p.
- Bryndzia, L. T., Wood, B. J. and Dick, H. J. B.: 1989, The oxidation state of the Earth's suboceanic mantle from oxygen thermobarometry of abyssal spinel peridotites, *Nature* **341**, 526-527.
- Budgen, N. and Danson, M. J.: 1986, Metabolism of glucose via a modified Entner-Doudoroff pathway in the thermoacidophilic archaeobacterium *Thermoplasma acidophilum*, *FEBS Lett.* **196**, 207-210.
- Burke, K. C. and Wilson, J. T.: 1976, Hot spots on the Earth's surface, in *Continents Adrift and Continents Aground*, W.H. Freeman, San Francisco, pp. 58-72.
- Burnham, W. C.: 1979, Magmas and hydrothermal fluids, in *Geochemistry of Hydrothermal Ore Deposits* (ed. H. L. Barnes), John Wiley & Sons, New York, pp. 71-136.
- Burns, R. G.: 1988, Gossans on Mars, *Proc. 18th Lunar & Planetary Science Conf.*, pp. 713-721.
- Butterfield, D. A., Massoth, G. J., McDuff, R. E., Lupton, J. E. and Lilley, M. D.: 1990, Geochemistry of hydrothermal fluids from Axial Seamount Hydrothermal Emissions Study Vent Field, Juan de Fuca Ridge: subseafloor boiling and subsequent fluid-rock interaction, *J. Geophys. Res.* **95**, 12,895-12,921.
- Cairns-Smith, A. G.: 1982, *Genetic Takeover and the Mineral Origins of Life*, Cambridge University Press.
- Cairns-Smith, A. G.: 1985, The first organisms, *Sci. Amer.* **252**, 90-100.
- Cameron, A. G. W.: 1986, The impact theory for origin of the moon, in *Origin of the Moon* (eds. W. K. Hartmann, R. J. Phillips and G. J. Taylor), Lunar and Planetary Institute, Houston, pp. 609-616.
- Campbell, A. C. and Edmond, J. M.: 1989, Halide systematics of submarine hydrothermal vents, *Nature* **342**, 168-170.
- Campbell, A. C., Bowers, T. S., Measures, C. I., Falkner, K. K., Khadem, M. and Edmond, J. M.: 1988a, A time series of vent compositions from 21°N, East Pacific Rise (1979, 1981, 1985), and the Guaymas Basin, Gulf of California (1982, 1985), *J. Geophys. Res.* **93**, 4537-4549.
- Campbell, A. C., Palmer, M. R., Klinkhammer, G. P., Bowers, T. S., Edmond, J. M., Lawrence, J. R., Casey, J. F., Thompson, G., Humphris, S., Rona P. and Karson, J. A.: 1988b, Chemistry of hot springs on the Mid-Atlantic Ridge, *Nature* **335**, 514-519.
- Cann, J. R. and Strens, M. R.: 1989, Modeling periodic megaplume emission by black smoker systems, *J. Geophys. Res.* **94**, 12,227-12,237.
- Cannant, M., Mével, C. and Stakes, D.: 1991, Normal ductile shear zones at an oceanic spreading ridge: Tectonic evolution of site 735 gabbros (Southwest Indian Ocean), *Proc. Ocean Drilling Program, Scientific Results* **118**, 415-429.
- Canuto, V. M., Levine, J. S., Augustsson, T. R. and Imhoff, C. L.: 1982, UV radiation from the young sun and oxygen and ozone levels in the prebiological paleoatmosphere, *Nature* **296**, 816-820.
- Canuto, V. M., Levine, J. S., Augustsson, T. R., Imhoff, C. L. and Giampapa, M. S.: 1983, The young sun and the atmosphere and photochemistry of the early Earth, *Nature* **305**, 281-286.

- Card, K. D.: 1990, A review of the Superior Province of the Canadian Shield, a product of Archean accretion, *Precambrian Research* **48**, 99-156.
- Carothers, W. W. and Kharaka, Y. K.: 1978, Aliphatic acid anions in oil-field waters - implications for origin of natural gas, *Amer. Assoc. Petrol. Geol. Bull.* **62**, 2441-2453.
- Chang, S., DesMarais, D., Mack, R., Miller, S. L. and Strathearn, G. E.: 1983, Prebiotic organic syntheses and the origin of life, in *Earth's Earliest Biosphere* (ed. J. W. Schopf), Princeton University Press, Princeton, pp. 53-92.
- Chase, R. L., Delaney, J. R., Karsten, J. L., Johnson, H. P., Juniper, S. K., Lupton, J. E., Scott, S. D., Tunnicliffe, V., Hammond, S. R. and McDuff, R. E.: 1985, Hydrothermal vents on an axis seamount of the Juan de Fuca ridge, *Nature* **313**, 212-214.
- Chen, C.-T. A.: 1981, Geothermal systems at 21°N, *Science* **211**, 298.
- Childress, J. J. (Ed.): 1988, Hydrothermal vents, a case study of the biology and chemistry of a deep-sea hydrothermal vent of the Galapagos Rift, the Rose Garden in 1985, *Deep-Sea Res.* **35**, 1677-1849.
- Choughuley, A. S. U. and Lemmon, R. M.: 1966, Production of cysteic acid, taurine and cystamine under primitive Earth conditions, *Nature* **210**, 628-629.
- Chyba, C. F. and Sagan, C.: 1992, Endogenous production, exogenous delivery and impact shock synthesis of organic molecules: an inventory for the origins of life, *Nature* **355**, 125-132.
- Chyba, C. F., Thomas, P. J., Brookshaw, L. and Sagan, C.: 1990, Cometary delivery of organic molecules to the early Earth, *Science* **249**, 366-373.
- Clark, P. D., Clarke, R. A. and Hyne, J. B.: 1986, Aquathermolysis: The chemical reaction of steam with heavy oils - emphasizing the critical role of sulphur compounds, Alberta Sulphur Research Ltd., *Quart. Bull.* **21**, 1 and 2, 20 pp.
- Clark, P. D., Hyne, J. B. and Tyrer, J. D.: 1983, Chemistry of organosulfur compound types occurring in heavy oil sands. 1. High temperature hydrolysis and thermolysis of tetrahydrothiophene in relation to steam stimulation processes, *Fuel* **62**, 959-962.
- Clemmey, H. and Badham, N.: 1982, Oxygen in the Precambrian atmosphere: An evaluation of the geological evidence, *Geology* **10**, 141-146.
- Clifton, C. G., Walters, C. C. and Simoneit, B. R. T.: 1990, Hydrothermal petroleums from Yellowstone National Park, Wyoming, U.S.A, in *Organic Matter in Hydrothermal Systems - Petroleum Generation, Migration and Biogeochemistry* (ed. B. R. T. Simoneit), *Appl. Geochem.* **5**, 169-191.
- Coatman, R. D., Thomas, N. L. and Double, D. D.: 1980, Studies of the growth of "silicate gardens" and related phenomena, *J. Materials Sci.* **15**, 2017-2026.
- Cocker, J. D., Griffin, B. J. and Muehlenbachs, K.: 1982, Oxygen and carbon isotope evidence for seawater-hydrothermal alteration of the Macquarie Island ophiolite, *Earth Planet. Sci. Lett.* **61**, 112-122.
- Cogley, J. G. and Henderson-Sellers, A.: 1984, The origins and earliest state of the Earth's hydrosphere, *Rev. Geophys. Space Physics* **22**, 131-175.
- Coish, R. A.: 1977, Ocean floor metamorphism in the Betts Cove ophiolite, Newfoundland, *Contrib. Mineral. Petrol.* **60**, 255-270.

- Cole, D. R., Mottl, M. J. and Ohmoto, H.: 1987, Isotopic exchange in mineral-fluid systems. II. Oxygen and hydrogen isotopic investigation of the experimental basalt-seawater system, *Geochim. Cosmochim. Acta.* **51**, 1523-1538.
- Conant, J. B., ed.: 1953, Pasteur's and Tyndall's study of spontaneous generation, in *Harvard Case Histories in Experimental Science*, Harvard University Press, Cambridge.
- Condie, K. C.: 1981, *Archean Greenstone Belts*, Developments in Precambrian Geology 3, Elsevier, Amsterdam.
- Connolly, J. F.: 1966, Solubility of hydrocarbons in water near the critical solution temperatures, *J. Chem. Eng. Data* **11**, 13-16.
- Converse, D. R., Holland, H. D. and Edmond, J. M.: 1984, Flow rates in the axial hot springs of the East Pacific Rise (21°N): Implications for the heat budget and the formation of massive sulfide deposits, *Earth Planet. Sci. Lett.* **69**, 159-175.
- Corliss, J. B.: 1979, Metallogenesis at oceanic spreading centres, *J. Geol. Soc. Lond.* **136**, 621-626.
- Corliss, J. B.: 1986, On the creation of living cells in submarine hot spring flow reactors: Attractors and bifurcations in the natural hierarchy dissipative systems, *Origins Life Evol. Biosphere* **16**, 381-382.
- Corliss, J. B.: 1989, Submarine hot springs again (abstr.), *Origins Life Evol. Biosphere* **19**, 534-535.
- Corliss, J. B.: 1990, Hot springs and the origin of life, *Nature* **347**, 624.
- Corliss, J. B., Baross, J. A. and Hoffman, S. E.: 1981, An hypothesis concerning the relationship between submarine hot springs and the origin of life on Earth, *Ocean. Acta N° SP*, 59-69.
- Corliss, J. B., Dymond, J., Gordon, L. I., Edmond, J. M., von Herzen, R. P., Ballard, R. D., Green, K., Williams, D., Bainbridge, A., Crane, K. and van Andel, T. H.: 1979, Submarine thermal springs on the Galapagos Rift, *Science* **203**, 1073-1083.
- Cornejo, J., Criado, J. M. and Trillo, J. M.: 1979, Decomposition of acetic acid on manganese (II), oxide, *An. Quim.* **75**, 460; *Chem. Abstr.* **91**, 157024n.
- COSOD II Report: 1987, Report of the Second Conference on Scientific Ocean Drilling, Joint Oceanographic Institutions for Deep Earth Sampling/European Science Foundation, Washington, D.C./Strasbourg, 142 pp.
- Courtillot, V. E.: 1990, What caused the mass extinction? A volcanic eruption, *Sci. Amer.* **263**(4), 53-60.
- Courtillot, V. and Besse, J.: 1987, Magnetic field reversals, polar wander, and core-mantle coupling, *Science* **237**, 1140-1147.
- Coveney, R. M., Geobel, E. D., Zeller, E. J., Dreschhoff, G. A. M. and Angino, E. E.: 1987, Serpentinization and the origin of hydrogen gas in Kansas, *Amer. Assoc. Petrol. Geol. Bull.* **71**, 39-48.
- Cowan, D. A., Smolenski, K. A., Daniel, R. M. and Morgan, H. W.: 1987, An extremely thermostable extracellular proteinase from a strain of the archaeobacterium *Desulfurococcus* growing at 88°C, *J. Biochem.* **207**, 641-644.
- Cowan, J. and Cann, J.: 1988, Supercritical two-phase separation of hydrothermal fluids in the Troodos ophiolite, *Nature* **333**, 259-261.

- Crerar, D. A., Susak, N. J., Borcsik, M. and Schwartz, S.: 1978, Solubility of the buffer assemblage pyrite + pyrrhotite + magnetite in NaCl solutions from 200 to 350°C, *Geochim. Cosmochim. Acta* **42**, 1427-1437.
- Cronin, J. R., Pizzarello, S. and Cruickshank, D. P.: 1988, in *Meteorites and the Early Solar System* (eds. J. F. Kerridge and M. S. Mathews), Univ. of Arizona Press, Tucson, pp. 819-857.
- Crozier, T. E. and Yamamoto, S.: 1974, Solubility of hydrogen in water, seawater, and NaCl solutions, *J. Chem. Eng. Data* **19**, 242-244.
- Curray, J. R., Moore, D. G., Aguayo, J. E., Aubry, M. P., Einsele, G., Fornari, D. J., Gieskes, J., Guerrero-Garcia, J. C., Kastner, M., Kelts, K., Lyle, M., Matoba, Y., Molina-Cruz, A., Niemitz, J., Rueda-Gaxiola, J., Saunders, A. D., Schrader, J., Simoneit, B. R. T., and Vacquier, V.: 1979, Deep sea drilling in the Gulf of California, Leg 64, *Geotimes* **24**, 18-20.
- Curray, J. R., Moore, D. G., Aguayo, J. E., Aubry, M. P., Einsele, G., Fornari, D. J., Gieskes, J., Guerrero, J. C., Kastner, M., Kelts, K., Lyle, M., Matoba, Y., Molina-Cruz, A., Niemitz, J., Rueda, J., Saunders, A. D., Schrader, H., Simoneit, B. R. T. and Vacquier, V.: 1982, *Initial Reports of the Deep Sea Drilling Project*, Vol. 64, Parts I and II, U.S. Government Printing Office, Washington, D.C., 1314 p.
- Czamanske, G. K., Erd, R. C., Sokolova, M. N., Dobrovol'skaya, M. G. and Dmitrieva, M. T.: 1979, New data on rasvumite and djerfisherite, *Amer. Mineral.* **64**, 776-778.
- Czamanske, G. K., Leonard, B. F. and Clark, J. R.: 1980, Erdite, a new hydrated sodium iron sulfide mineral, *Amer. Mineral.* **65**, 509-515.
- Czochanska, Z., Sheppard, C. M., Weston, R. J., Woolhouse, A. D. and Cook, R. A.: 1986, Organic geochemistry of sediments in New Zealand, Part I. A biomarker study of the petroleum seepage at the geothermal region of Waiotapu, *Geochim. Cosmochim. Acta* **50**, 507-515.
- Daniel, R. M.: 1985, The stability of proteins from extreme thermophiles, *J. Cell. Biochem., Suppl.* **9B**, 144.
- Daniel, R. M.: 1986, The immune response to proteins from extreme thermophiles, *J. Theoret. Biol.* **120**, 125-127.
- Daniel, R. M., Bragger, J. and Morgan, H. W.: 1990, Enzymes from extreme environments, in *Biocatalysis* (ed. D. A. Abranowicz), Van Nostrand Reinhold, New York, pp. 243-254.
- Daniel, R. M., Cowan, D. A., Curran, M. P. and Morgan, H. W.: 1982, A correlation between protein thermostability and resistance to proteolysis, *J. Biochem.* **207**, 641-644.
- Danson, M. J.: 1988, Archaeobacteria: The comparative enzymology of their central metabolic pathways, *Adv. Microbial Physiol.* **29**, 165-231.
- Darken, L. S.: 1941, The ionization constants of oxalic acid at 25° from conductance measurements, *J. Amer. Chem. Soc.* **63**, 1007-1011.
- Davies, G. F.: 1980, Thermal histories of convective Earth models and constraints on radiogenic heat production in the Earth, *J. Geophys. Res.* **85**, 2517-2530.
- Davies, G. H.: 1990, Heat and mass transport in the early Earth, in *Origin of the Earth* (eds. H. E. Newson and J. H. Jones), Oxford University Press, New York, pp. 175-194.

- Davis, S. N.: 1969, Porosity and permeability of natural materials, in *Flow through Porous Materials* (ed. R. J. M. DeWiest), Academic Press, New York, pp. 54-89.
- Dawkins, R.: 1986, *The Blind Watchmaker*, Harlow, Essex: Longman.
- Dayhoff, M. O., Lippincott, E. R., Eck, R.V. and Nagarajan, G.: 1967, *Thermodynamic Equilibrium in Prebiological Atmospheres of C, H, O, N, P, S, and Cl.*, NASA SP-3040 Washington, D.C., 259p.
- de Duve, C.: 1991, *Blueprint for a Cell: The Nature and Origin of Life*, Neil Patterson Publishers, Burlington, North Carolina, pp. 126-127.
- Degens, E. T.: 1979, Primordial synthesis of organic matter, in *The Global Carbon Cycle*, Chapt. 2 (eds. B. Bolin, E. T. Degens, S. Kempe and P. Ketner), John Wiley & Sons, Chichester, pp. 57-77.
- Degens, E. T. and Matheja, J. H.: 1968, Origin, development and diagenesis of biogeochemical compounds, *J. Brit. Interplanet. Soc.* **21**, 52-82.
- Degens, E. T. and Ross, D. A.: 1969, *Hot Brines and Recent Heavy Metal Deposits in the Red Sea*, Springer-Verlag, New York.
- Delaney, J. R., Mogk, D. W. and Mottl, M. J.: 1987, Quartz-cemented breccias from the mid-Atlantic Ridge: Samples of a high-salinity hydrothermal upflow zone, *J. Geophys. Res.* **92**, 9175-9192.
- Deming, J. W.: 1991, Deep-sea and laboratory evidence for the existence of microorganisms at high temperatures and pressures (abs.), *Geol. Soc. Amer. Abstr. & Prog.* **23**, A19.
- DeRosa, M., Gambacorta, A., Nicholaus, B., Giardina, P., Paerio, E. and Buonocore, V.: 1984, Glucose metabolism in the extreme thermoacidophilic archaebacterium *Sulfolobus solfataricus*, *J. Biochem.* **224**, 407.
- de Wit, M. J., Hart, R., Martin, A. and Abbott, P.: 1982, Archean abiogenic and probable biogenic structures associated with mineralized hydrothermal vent systems and regional metasomatism, with implications for greenstone belt studies, *Econ. Geol.* **77**, 1783-1802.
- de Wit, M. J., Hart, R., Stern, C. R. and Barton, C. M.: 1980, Metallogenesis related to seawater interaction with 3.5 b.y. oceanic crust, *EOS* **61**, 386.
- Dick, H. J. B., Meyer, P. S., Bloomer, S., Kirby, S., Stakes, D. and Mawer, C.: 1991, Lithostratigraphic evolution of an *in-situ* section of oceanic layer 3, *Proc. Ocean Drilling Program, Scientific Results* **118**, 439-538.
- Didyk, B. M. and Simoneit, B. R. T.: 1989, Hydrothermal oil of Guaymas Basin and implications for petroleum formation mechanisms, *Nature* **342**, 65-69.
- Didyk, B. M. and Simoneit, B. R. T.: 1990, Petroleum characteristics of the oil in a Guaymas Basin hydrothermal chimney, in *Organic Matter Alteration in Hydrothermal Systems - Petroleum Generation, Migration and Biogeochemistry* (ed. B. R. T. Simoneit), *Appl. Geochem.* **5**, 29-40.
- Donn, B.: 1982, Comets: Chemistry and chemical evolution, *J. Molec. Evol.* **18**, 157-160.
- Dowler, M. J. and Ingmanson, D. E.: 1979, Thiocyanate in Red Sea brine and its implications, *Nature* **279**, 51-52.
- Drucker, C.: 1920, Weitere Untersuchungen über die Dissoziation ternärer Elektrolyte, *Z. Physik. Chem.* **96**, 381-427.

- Drummond, S. E.: 1981, Boiling and mixing of hydrothermal fluids: effects on mineral deposition, Ph.D. Thesis, Pennsylvania State University, 400 p.
- Drummond, S. E. and Palmer, D. A.: 1985, Thermal decarboxylation of acetate, Part II. Boundary conditions for the role of acetate in the primary migration of natural gas and the transportation of metals in hydrothermal systems, *Geochim. Cosmochim. Acta* **50**, 825.
- Dunn, L. A. and Marshall, W. L.: 1969, Electrical conductances of aqueous sodium iodide and the comparative thermodynamic behavior of aqueous sodium halide solutions to 800° and 4000 bars, *J. Phys. Chem.* **73**, 723-728.
- Eckert, C. A., Van Alsten, J. G. and Stoicos, T.: 1986, Supercritical fluid processing, *Environ. Sci. Technol.* **20**, 319-325.
- Edmond, J. M.: 1991, U.S. research on oceanic hydrothermal chemistry: 1987-1990, Reviews of Geophysics Suppl., *U.S. National Report 1987-1990*, 645-647.
- Edmond, J. M. and Von Damm, K.: 1983, Hot springs on the ocean floor, *Sci. Amer.* **248**(4), 78-93.
- Edmond, J. M., von Damm, K. L. and Bowers, T. S.: 1987, The chemistry of submarine ore-forming solutions, in *Marine Minerals* (eds. P.G. Teleki *et al.*), Reidel Publishing Co., pp. 339-347.
- Edmond, J. M., Measures, C., McDuff, R. E., Chan, L., Collier, R., Grand, B., Gordon, L. I. and Corliss, J.: 1979a, Ridge crest hydrothermal activity and the balances of the major and minor elements in the ocean: the Galapagos data, *Earth Planet. Sci. Lett.* **46**, 1-18.
- Edmond, J. M., Measures, C., Mangum, B., Grant, B., Sclater, F. R., Collier, R., Hudson, A., Gordon, L. I. and Corliss, J.: 1979b, On the formation of metal-rich deposits at ridge crests, *Earth Planet. Sci. Lett.* **46**, 19-30.
- Edmond, J. M., von Damm, K. L., McDuff, R. E. and Measures, C. I.: 1982, Chemistry of hot springs on the East Pacific Rise and their effluent dispersal, *Nature* **297**, 187-191.
- Egami, F.: 1974, Minor elements and evolution, *J. Molec. Evol.* **4**, 113-120.
- Egami, F.: 1981, A working hypothesis on the interdependent genesis of nucleotide bases, protein amino acids, and primitive genetic code, *Origins Life Evol. Biosphere* **11**, 197-202.
- Eigen, M. and Shuster, P.: 1978, The hypercycle: A principle of natural self-organization, Part C: The realistic hypercycle, *Naturwissenschaften* **65**, 341-369.
- Eigen, M. and Wick, E. E.: 1954, The thermodynamics of electrolytes at higher concentration, *J. Phys. Chem.* **58**, 702-714.
- Einsele, G., Gieskes, J. M., Curray, J., Moore, D. M., Aguayo, E., Aubry, M.-P., Fornari, D., Guerrero, J., Kastner, M., Kelts, K., Lyle, M., Matoba, Y., Molina-Cruz, A., Niemitz, J., Rueda, J., Saunders, A., Schrader, H., Simoneit, B. and Vacquier, V.: 1980, Intrusion of basaltic sills into highly porous sediments, and resulting hydrothermal activity, *Nature* **283**, 441-445.
- Ellis, A. J. and Golding, R. M.: 1963, The solubility of carbon dioxide above 100°C in water and in sodium chloride solutions, *Amer. J. Sci.* **261**, 47-60.
- Epps, D. E., Sherwood, E., Eichberg, J. and Oró, J.: 1978, Cyanamide mediated syntheses under plausible primitive Earth conditions. V. The synthesis of phosphatidic acids, *J. Molec. Evol.* **11**, 279-292.

- EPRDPG (Ocean Drilling Program East Pacific Rise Detailed Planning Group): 1991, Recommendations for an East Pacific Rise drilling program, *JOIDES Journal* **17**, 35-53.
- Evans, W. C., White, L. D. and Rapp, J. B.: 1988, Geochemistry of some gases in hydrothermal fluids from the southern Juan de Fuca Ridge, *J. Geophys. Res.* **93**, 15,305-15,313.
- Evarts, R. C. and Schiffman, P.: 1983, Submarine hydrothermal metamorphism of the Del Puerto Ophiolite, California, *Amer. J. Sci.* **283**, 289-340.
- Falbe, J.: 1980, *New Syntheses with Carbon Monoxide*, Springer-Verlag, Berlin.
- Fegley, B., Jr. and Prinn, R. G.: 1989, Chemical reprocessing of the Earth's present and primordial atmosphere by large impacts, in *Interactions of the Solid Planet with the Atmosphere and Climate* (ed. G. Visconti).
- Fegley, B., Jr., Prinn, R. G., Hartman H. and Watkins, G. H.: 1986, Chemical effects of large impacts on the Earth's primitive atmosphere, *Nature* **319**, 305-308.
- Fehn, U.: 1986, The evolution of low-temperature convection cells near spreading centers: A mechanism for the formation of the Galapagos mounds and similar manganese deposits, *Econ. Geol.* **81**, 1396-1407.
- Fehn, U. and Cathles, L. M.: 1986, The influence of plate movement on the evolution of hydrothermal convection cells in the oceanic crust, *Tectonophysics* **125**, 289-312.
- Fehn, U., Green, K. E., von Herzen, R. P. and Cathles, L. M.: 1983, Numerical models for the hydrothermal field at the Galapagos Spreading Center, *J. Geophys. Res.* **88**, 1033-1048.
- Ferris, J. P.: 1987, Prebiotic synthesis - problems and challenges, Cold Spring Harbor Symp., *Quant. Biol.* **52**, 29-35.
- Ferris, J. P. and Chen, C. T.: 1975a, Photosynthesis of organic compounds in the atmosphere of Jupiter, *Nature* **258**, 587-588.
- Ferris, J. P. and Chen, C. T.: 1975b, Chemical evolution XXVI. Photochemistry of methane, nitrogen and water mixtures as a model for the atmosphere of the primitive Earth, *J. Amer. Chem. Soc.* **97**, 2962-2967.
- Ferris, J. P. and Edelson, E. H.: 1978, Chemical evolution XXXI. Mechanism of the condensation of cyanide to HCN oligomers, *J. Org. Chem.* **43**, 3989-3995.
- Ferris, J. P. and Guillemin, J.-C.: 1990, Photochemical cycloaddition reactions of cyanoacetylene and dicyanoacetylene, *J. Org. Chem.* **55**, 5601-5606.
- Ferris, J. P. and Hagan, W. J., Jr.: 1984, HCN and chemical evolution: The possible role of cyano compounds in prebiotic synthesis, *Tetrahedron* **40**, 1093-1120.
- Ferris, J. P. and Ishikawa, Y.: 1988, The formation of HCN and acetylene oligomers by photolysis of ammonia in the presence of acetylene: Applications to the atmospheric chemistry of Jupiter, *J. Amer. Chem. Soc.* **110**, 4306-4312.
- Ferris, J. P. and Joshi, P.: 1979, Chemical evolution XXXIII. Photochemical decarboxylation of orotic acid, orotidine and orotidine 5'-phosphate, *J. Org. Chem.* **44**, 2133-2137.
- Ferris, J. P. and Kamaluddin: 1989, Oligomerisation reactions of deoxyribonucleotides on montmorillonite clay: the effect of mononucleotide structure on phosphodiester bond formation, *Origins Life Evol. Biosphere* **19**, 609-619.

- Ferris, J. P. and Orgel, L. E.: 1966, An unusual photochemical rearrangement in the synthesis of adenine, *J. Amer. Chem. Soc.* **88**, 1074.
- Ferris, J. P., Goldstein, G. and Beaulieu, D. J.: 1970, Chemical evolution IV. An evaluation of cyanovinyl phosphate as a prebiotic phosphorylating agent, *J. Amer. Chem. Soc.* **92**, 6598-6603.
- Ferris, J. P., Gözen, E. and Agarwal, V.: 1989, 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, *Origins Life Evol. Biosphere* **19**, 165-178.
- Ferris, J. P., Joshi, P. C., Edelson, E. H. and Lawless, J. G.: 1978, HCN: A plausible source of purines, pyrimidines and amino acids on the primitive Earth, *J. Molec. Evol.* **11**, 293-311.
- Ferris, J. P., Kamaluddin and Ertem, G.: 1990, Oligomerization reactions of deoxyribonucleotides on montmorillonite clay: The effect of mononucleotide structure, phosphate activation and montmorillonite composition on phosphodiester bond formation, *Origins Life Evol. Biosphere* **20**, 279-291.
- Ferris, J. P., Sanchez, R. A. and Orgel, L. E.: 1968, Studies in prebiotic synthesis III. Synthesis of pyrimidines from cyanoacetylene and cyanate, *J. Molec. Biol.* **33**, 693-704.
- Ferris, J. P., Williams, E. A., Nicodem, D. E., Hubbard, J. S. and Voecks, G. E.: 1974a, Photolysis of CO-NH₃ mixtures and the Martian atmosphere, *Nature* **249**, 437-439.
- Ferris, J. P., Zamek, O. S., Altbuch, A. M. and Freiman, H.: 1974b, Chemical evolution XVIII. Synthesis of pyrimidines from guanidine and cyanoacetaldehyde, *J. Molec. Evol.* **3**, 301-309.
- Fiala, G. and Stetter, K.O.: 1986, *Pyrococcus furiosus* sp. nov. represents a novel genus of marine heterotrophic archaeobacteria growing optimally at 100°C, *Arch. Microbiol.* **145**, 56-61.
- Field, B. O. and Spencer, J. E. D.: 1990, The synthesis of amino acids and sugars on an inorganic template from constituents of the prebiotic atmosphere, *Origins Life Evol. Biosphere* **20**, 233-248.
- Finklea, S. L., III, Cathey, S. and Amma, E. L.: 1976, Investigation of the bonding mechanism in pyrite using the Mössbauer effect, *Acta Crystall.* **A32**, 529-537.
- Finn, M. J., Bower, C. J. and Hughes, R. D.: 1983, The extraction of coal with supercritical hydrocarbon mixtures, *Fluid Phase Equilibria* **10**, 327-336.
- Fischer, F., Zillig, W., Stetter, K. O. and Schreiber, G.: 1983, Chemolithoautotrophic metabolism of anerobic extremely thermophilic archaeobacteria, *Nature* **301**, 511-513.
- Fisher, A. T. and Becker, K.: 1991, Heat flow, hydrothermal circulation and basalt intrusions in the Guaymas Basin, Gulf of California, *Earth Planet. Sci. Lett.* **103**, 84-99.
- Fisher, A. T. and Narasimhan, T. N.: 1991, Numerical simulations of hydrothermal circulation resulting from basalt intrusions in a buried spreading center, *Earth Planet. Sci. Lett.* **193**, 100-115.
- Fisher, A. T., Becker, K., Narasimhan, T. N., Langseth, M. G. and Mottl, M.J.: 1990, Passive, off-axis convection through the southern flank of the Costa Rica Rift, *J. Geophys. Res.* **95**, 9343-9370.
- Fisher, J. R. and Barnes, H. L.: 1972, The ion-product constant of water to 350°, *J. Phys. Chem.* **76**, 90-99.

- Flegmann, A. W. and Tattersall, R.: 1979, Energetics of peptide bond formation at elevated temperatures, *J. Molec. Evol.* **12**, 349-355.
- Fouche, C. E., Jr. and Rohlfing, D. L.: 1976, Thermal polymerization of amino acids under various atmospheres or at low pressures, *Biosystems* **8**, 57-65.
- Fouquet, Y., von Stackelberg, U., Charlou, J. L., Donval, J. P., Erzinger, J., Foucher, J. P., Herzig, P., Mähe, R., Soakai, S., Wiedicke, M. and Whitechurch, H.: 1991, Hydrothermal activity and metallogenesis in the Lau back-arc basin, *Nature* **349**, 778-781.
- Fox, C. G.: 1990, Consequences of phase separation on the distribution of hydrothermal fluids at ASHES Vent Field, Axial Volcano, Juan de Fuca Ridge, *J. Geophys. Res.* **95**, 12,923-12,926.
- Fox, G. E., Stackebrandt, E., Hespell, R. B., Gibson, J., Maniloff, J., Dyer, T. A., Wolfe, R. S., Bolch, W. E., Tanner, R. S., Mogrum, L. J., Zablen, L. B., Blackmore, R., Gupta, R., Bonen, L., Lennis, B. J., Stahl, D. A., Leuhusen, K. R., Chen, K. N. and Woese, C. R.: 1980, The phylogeny of prokaryotes, *Science* **209**, 457-463.
- Fox, S. W.: 1963, Prebiological formation of biochemical substances, *Int. Series Monographs on Earth Sciences* **16**, 36-49.
- Fox, S. W.: 1964, Thermal polymerization of amino-acids and production of formed microparticles on lava, *Nature* **201**, 336-337.
- Fox, S. W.: 1965, A theory of macromolecular and cellular origins, *Nature* **205**, 328-340.
- Fox, S. W. and Dose, K.: 1977, *Molecular Evolution and the Origin of Life* (eds. S. W. Fox and K. Dose), Marcel Dekker, Inc., New York.
- Fox, S. W. and Harada, K.: 1958, Thermal copolymerization of amino acids to a product resembling protein, *Science* **128**, 1214.
- Fox, S. W. and Harada, K.: 1960, The thermal copolymerization of amino acids common to protein, *J. Amer. Chem. Soc.* **82**, 3745-3751.
- Fox, S. W. and Harada, K.: 1961, Synthesis of uracil under conditions of a thermal model of prebiological chemistry, *Science* **133**, 1923-1924.
- Fox, S. W. and Nakashima, T.: 1981, Terrestrial evolution of polymerization of amino acids: Heat to ATP, in *Origin of Life* (ed. Y. Wolman), Reidel Publishing Co., Dordrecht, pp. 271-276.
- Fox, S. W. and Waehneltd, T. V.: 1968, The thermal synthesis of neutral and basic proteinoids, *Biochim. Biophys. Acta* **160**, 246-249.
- Fox, S. W. and Windsor, C. R.: 1970, Synthesis of amino acids by the heating of formaldehyde and ammonia, *Science* **170**, 984-985.
- Fox, S. W., Harada, K. and Vegotsky, A.: 1959, Thermal polymerization of amino acids and a theory of biochemical origins, *Experientia* **15**, 81-84.
- Fox, S. W., Harada, K., Woods, K. R. and Windson, C. R.: 1963, Amino acid compositions of proteinoids, *Archives of Biochem. Biophys.* **102**, 430-445.
- Fox, S. W., Johnson, J. E. and Middlebrook, M.: 1955, Pyrosynthesis of aspartic acid and alanine from citric acid cycle intermediates, *J. Amer. Chem. Soc.* **77**, 1048-1049.
- Fox, S. W., Vegotsky, A., Harada, K. and Hoagland, P. D.: 1957, Spontaneous generation of anabolic pathways, protein, and nucleic acid, *Annals New York Acad. Sci.* **69**, 328-337.

- Francheteau, J., Needham, H. D., Chroukroune, P., Juteau, T., Séguret, M., Ballard, R. D., Fox, P. J., Normark, W., Carranza, A., Cordoba, D., Guerrero, J., Rangin, C., Bougalt, H., Cambon, P. and Hékinian, R.: 1979, Massive deep-sea sulphide ore deposits discovered on the East Pacific Rise, *Nature* **277**, 523-528.
- Franck, E. U.: 1987, Fluids at high pressures and temperatures, *J. Chem. Thermodynamics* **19**, 225-242.
- Franck, E. U. *et al.* (Eds.): 1983, Supercritical fluids, their chemistry and application, *Fluid Phase Equilibria* **10**, 135-354.
- Franklin, J. M., Lydon, J. W. and Sangster, D. F.: 1981, Volcanic-associated massive sulfide deposits, *Econ. Geol. Seventy-Fifth Anniv. Vol.*, 485-627.
- French, B. M.: 1964, 1. Synthesis and stability of siderite, FeCO₃, 2. Progressive contact metamorphism of the Biwabik Iron Formation on the Mesabi Range, Minnesota, Ph.D. Thesis, The Johns Hopkins University, Baltimore, MD.
- French, B. M.: 1971, Stability relations of siderite (FeCO₃), in the system Fe-C-O, *Amer. J. Sci.* **271**, 37-78.
- French, B. M. and Eugster, H. P.: 1965, Experimental control of oxygen fugacities by graphite-gas equilibria, *J. Geophys. Res.* **70**, 6, 1529-1539.
- Fripp, R. E. P.: 1976, Stratabound gold deposits in Archean banded iron-formation, Rhodesia, *Econ. Geol.* **71**, 58-75.
- Fuki, M., Furukawa, S., Koga, I. and Inoi, T.: 1974, Ketones from carboxylic acids, Japan Patent 490 30309, 18 March, 1974; *Chem. Abstr.* **81**, 77474n.
- Funazukuri, T., Takanashi, T. and Wakao, N.: 1987, Supercritical extraction of used automotive tire with water, *J. Chem. Eng. Japan* **20**, 23-27.
- Fühner, H.: 1924, Die Wasserlöslichkeit in homologen Reihen, *Chem. Ber.* **57**, 510-515.
- Fyfe, W. S.: 1978, The evolution of the Earth's crust: Modern plate tectonics to ancient hot spot tectonics, *Chem. Geol.* **23**, 89-114.
- Gabel, N. W. and Ponnampertuma, C.: 1967, Model for origin of monosaccharides, *Nature* **216**, 453.
- Garrison, W. M., Morrison, D. C., Hamilton, J. G., Benson, A. A. and Calvin, M.: 1951, Reduction of carbon dioxide in aqueous solutions by ionizing radiation, *Science* **114**, 416-418.
- Geissman, T. A., Sim, K. Y. and Murdoch, J.: 1967, Organic minerals. Picene and chrysene as constituents of the mineral curtsite (idrialite), *Experientia* **23**, 793-794.
- Genkin, A. D., Troneva, N. V. and Zhuravlev, N. N.: 1970, The first occurrence in ores of the sulfide of potassium, iron, and copper, djervisherite, *Geochem. Internat.* **7**, 693-701.
- Getoff, N.: 1962, Reduktion der Kohlensäure in wässriger Lösung unter Einwirkung von UV-Licht, *Zeitschrift für Naturforschung* **17B**, 87-90.
- Gieskes, J. M., Elderfield, H., Lawrence, J. R., Johnson, J., Meyers, B. and Campbell, A. C.: 1982a, Geochemistry of interstitial waters and sediments, Leg 64, Gulf of California, in *Initial Reports of the Deep Sea Drilling Project* **64(2)**, 675-694.

- Gieskes, J. M., Kastner, M., Einsele, G., Kelts, K. and Niemitz, J.: 1982b, Hydrothermal activity in the Guaymas Basin, Gulf of California: A synthesis, in *Initial Reports of the Deep Sea Drilling Project* **64(2)**, 1159-1168.
- Gieskes, J. M., Simoneit, B. R. T., Brown, T., Shaw, T., Wang, Y.-C. and Magenheimer, A.: 1988, Hydrothermal fluids and petroleum in surface sediments of Guaymas Basin, Gulf of California: A case study, *Can. Mineral.* **26**, 589-602.
- Gillan, F. T. and Johns, R. B.: 1986, Chemical markers for marine bacteria: fatty acids and pigments, in *Biological Markers in the Sedimentary Record* (ed. R. B. Johns), Elsevier, Amsterdam, pp. 291-309.
- Goldfarb, M. S. and Delaney, J. R.: 1988, Response of two-phase fluids to fracture configurations within submarine hydrothermal systems, *J. Geophys. Res.* **93**, 4585-4594.
- Goldschmidt, V. M.: 1952, Geochemical aspects of the origin of complex organic molecules on the Earth, as precursors to life, *New Biology* **12**, 97-105.
- Gole, M. J. and Klein, C.: 1981, Banded iron formation through much of Precambrian time, *J. Geol.* **89**, 169-183.
- Granick, S.: 1957, Speculations on the origins and evolution of photosynthesis, *Annals New York Acad. Sci.* **69**, 292-308.
- Grant-Taylor, D. F.: 1981, Partial molal volumes of sodium chloride solutions at 200 bar, and temperatures from 175° to 350°C, *J. Soln. Chem.* **10**, 621-630.
- Grassle, J. F.: 1985, Hydrothermal vent animals: Distribution and biology, *Science* **229**, 713-717.
- Gregory, R.T. and Taylor, H.P.: 1981, An oxygen isotopic profile in a section of Cretaceous oceanic crust, Samail Ophiolite, Oman: Evidence for ¹⁸O buffering of the oceans by deep (> 5 km, seawater-hydrothermal circulation at mid-ocean ridges, *J. Geophys. Res.* **86**, 2737-2756.
- Gresham, J. J. and Loftus-Hills, G. D.: 1981, The geology of the Kambalda nickel field, Western Australia, *Econ. Geol.* **76**, 1373-1416.
- Grote, J. R., Syren, R. M. and Fox, S. W.: 1978, Effect of products from heated amino acids on conductance in lipid bilayer membranes and non-aqueous solvents, *Biosystems* **10**, 287-292.
- Grutter, M. G., Hawkes, R. M. and Matthews, B. W.: 1979, Molecular basis of thermostability in the lysozyme of bacteriophage T4, *Nature* **277**, 667-669.
- Guillemin, J. C. and Denis, J. M.: 1985, Flash vacuum thermolysis of α -aminonitriles and subsequent HCN removal on solid base, a "one line" multistep sequence to reactive N-methyle-namines, *J. Chem. Soc. Chem. Commun.*, 951.
- Guillemin, J. C. and Denis, J. M.: 1988, Synthèse d'imines linéaires non-stabilisées par réactions gaz-solide sous vide, *Tetrahedron* **44**, 4431-4446.
- Hajash, A. and Chandler, G. W.: 1981, An experimental investigation of high temperature interactions between sea-water and rhyolite, andesite, basalt and peridotite, *Contrib. Mineral. Petrol.* **78**, 240-250.
- Haldane, J. B. S.: 1929, The Origin of Life, *The Rationalist Annual*.
- Hall, A. J.: 1986, Pyrite-pyrrhotite redox reactions in nature, *Mineral. Mag.* **50**, 223-229.

- Hall, A. J., Boyce, A. J. and Fallick, A. E.: 1987, Iron sulphides in metasediments: isotopic support for a retrogressive pyrrhotite to pyrite reaction, *Chem. Geol.*, Isotope Geoscience section **65**, 305-310.
- Hall, D. O., Cammack, R. and Rao, K. K.: 1971, Role for ferredoxins in the origin of life and biological evolution, *Nature* **233**, 136-138.
- Hamann, S. D. and Strauss, W.: 1955, The chemical effects of pressure: Part 3. Ionization constants at pressures up to 1200 atm, *Trans. Faraday Soc.* **51**, 1684-1690.
- Harada, K.: 1967, Formation of amino acids by thermal decomposition of formamide - oligomerization of hydrogen cyanide, *Nature* **214**, 479-480.
- Harada, K. and Fox, S. W.: 1958, The thermal condensation of glutamic acid and glycine to linear peptides, *J. Amer. Chem. Soc.* **80**, 2694-2697.
- Harada, K. and Fox, S. W.: 1964, Thermal synthesis of natural amino-acids from a postulated primitive terrestrial atmosphere, *Nature* **201**, 335-336.
- Harada, K. and Fox, S. W.: 1965, Characterization of thermal polymers of neutral α -amino acids with dicarboxylic amino acids or lysine, *Archiv. Biochem. Biophys.* **109**, 49-56.
- Harada, K. and Fox, S. W.: 1965, *The Origins of Prebiological Systems* (ed. S. W. Fox), Academic Press, New York, pp. 187-201.
- Harada, K. and Fox, S. W.: 1975, Characterization of functional groups of acidic thermal polymers of α -amino acids, *Biosystems* **7**, 213-221.
- Harada, K. and Matsuyama, M.: 1979, Polycondensation of thermal precursors of amino acids and characterization of constituent amino acids, *Biosystems* **11**, 47-53.
- Harned, H. S. and Davis, R., Jr.: 1943, The ionization constant of carbonic acid in water and the solubility of carbon dioxide in water and aqueous salt solutions from 0 to 50°, *J. Amer. Chem. Soc.* **65**, 2030-2037.
- Harned, H. S. and Ehlers, R. W.: 1933, The dissociation constant of acetic acid from 0 to 60° Centigrade, *J. Amer. Chem. Soc.* **55**, 652-656.
- Harned, H. S. and Fallon, L. D.: 1939, The second ionization constant of oxalic acid from 0 to 50 degrees, *J. Amer. Chem. Soc.* **61**, 3111-3113.
- Harper, G.: 1986, The Josephine ophiolite, northwestern California, *Geol. Soc. Amer. Bull.* **95**, 1009-1026.
- Harper, G. D., Bowman, J. R. and Kuhns, R.: 1988, A field, chemical, and stable isotope study of subseafloor metamorphism of the Josephine ophiolite, California-Oregon, *J. Geophys. Res.* **93**, 4625-4656.
- Hartman, H.: 1975, Speculations on the origin and evolution of metabolism, *J. Molec. Evol.* **4**, 359-370.
- Hartman, J., Brand, M. C. and Dose, K.: 1981, Formation of specific amino acid sequences during thermal polymerization of acids, *Biosystems* **13**, 141-147.
- Hartmann, M.: 1980, Atlantis II Deep geothermal brine system. Hydrographic situation in 1977 and changes since 1965, *Deep-Sea Res.* **27**, 161-171.
- Hartmann, M.: 1985, Atlantis II Deep geothermal brine system. Chemical processes between hydrothermal brines and Red Sea deep water, *Mar. Geol.* **64**, 157-177.

- Hatanaka, H. and Egami, F.: 1977a, Selective formation of certain amino acids from formaldehyde and hydroxylamine in a modified sea medium enriched with molybdate, *J. Biochem.* **82**, 499-502.
- Hatanaka, H. and Egami, F.: 1977b, The formation of amino acids and related oligomers from formaldehyde and hydroxylamine in modified sea mediums related to prebiotic conditions, *Bull. Chem. Soc. Japan* **50**, 1147-1156.
- Hawker, J. R., Jr. and Oró, J.: 1981a, Cyanamide mediated syntheses of LEU, ALA, and PHE peptides under plausible primitive Earth conditions, in *Origins of Life* (ed. Y. Wolman), Reidel Publishing Co., Dordrecht, pp. 225-232.
- Hawker, J. R., Jr. and Oró, J.: 1981b, Cyanamide mediated syntheses of peptides containing histidine and hydrophobic amino acids, *J. Molec. Evol.* **17**, 285-294.
- Hawthorne, S. B.: 1990, Analytical-scale supercritical fluid extraction, *Anal. Chem.* **62**, 633A-642A.
- Hayatsu, R. and Anders, E.: 1981, Organic compounds in meteorites and their origins, *Topics in Current Chem.* **99**, 1-37.
- Hayatsu, R., Studier, M. H. and Anders, E.: 1971, Origin of organic matter in early solar system IV. Amino acids: Confirmation of catalytic synthesis by mass spectrometry, *Geochim. Cosmochim. Acta* **35**, 939-951.
- Hayatsu, R., Studier, M. H., Matsuoka, S. and Anders, E.: 1972, Origin of organic matter in the solar system VI. Catalytic synthesis of nitriles, nitrogen bases and porphyrin-like pigments, *Geochim. Cosmochim. Acta* **36**, 555-571.
- Hayatsu, R., Studier, M. H., Moore, L. P. and Anders, E.: 1975, Purines and triazines in the Murchison meteorite, *Geochim. Cosmochim. Acta* **39**, 471-488.
- Hayatsu, R., Studier, M. H., Oda, A., Fuse, K. and Anders, E.: 1968, Organic matter in the solar system II. Nitrogen compounds, *Geochim. Cosmochim. Acta* **32**, 175-190.
- Haymon, R. M.: 1983, Growth history of hydrothermal black smoker chimneys, *Nature* **301**, 695-698.
- Haymon, R. M.: 1989, Hydrothermal processes and products on the Galapagos Rift and East Pacific Rise, in *The Geology of North America*, Vol. N, The Eastern Pacific Ocean and Hawaii, Geological Society of America, pp. 125-144.
- Haymon, R. M. and Kastner, M.: 1981, Hot spring deposits on the East Pacific Rise at 21°N: preliminary description of mineralogy and genesis, *Earth Planet. Sci. Lett.* **53**, 63-381.
- Haymon, R. M., Koski, R. A. and Abrams, M. J.: 1989, Hydrothermal discharge zones beneath massive sulfide deposits mapped in the Oman ophiolite, *Geology* **17**, 531-535.
- Haymon, R. M., Koski, R. A. and Sinclair, C.: 1984, Fossils of hydrothermal vent worms from Cretaceous ores of the Samail ophiolite, Oman, *Science* **223**, 1407-1409.
- Heinz, B., Ried, W. and Dose, K.: 1979, Thermal generation of pteridines and flavins from amino acid mixtures, *Angew. Chem., Int. Ed.* **18**, 479.
- Hékinian, R., Francheteau, J., Renard, V., Ballard, R. D., Choukroune, P., Cheminée, J. L., Albarede, F., Minster, J. F., Charlou, J. L., Marty, J. C. and Boulègue, J.: 1983, Intense hy-

- drothermal activity at the axis of the East Pacific Rise near 13°N: Submersible witnesses the growth of sulfide chimney, *Mar. Geophys. Res.* **6**, 1-14.
- Hékinian, R., Fevrier, M., Avedik, F., Cambon, P., Charlou, J. L., Needham, H. D., Raillard, J., Boulègue, J., Merlivat, L., Moinet, A., Manganini, S. and Lange, J.: 1983, East Pacific Rise near 13°N: Geology of new hydrothermal fields, *Science* **219**, 1321-1324.
- Helgeson, H. C.: 1979, Mass transfer among minerals and hydrothermal solutions, in *Geochemistry of Hydrothermal Ore Deposits, 2nd ed.* (ed. H. L. Barnes), John Wiley & Sons, pp. 568-610.
- Helgeson, H. C.: 1985, Some thermodynamic aspects of geochemistry, *Pure and Applied Chem.* **57**, 31-44.
- Helgeson, H. C.: 1991, Thermodynamic constraints on the geobiochemical evolution of petroleum in the Earth's crust (abstr.), *Geol. Soc. Amer. Abstr. Prog.* **23**, A25.
- Helgeson, H. C. and Kirkham, D. H.: 1974a, Theoretical prediction of the thermodynamic behavior of aqueous electrolytes at high pressures and temperatures. I. Summary of the thermodynamic/electrostatic properties of the solvent, *Amer. J. Sci.* **274**, 1089-1198.
- Helgeson, H. C. and Kirkham, D. H.: 1974b, Thermodynamic properties of hydrothermal systems at high pressures and temperatures (abstr.), *Geol. Soc. Amer. Abstr. Prog.* **87**, 788-789.
- Helgeson, H. C. and Kirkham, D. H.: 1976, Theoretical prediction of the thermodynamic behavior of aqueous electrolytes at high pressures and temperatures. III. Equations of state for aqueous species at infinite dilution, *Amer. J. Sci.* **276**, 97-240.
- Helgeson, H. C. and Shock, E. L.: 1988, Role of oxidation/reduction reactions in the hydrothermal transport and deposition of petroleum (abstr.), *Geol. Soc. Amer. Abstr. Prog.* **20**, A95.
- Helgeson, H. C., Delany, J. M., Nesbitt, H. W. and Bird, D. K.: 1978, Summary and critique of the thermodynamic properties of rock-forming minerals, *Amer. J. Sci.* **278a**, 1-229.
- Helgeson, H. C., Kirkham, D. H. and Flowers, G. C.: 1981, Theoretical prediction of the thermodynamic behavior of aqueous electrolytes at high pressures and temperatures. IV. Calculation of activity coefficients, osmotic coefficients, and apparent molal and standard and relative partial molal properties to 600°C and 5 kb, *Amer. J. Sci.* **281**, 1241-1516.
- Helgeson, H. C., Knox, A. M. and Shock, E. L.: 1991, Petroleum, oil field brines and authigenic mineral assemblages: Are they in metastable equilibrium? (abstr.), 15th International Organic Geochemistry Conference.
- Helling, R. K. and Tester, J. W.: 1988, Oxidation of simple compounds and mixtures in supercritical water: Carbon monoxide, ammonia and ethanol, *Environ. Sci. Technol.* **22**, 1319-1324.
- Hennet, J.-C., Holm, N. G. and Engel, M. H.: 1992, Abiotic synthesis of amino acids under hydrothermal conditions and the origin of life: a perpetual phenomenon?, *Naturwissenschaften* **79**, 00-00.
- Herrera, A. L.: 1942, A new theory of the origin and nature of life, *Science* **96**, 14.
- Heyns, K. and Pavel, K.: 1957a, Thermische Umwandlungsprodukte von Aminosäuren I, *Zeit. Naturforsch.* **12B**, 97-109.
- Heyns, K. and Pavel, K.: 1957b, Thermische Umwandlungsprodukte von Aminosäuren II, *Zeit. Naturforsch.* **12B**, 109-115.

- Higman, E. B., Schmeltz, I. and Schlotzhauer, W. S.: 1970, Products from the thermal degradation of some naturally occurring materials, *J. Agr. Food Chem.* **18**, 636.
- Hilbert, R.: 1979, pVT-Daten von Wasser und wässrigen Natriumchlorid-Lösungen bis 873 K, 400 Bar und 25 Gewichtsprozent NaCl, Ph.D. Thesis, University of Karlsruhe, Karlsruhe, West Germany.
- Hinshelwood, C. N. and Topley, B.: 1923, Energy of activation in heterogeneous gas reactions with relation to the thermal decomposition of formic acid vapor, *J. Chem. Soc.* **123**, 1014.
- Hitch, B. F. and Mesmer, R. E.: 1976, The ionization of aqueous ammonia to 300° in KCl media, *J. Soln. Chem.* **5**, 667-680.
- Hochella, F. M. and White, A. F.: 1990, *Mineral-Water Interface Geochemistry*, Mineralogical Society of America, Washington, D.C., 603 p.
- Hodgson, C. J. and Lydon, J. W.: 1977, Geological setting of volcanogenic massive sulphide deposits and active hydrothermal systems: Some implications for exploration, *CIM Bulletin* **70**, 95-106.
- Hoering, T. C.: 1984, Thermal reactions of kerogen with added water, heavy water and pure organic substances, *Org. Geochem.* **5**, 267-278.
- Holland, H. D.: 1973, The oceans: a possible source of iron in iron-formations, *Econ. Geol.* **68**, 1169-1172.
- Holloway, J. R.: 1984, Graphite-CH₄-H₂O-CO₂ equilibria at low-grade metamorphic conditions, *Geology* **12**, 455-458.
- Holloway, J. R.: 1988, Planetary atmospheres during accretion: The effect of C-O-H-S equilibria, in *Lunar and Planetary Science* (Lunar and Planetary Institute, Houston) **19**, 499-500.
- Holloway, J. R. and Wood, B. J.: 1988, *Simulating the Earth: Experimental Geochemistry*, Unwin Hyman, Boston, 196 p.
- Holm, N. G.: 1987, Possible biological origin of banded iron-formations from hydrothermal solutions, *Origins Life Evol. Biosphere* **17**, 229-250.
- Holm, N. G.: 1990, Report on the workshop: 'Chemical evolution and neo-abiogenesis in marine hydrothermal systems', *Origins Life Evol. Biosphere* **20**, 93-98.
- Holm, N. G., Ertem, G. and Ferris, J. P.: 1992, The binding and reactions of nucleotides and polynucleotides on iron oxide hydroxide polymorphs, *Origins Life Evol. Biosphere*, submitted.
- Hong, G. T., Fowler, P. K., Killilea, W. R. and Swallow, K. C.: 1987, Supercritical water oxidation: Treatment of human waste and system configuration tradeoff study, SAE Technical Paper Series 871444.
- Hong, G. T., Killilea, W. R. and Thomason, T. B.: 1988, Supercritical water oxidation: Space applications, in *Engineering, Construction and Operations in Space*, Proceedings of Space 88 (eds. S. W. Johnson and J. P. Wetzel), Amer. Soc. Civil Eng., New York, pp. 987-998.
- Horibe, Y., Kim, K.-R. and Craig, H.: 1986, Hydrothermal methane plumes in the Mariana back-arc spreading centre, *Nature* **324**, 131-133.
- Houser, T. J., Tiffany, D. M., Li, Z., McCarville, M. E. and Houghton, M. E.: 1986, Reactivity of some organic compounds with supercritical water, *Fuel* **65**, 827-832.

- Houser, T. J., Tsao, C.-C., Dyla, J. E., Van Atten, M. K. and McCarville, M. E.: 1989, The reactivity of tetrahydroquinoline, benzylamine and bibenzyl with supercritical water, *Fuel* **68**, 323-327.
- Huber, R., Kristjansson, J. K. and Stetter, K. O.: 1987, *Pyrobaculum* gen. nov., a new genus of neutrophilic rod-shaped archaeobacteria from continental solfataras growing optimally at 100°C, *Arch. Microbiol.* **149**, 95-101.
- Huber, R., Kurr, M., Jannasch, H. W. and Stetter, K. O.: 1989, A novel group of abyssal methanogenic archaeobacteria (*Methanopyrus*), growing at 110°C, *Nature* **342**, 833-834.
- Huber, R., Langworthy, T. A., Konig, K., Thomm, M., Woese, C. R., Sletyr, U. B. and Stetter, K. O.: 1986, *Thermotoga maritima* sp. nov. represents a new genus of unique extremely thermophilic eubacteria growing up to 90°C, *Arch. Microbiol.* **144**, 324-333.
- Huebner, W. F.: 1987, First polymer in space identified in Comet Halley, *Science* **237**, 628-630.
- Hulett, H. R.: 1969, Limitations on prebiological synthesis, *J. Theoret. Biol.* **24**, 56-72.
- Hull, D. E.: 1960, Thermodynamics and kinetics of spontaneous generation, *Nature* **186**, 693-694.
- Humphris, S. E. and Thompson, G.: 1978, Hydrothermal alteration of oceanic basalts by seawater, *Geochim. Cosmochim. Acta* **42**, 107-125.
- Hunt, J. M.: 1979, *Petroleum Geochemistry and Geology*, W.H. Freeman and Company.
- Hunt, J. M., Lewan, M. D. and Hennet, R. J.-C.: 1991, Modeling oil generation with time-temperature index graphs on the Arrhenius Equation, *Amer. Assoc. Petrol. Geol. Bull.* **75**, 795-807.
- Huser, B. A., Patel, B. K. C., Daniel, R. M. and Morgan, H. W.: 1986, Isolation and characterisation of a novel extremely thermophilic, anaerobic, chemo-organotrophic eubacterium, *FEMS Microbiol. Lett.* **37**, 121-127.
- Ibanez, J. D., Kimball, A. P. and Oró, J.: 1971, Possible prebiotic condensation of mononucleotides by cyanamide, *Science* **173**, 444-446.
- Ingmanson, D. E. and Dowler, M. J.: 1977, Chemical evolution and the evolution of the Earth's crust, *Origins Life Evol. Biosphere* **8**, 221-224.
- Ingmanson, D. E. and Dowler, M. J.: 1980, Unique amino acid composition of Red Sea brine, *Nature* **286**, 51-52.
- Ingmanson, D. E. and Dowler, M. J.: 1981, Chemical evolution and plate tectonics, in *Origin of Life* (ed. Y. Wolman), Reidel Publishing Co., Dordrecht, pp.129-134.
- InterRIDGE Meeting Report: 1990, RIDGE Office, University of Washington, Seattle, WA.
- Ito, E. and Clayton, R. N.: 1983, Submarine metamorphism of gabbros from the Mid-Cayman Rise: An oxygen isotopic study, *Geochim. Cosmochim. Acta* **47**, 535-546.
- Ito, M., Handa, N. and Yanagawa, H.: 1990, Synthesis of polypeptides by microwave heating: II. Function of polypeptides synthesized during repeated hydration-dehydration cycles, *J. Molec. Evol.* **31**, 187-194.
- Ivanov, Ch. P. and Slavcheva, N. N.: 1977, Formation of amino acids on heating glycine with alumina, *Origins Life Evol. Biosphere* **8**, 13-19.
- Janecky, D. R. and Seyfried, W. E.: 1984, Formation of massive sulfide deposits on oceanic ridge crests: Incremental reaction models for mixing between hydrothermal solutions and seawater, *Geochim. Cosmochim. Acta* **48**, 2723-2738.

- Janecky, D. R. and Seyfried, W. E., Jr.: 1986, Hydrothermal serpentinization of peridotite within the oceanic crust: Experimental investigations of mineralogy and major element chemistry, *Geochim. Cosmochim. Acta* **50**, 1357-1378.
- Janecky, D. R. and Shanks, W. C., III.: 1988, Computational modeling of chemical and sulfur isotopic reaction processes in seafloor hydrothermal systems: Chimneys, massive sulfides, and subadjacent alteration zones, *Can. Mineral.* **26**, 805-825.
- Jannasch, H. W., Wirsén, C. O., Molyneux, S. J. and Langworthy, T. A.: 1988, Extremely thermophilic fermentative archaeobacteria of the genus *Desulfurococcus* from deep-sea hydrothermal vents, *Appl. Environ. Microbiol.* **54**, 1203-1209.
- Jeanloz, R. and Morris, S.: 1986, Temperature distribution in the crust and mantle, *Ann. Rev. Earth Planet. Sci.* **14**, 377-415.
- Joe, H., Kuma, K., Paplawsky, W., Rea, A. and Arrhenius, G.: 1986, Abiotic photosynthesis from ferrous carbonate (siderite) and water, *Origins Life Evol. Biosphere* **16**, 369-370.
- Johnson, A. I. and Morris, D. A.: 1962, Physical and hydrologic properties of water bearing deposits from core holes in the Las Banos-Kettleman City area, California, U.S. Geol. Survey, Open File Report, Denver, CO.
- Johnson, J. W. and Norton, D.: 1991, Critical phenomena in hydrothermal systems: State, thermodynamic, electrostatic, and transport properties of H₂O in the critical region, *Amer. J. Sci.* **291**, 541-648.
- Johnson, J. W., Oelkers, E. H. and Helgeson, H. C.: 1992, SUPCRT92: A software package for calculating the standard molal thermodynamic properties of minerals, gases, aqueous species and reactions from 1 to 5000 bars and 0° to 1000°C, *Computers in Geosciences* (submitted).
- Johnson, W. R. and Kang, J. C.: 1971, Mechanisms of hydrogen cyanide formation from the pyrolysis of amino acids and related compounds, *J. Org. Chem.* **36**, 189-192.
- Johnston, K. P. and Penninger, J. M. L. (Eds.): 1989, Supercritical Fluid Science and Technology, ACS Symposium Series 406, American Chemical Society, Washington, DC, 540 pp.
- Johnston, K. P., Zieger, D. H. and Eckert, C. A.: 1982, Solubilities of hydrocarbon solids in supercritical fluids. The augmented van der Waals treatment, *Ind. Eng. Chem. Fundam.* **21**, 191-197.
- Jones, J. D. and Vallentyne, J. R.: 1960, Biogeochemistry of organic matter-I. Polypeptides and amino acids in fossils and sediments in relation to geothermometry, *Geochim. Cosmochim. Acta* **21**, 1-34.
- Jones, J. L. and Radding, S. B. (Eds.): 1980, Thermal conversion of solid wastes and biomass, ACS Symposium Series 130, American Chemical Society, Washington, DC, 745 pp.
- Jones, M. L. (Ed.): 1985, Hydrothermal vents of the Eastern Pacific: An overview, *Bull. Biol. Soc. Wash.* **6**, 1-566.
- Jones, W. J., Leigh, J. A., Mayer, F., Woese, C. R. and Wolfe, R. S.: 1983, *Methanococcus jannaschii* sp. nov., an extremely thermophilic methanogen from a submarine hydrothermal vent, *Arch. Microbiol.* **136**, 254-261.
- Jones, W. J., Stügar, C. E. and Jannasch, H. W.: 1989, Comparison of thermophilic methanogens from submarine hydrothermal vents, *Arch. Microbiol.* **151**, 314-318.

- Josephson, J.: 1982, Supercritical fluids, *Environ. Sci. Technol.* **16**, 548A-551A.
- Joyce, G. F., Schwartz, A. W., Miller, S. L. and Orgel, L. E.: 1987, The case for an ancestral genetic system involving simple analogues of the nucleotides, *Proc. Nat. Acad. Sci.* **84**, 4398.
- Kadko, D. and Moore, W.: 1988, Radiochemical constraints on the crustal residence time of submarine hydrothermal fluids: Endeavour Ridge, *Geochim. Cosmochim. Acta* **52**, 659-668.
- Kamaluddin, Yanagawa, H. and Egami, F.: 1979, Formation of molecules of biological interest from formaldehyde and hydroxylamine in a modified sea medium, *J. Biochem.* **85**, 1503-1507.
- Karl, D. M., Brittain, A. M. and Tilbrook, B. D.: 1989, Hydrothermal and microbial processes at Loihi Seamount, a mid-plate hot-spot volcano, *Deep-Sea Res.* **36**, 1655-1673.
- Karl, D. M., McMurtry, G. M., Malahoff, A. and Garcia, M. O.: 1988, Loihi Seamount, Hawaii: A midplate volcano with a distinctive hydrothermal system, *Nature* **335**, 532-535.
- Kasting, J.: 1990, Bolide impacts and the oxidation state of carbon in the Earth's early atmosphere, *Origins Life Evol. Biosphere* **20**, 199-231.
- Kasting, J. F.: 1988, Runaway and moist greenhouse atmospheres and the evolution of Earth and Venus, *Icarus* **74**, 472-494.
- Kasting, J. F., Zahnle, K. J. and Walker, J. C. G.: 1983, Photochemistry of methane in the Earth's early atmosphere, *Precamb. Res.* **20**, 121-148.
- Katritzky, A. R., Lapucha, A. R., Murugan, R., Luxem, F. J., Siskin, M. and Brons, G.: 1990a, Aqueous high-temperature chemistry of carbo-cycles and heterocycles. 1. Introduction and reaction of 3-pyridylmethanol, pyridine-3-carboxaldehyde, and pyridine-3-carboxylic acid, *Energy & Fuels* **4**, 493-498.
- Katritzky, A. R., Balasubramanian, M. and Siskin, M.: 1990b, Aqueous high-temperature chemistry of carbo-cycles and heterocycles. 2. Monosubstituted benzenes - benzyl alcohol, benzaldehyde, and benzoic acid, *Energy & Fuels* **4**, 499-505.
- Katritzky, A. R., Lapucha, A. R. and Siskin, M.: 1990c, Aqueous high-temperature chemistry of carbo-cycles and heterocycles. 3. 2-Substituted pyridines, *Energy & Fuels* **4**, 506-510.
- Katritzky, A. R., Lapucha, A. R. and Siskin, M.: 1990d, Aqueous high-temperature chemistry of carbo-cycles and heterocycles. 4. 4-Substituted pyridines, *Energy & Fuels* **4**, 510-514.
- Katritzky, A. R., Luxem, F. J. and Siskin, M.: 1990e, Aqueous high-temperature chemistry of carbo-cycles and heterocycles. 5. Monosubstituted benzenes with a 2 carbon atom side chain oxygenated at the beta-position, *Energy & Fuels* **4**, 514-517.
- Katritzky, A. R., Luxem, F. J. and Siskin, M.: 1990f, Aqueous high-temperature chemistry of carbo-cycles and heterocycles. 6. Monosubstituted benzenes with 2 carbon atom side chains unsubstituted or oxygenated at the alpha-position, *Energy & Fuels* **4**, 518-524.
- Katritzky, A. R., Luxem, F. J. and Siskin, M.: 1990g, Aqueous high-temperature chemistry of carbo-cycles and heterocycles. 7. Monosubstituted benzenes with 2 carbon atom side chains oxygenated at the alpha-position and beta-position, *Energy & Fuels* **4**, 525-531.
- Katritzky, A. R., Murugan, R. and Siskin, M.: 1990h, Aqueous high-temperature chemistry of carbo-cycles and heterocycles. 8. Aquathermolysis of para-substituted phenols in the presence and absence of sodium bisulfite, *Energy & Fuels* **4**, 531-538.

- Katritzky, A. R., Murugan, R. and Siskin, M.: 1990i, Aqueous high-temperature chemistry of carbo-cycles and heterocycles. 9. Aquathermolysis of ortho-substituted, meta-substituted, and multisubstituted phenols in the presence and absence of sodium bisulfite, *Energy & Fuels* **4**, 538-543.
- Katritzky, A. R., Murugan, R., Balasubramanian, M. and Siskin, M.: 1990j, Aqueous high-temperature chemistry of carbo-cycles and heterocycles. 10. Aquathermolysis of acyclic and cyclic phenol ethers in the presence of sodium bisulfite or phosphoric acid, *Energy & Fuels* **4**, 543-546.
- Katritzky, A. R., Murugan, R., Balasubramanian, M. and Siskin, M.: 1990k, Aqueous high-temperature chemistry of carbo-cycles and heterocycles. 11. Aquathermolysis of arylamines in the presence and absence of sodium bisulfite, *Energy & Fuels* **4**, 547-555.
- Katritzky, A. R., Lapucha, A. R. and Siskin, M.: 1990l, Aqueous high-temperature chemistry of carbo-cycles and heterocycles. 12. Benzonitriles and pyridinecarbonitriles, benzamides and pyridinecarboxamides, and benzylamines and pyridylamines, *Energy & Fuels* **4**, 555-561.
- Katritzky, A. R., Lapucha, A. R., Greenhill, J. V. and Siskin, M.: 1990m, Aqueous high-temperature chemistry of carbo-cycles and heterocycles. 13. Sulfides and disulfides, *Energy & Fuels* **4**, 562-571.
- Katritzky, A. R., Lapucha, A. R., Luxem, F. J., Greenhill, J. V. and Siskin, M.: 1990n, Aqueous high-temperature chemistry of carbo-cycles and heterocycles. 14. Mercaptans and sulfonic acids, *Energy & Fuels* **4**, 572-577.
- Katritzky, A. R., Murugan, R. and Siskin, M.: 1990o, Aqueous high-temperature chemistry of carbo-cycles and heterocycles. 15. Aquathermolysis of arenethiols and aryl sulfides in the presence and absence of sodium bisulfite, *Energy & Fuels* **4**, 577-584.
- Katritzky, A. R., Murugan, R., Balasubramanian, M. Greenhill, J. V., Siskin, M. and Brons, G.: 1991, Aqueous high-temperature chemistry of carbo-cycles and heterocycles. 16. Model sulfur compounds: A study of hydrogen sulfide generation, *Energy & Fuels* **5**, 823-834.
- Kawahata, H. and Shikazono, N.: 1988, Sulfur isotope and total sulfur studies of basalts and greenstones from DSDP Hole 504B, Costa Rica Rift: Implications for hydrothermal alteration, *Can. Mineral.* **26**, 555-565.
- Kawka, O. E. and Simoneit, B. R. T.: 1987, Survey of hydrothermally-generated petroleum from the Guaymas Basin spreading center, *Org. Geochem.* **11**, 311-328.
- Kawka, O. E. and Simoneit, B. R. T.: 1990, Polycyclic aromatic hydrocarbons in hydrothermal petroleum from the Guaymas Basin spreading center, in *Organic Matter Alteration in Hydrothermal Systems - Petroleum Generation, Migration and Biogeochemistry* (ed. B. R. T. Simoneit), *Appl. Geochem.* **5**, 17-27.
- Kelley, D. S. and Delaney, J. R.: 1987, Two-phase separation and fracturing in mid-ocean ridge gabbros at temperatures greater than 700°C, *Earth Planet. Sci. Lett.* **83**, 53-66.
- Kelley, D. S. and Robinson, P. T.: 1990, Development of a brine-dominated hydrothermal system at temperatures of 400-500°C in the upper level plutonic sequence, Troodos ophiolite, Cyprus, *Geochim. Cosmochim. Acta* **54**, 653-661.

- Kempton, P. D., Hawkesworth, C. J. and Fowler, M.: 1991, Geochemistry and isotopic composition of gabbros from layer 3 of the Indian Ocean Crust, hole 735B, *Proc. Ocean Drilling Program, Scientific Results* **118**, 127-142.
- Kenyon, D. H. and Steinman, G.: 1969, *Biochemical Predestination*, McGraw-Hill Book Company, New York, 301 pp.
- Kerr, P. F., Hamilton, P. K. and Pill, R. J.: 1951, American Petroleum Institute, Clay Mineral Standards, Project 49, Preliminary Report 7B, Chemical Analysis, Columbia University, New York, pp. 38-40.
- Kerr, R. A.: 1980, Origin of life: new ingredients suggested, research news, *Science* **210**, 42-43.
- Kettler, R. M., Palmer, D. A., and Wesolowski, D. J.: 1991, Dissociation quotients of oxalic acid in aqueous sodium chloride media to 175°C, *J. Soln. Chem.* **20**, 905-927.
- Kimball, K. L.: 1988, High-temperature hydrothermal alteration of ultramafic cumulates from the base of the sheeted dikes in the Josephine ophiolite, NW California, *J. Geophys. Res.* **93**, 4675-4687.
- Kimoto, T. and Fujinagu, T.: 1988, Non-biotic synthesis of cellular organic polymers in the presence of hydrogen sulphide, *Chem. Express* **2**, 123-136.
- Kimoto, T. and Fujinagu, T.: 1990 Non-biotic synthesis of organic polymers on H₂S-rich sea-floor: a possible reaction in the origin of life, *Mar. Chem.* **30**, 179-192.
- Kobayashi, K. and Ponnampuruma, C.: 1985, Trace elements in chemical evolution, I, *Origins Life Evol. Biosphere* **16**, 41-55.
- Kobayashi, K., Hua, L.-L., Gerke, C. W., Gerhardt, K. O. and Ponnampuruma, C.: 1986, Abiotic synthesis of nucleosides by electric discharge in a simulated primitive Earth atmosphere, *Origins Life Evol. Biosphere* **16**, 277.
- Kobayashi, K., Oshima, T. and Yanagawa, H.: 1989, Abiotic synthesis of amino acids by proton irradiation of a mixture of carbon monoxide, nitrogen, and water, *Chem. Lett.* 1527-1530.
- Kobayashi, K., Tsuchiya, M., Oshima, T. and Yanagawa, H.: 1990, Abiotic synthesis of amino acids and imidazole by proton irradiation of stimulated primitive Earth atmospheres, *Origins Life Evol. Biosphere* **20**, 99-109.
- Koberstein, E.: 1973, Model reactor studies of the hydrogen cyanide synthesis from methane and ammonia, *Ind. Eng. Chem. Process. Des. Dev.* **12**, 444.
- Kokufuta, E., Terada, T., Suzuki, S. and Harada, K.: 1978, Potentiometric titration behavior of a copolymer of glutamic acid and alanine prepared by thermal polycondensation, *Biosystems* **10**, 299-306.
- Köll, P., Brönstrup, B. and Metzger, J. O.: 1983, Liquefaction of biomass with supercritical fluids in a high pressure/high temperature flow reactor, in *Chemical Engineering at Supercritical Fluid Conditions* (eds. M. E. Paulaitis, J. M. L. Penninger, R. D. Gray, Jr. and P. Davidson), Ann Arbor Science, Ann Arbor, pp. 499-514.
- Konnert, J. A. and Evans, H. T., Jr.: 1980, Crystal structure of erdite, NaFeS₂·2H₂O, *Amer. Mineral.* **65**, 516-521.
- Kopple, K. D.: 1966, *Peptides and Amino Acids*, W. A. Benjamin, New York, pp. 11-12.

- Koski, R. A., Lonsdale, P. F., Shanks, W. C., Berndt, M. E. and Howe, S. S.: 1985, Mineralogy and geochemistry of a sediment-hosted hydrothermal sulfide deposit from the southern trough of Guaymas Basin, Gulf of California, *J. Geophys. Res.* **90**, 6695-6707.
- Kovács, J. and Könyves, I.: 1954, Über DL- α - β -Polyasparaginsäure, *Naturwissenschaften* **41**, 333.
- Kovács, J., Könyves, I. and Pusztai, A.: 1953, Darstellung von Polyasparaginsäuren (Polyasparaginsäuren), aus dem thermischen Autokondensationsprodukt der Asparaginsäure, *Experientia* **9**, 459-460.
- Kröbek, B.: 1975, The origin of framboidal pyrite as a surface effect of sulphur grains, *Mineralium Deposita* **10**, 389-396.
- Kuhn, W. R. and Atreya, S. K.: 1979, Ammonia photolysis and the greenhouse effect in the primordial atmosphere of the Earth, *Icarus* **37**, 207-213.
- Kuma, K., Paplawsky, B., Gedulin, B. and Arrhenius, G.: 1989, Mixed-valence hydroxides as bioorganic host minerals, *Origins Life Evol. Biosphere* **19**, 573-602.
- Kunde, V. G., Aiken, A. C., Hanel, R. A., Jennings, D. E., Maguire, W. C., Samuelson, R. E.: 1981, C₄H₂, HC₃N and C₂N₂ in Titan's atmosphere, *Nature* **292**, 686-688.
- Kurz, J. L. and Farrar, J. M.: 1969, The entropies of dissociation of some moderately strong acids, *J. Amer. Chem. Soc.* **91**, 6057-6062.
- Kuznetsov, A. P., Maslennikov, V. V., Zajkov, V. V., and Sobetskij, V. A.: 1988, Hydrothermal sulphide mounds in the Uralian paleo-ocean (mid-Devonian), *Doklady Akademii Nauk SSSR* **303**, 1477-1481 (in Russian).
- Kvenvolden, K. A. and Simoneit, B. R. T.: 1990, Hydrothermally derived petroleum: Examples from Guaymas Basin, Gulf of California and Escanaba Trough, Northeast Pacific, *Amer. Assoc. Petrol. Geol. Bull.* **74**, 223-237.
- Kvenvolden, K. A., Lawless, J., Pering, K., Peterson, E., Flores, J., Ponnampuruma, C., Kaplan, I. R. and Moore, C.: 1970, Evidence for extraterrestrial amino-acids and hydrocarbons in the Murchison meteorite, *Nature* **228**, 923-926.
- Kvenvolden, K. A., Rapp, J. B. and Hostettler, F. D.: 1990, Hydrocarbon geochemistry of hydrothermally-generated petroleum from Escanaba Trough, offshore California, in *Organic Matter Alteration in Hydrothermal Systems - Petroleum Generation, Migration and Biogeochemistry* (ed. B. R. T. Simoneit), *Appl. Geochem.* **5**, 83-91.
- Kvenvolden, K. A., Rapp, J. B., Hostettler, F. D., Morton, J. L., King, J. D. and Claypool, G. E.: 1986, Petroleum associated with polymetallic sulfide in sediment from Gorda Ridge, *Science* **234**, 1231-1234.
- Labadie, M., Jensen, R. and Neuzil, E.: 1968, Recherches sur l'évolution pré-biologique III. Les acides azulmiques noirs formés à partir du cyanure d' ammonium, *Biochim. Biophys. Acta* **165**, 525-533.
- Lacey, J. C., Jr., Yuki, A. and Fox, S. W.: 1979, Coprecipitation of thermal lysine-rich proteinoids with polyribonucleotides, *Biosystems* **11**, 1-7.
- Lahav, N. and Chang, S.: 1976, The possible role of solid surface area in condensation reactions during chemical evolution: Re-evaluation, *J. Molec. Evol.* **8**, 357-80.

- Lahav, N. and White, D. H.: 1980, A possible role of fluctuating clay-water systems in the production of ordered prebiotic oligomers, *J. Molec. Evol.* **16**, 11-21.
- Lahav, N., White, D. and Chang, S.: 1978, Peptide formation in the prebiotic era: Thermal condensation of glycine in fluctuating clay environments, *Science* **201**, 67-69.
- Lake, J. A.: 1988, Origin of the Eukaryotic nucleus determined by rate-invariant analysis of rRNA sequences, *Nature* **331**, 184-186.
- Lake, J. A.: 1991, Tracing origins with molecular sequences, *Trends Biochem. Sci.* **16**, 46-50.
- Langridge, J.: 1968, Genetic and enzymatic experiments relating to the tertiary structure of β -galactosidase, *J. Bacteriol.* **96**, 1711-1717.
- Larter, R. C. L., Boyce, A. J. and Russell, M. J.: 1981, Hydrothermal pyrite chimneys from the Ballynoe baryte deposit, Silvermines, County Tipperary, Ireland, *Mineral. Deposita* **16**, 309-318.
- Lavrent'ev, G. A., Strigunkova, T. F. and Yegorov, I. A.: 1985: Effects of silicates on amino-acid thermal stabilities, *Geochem. Int.* **22**, 52-57.
- Lawless, J. G.: 1986, Clay-organic interactions and the origin of life, in *Clay Minerals and the Origin of Life* (eds. A. G. Cairns-Smith and H. Hartman), Cambridge University Press, Cambridge, pp. 135-137.
- Lawless, J. G. and Boynton, C. D.: 1973, Thermal synthesis of amino acids from a simulated primitive atmosphere, *Nature* **243**, 405-407.
- Lawless, J. G. and Levi, N.: 1979, The role of metal ions in chemical evolution: polymerization of alanine and glycine in a cation-exchanged clay environment, *J. Molec. Evol.* **13**, 281-286.
- Lawrence, J. R.: 1979, Temperatures of formation of calcite veins in the basalts from Deep Sea Drilling Project holes 417A and 417D, in *Initial Reports of the Deep Sea Drilling Project*, U.S. Government Printing Office, Washington, D.C., Vol. 51-53, 1183-1184.
- Leach, W. W., Noonan, D. W. and Oró, J.: 1978, in "Origins of Life: Proceedings of the 2nd ISSOL Meeting, 5th ICOL Meeting (ed. H. Noda), Center for Academic Publications, Japan Scientific Societies Press, Tokyo, p. 113.
- Lecuyer, G., Brouxel, M. and Albareda, F.: 1990, Elemental fluxes during hydrothermal alteration of the Trinity ophiolite (California U.S.A.), by seawater, *Chem. Geol.* **89**, 87-115.
- Leif, R. N., Simoneit, B. R. T. and Kvenvolden, K.A.: 1991, Simulation of hydrothermal petroleum generation by laboratory hydrous pyrolysis, in *Organic Geochemistry, Advances and Applications in the Natural Environment* (ed. D. A. C. Manning), Manchester University Press, Manchester, pp. 300-303.
- Leja, J.: 1982, *Surface Chemistry of Froth Flotation*, Plenum, New York.
- Lemmon, R. M.: 1970, Chemical evolution, *Chem. Rev.* **70**, 95-109.
- Levine, J. S.: 1982, The photochemistry of the paleoatmosphere, *J. Molec. Evol.* **18**, 161-172.
- Levine, J. S.: 1985, The photochemistry of the early atmosphere, in *The Photochemistry of Atmospheres, Earth, the Other Planets and Comets* (ed. J. S. Levine), Academic Press, Orlando, pp. 3-38.
- Levine, J. S., Augustsson, T. R., and Natarajan, M.: 1982, The prebiological paleoatmosphere: stability and composition, *Origins Life Evol. Biosphere* **12**, 245-259.

- Lilley, M. D., Baross, J. A. and Gordon, L. I.: 1983, Reduced gases and bacteria in hydrothermal fluids: The Galapagos spreading center and 21°N East Pacific Rise, in *Hydrothermal Processes at Seafloor Spreading Centers*, NATO Conference series, Ser. IV: Marine Sciences, 12 (eds. P. A. Rona *et al.*), Plenum, pp. 411-449.
- Lilley, M. D. de Angelis, M. A. and Gordon, L. I.: 1982, CH₄, H₂, CO and N₂O in submarine hydrothermal vent waters, *Nature* **300**, 48-50.
- Little, S. A., Stolzenbach, K. D. and von Herzen, R. P.: 1991, Measurements of plume flow from a hydrothermal vent field, *J. Geophys. Res.* **92**, 2587-2596.
- Lohrmann, R.: 1972, The formation of urea and guanidine by irradiation of ammonium cyanide, *J. Molec. Evol.* **1**, 263-269.
- Lonsdale, P.: 1985, A transform continental margin rich in hydrocarbons, Gulf of California, *Amer. Assoc. Petrol. Geol. Bull.* **69**, 1160-1180.
- Lonsdale, P. and Becker, K.: 1985, Hydrothermal plumes, hot springs, and conductive heat flow in the Southern Trough of Guaymas Basin, *Earth Planet. Sci. Lett.* **73**, 211-225.
- Lonsdale, P. F., Bischoff, J. L., Burns, V. M., Kastner, M. and Sweeney, R. E.: 1980, A high-temperature hydrothermal deposit on the seabed at a Gulf of California spreading center, *Earth Planet. Sci. Lett.* **49**, 8-20.
- Love, J. D. and Good, J. M.: 1970, Hydrocarbons in thermal areas, northwestern Yellowstone National Park, Wyoming, *U.S. Geol. Surv. Prof. Pap.* **7644-B**.
- Lowe, C. U., Rees, M. W. and Markham, R.: 1963, Synthesis of complex organic compounds from simple precursors: Formation of amino acids, amino acid polymers, fatty acids and purines from ammonium cyanide, *Nature* **199**, 219-222.
- Lowell, R. P.: 1990, Thermoelasticity and the formation of black smokers, *Geophys. Res. Lett.* **17**, 709-712.
- Lowell, R. P.: 1991, Modeling continental and submarine hydrothermal systems, *Rev. Geophys.* **29**, 457-476.
- Lowell, R. P. and Burnell, D. K.: 1991, Mathematical modeling of conductive heat transfer from a freezing, convecting magma chamber to a single-pass hydrothermal system: Implications for seafloor black smokers, *Earth Planet. Sci. Lett.* **104**, 59-69.
- Lown, D. A., Thirsk, H. R. and Wynne-Jones, L.: 1970, Temperature and pressure dependence of the volume of ionization of acetic acid in water from 25 to 225°C and 1 to 3000 bars, *Trans. Faraday Soc.* **66**, 51-73.
- L'vov, S. N., Zarembo, V. I. and Gilyarov, V. N.: 1981, High-precision study of volume properties of water solutions of sodium chloride under high parameters, *Geokhimiya* **4**, 505-516.
- MacDonald, K. C., Becker, K., Spiess, F. N. and Ballard, R. D.: 1980, Hydrothermal heat flux of the black smoker vents on the east pacific rise, *Earth Planet. Sci. Lett.* **48**, 1-7.
- MacGeehan, P. J. and MacLean, W. H.: 1980, Tholeiitic basalt-rhyolite magmatism and massive sulphide deposits at Matagami, Quebec, *Nature* **283**, 153-157.
- Maher, K. A. and Stevenson, D. J.: 1988, Impact frustration of the origin of life, *Nature* **331**, 612-614.
- Mann, A. P. C. and Williams, D. A.: 1980, A list of interstellar molecules, *Nature* **283**, 721-725.

- Marshall, W. L.: 1987, Possible geochemical production of biological precursors: Amino acids and other amines (also hydrocarbons) from aqueous ammonium carbonate solutions and metal carbides at 200°C -300°C (abstr.), *EOS* **68**, 458.
- Marshall, W. L.: 1992, Hydrothermal synthesis of amines and amino acids from carbides and ammonium carbonate solutions (in prep).
- Marshall, W. L. and Franck, E. V.: 1981, Ion Product of Water Substance, 0-1000°C, 1-10,000 Bars New International Formulation and Its Background, *J. Phys. Chem. Ref. Data* **10**, 959.
- Martens, C. S.: 1990, Generation of short chain organic acid anions in hydrothermally altered sediments of the Guaymas Basin, Gulf of California, in *Organic Matter Alteration in Hydrothermal Systems - Petroleum Generation, Migration and Biogeochemistry* (ed. B. R. T. Simoneit), *Appl. Geochem.* **5**, 71-76.
- Massoth, G. J., Butterfield, D. A., Lupton, J. E., McDuff, R. E., Lilley, M. D., and Jonasson, I. R.: 1989, Submarine venting of phase-separated hydrothermal fluids at Axial Volcano, Juan de Fuca Ridge, *Nature* **340**, 702-705.
- Matheja, J. H. and Degens, E. T.: 1971, *Structural Molecular Biology of Phosphates*, Gustav Fischer Verlag, Stuttgart.
- Matsui, T. and Abe, Y.: 1986a, Evolution of an impact-induced atmosphere and magma ocean on the accreting Earth, *Nature* **319**, 303-305.
- Matsui, T. and Abe, Y.: 1986b, Impact-induced atmospheres and ocean on Earth and Venus, *Nature* **322**, 526-528.
- Matthews, B. W.: 1987, Genetic and structural analysis of the protein stability problem, *Biochemistry* **26**, 6885-6888.
- Mauzerall, D.: 1990, The photochemical origins of life and photoreaction of ferrous ion in the Archean oceans, *Origins Life Evol. Biosphere* **20**, 293-302.
- McAuley, A. and Nancollas, G. H.: 1961, Thermodynamics of ion association. Part VII. Some transition-metal oxalates, *J. Chem. Soc.*, 2215-2221.
- McAuliffe, C.: 1966, Solubility in water of paraffin, cycloparaffin, olefin, acetylene, cycloolefin, and aromatic hydrocarbons, *J. Phys. Chem.* **70**, 1267-1275.
- McDonald, E. C., Howard, J. and Bennett, B.: 1983, Chemicals from forest products by supercritical fluid extraction, *Fluid Phase Equilibria* **10**, 337-344.
- McKenzie, D. P. and Richter, F. M.: 1981, Parameterized thermal convection in a layered region and the thermal history of the Earth, *J. Geophys. Res.* **86**, 11667-11680.
- McLennan, S. M., and Taylor, S. R.: 1982, Geochemical constraints on the growth of the continental crust, *J. Geol.* **90**, 347-361.
- McLeod, G., McKeown, C., Hall, A. J., and Russell, M. J.: 1992, Computer modelling of medium enthalpy hydrothermal solutions, *Origins Life Evol. Biosphere*, in review.
- Meggy, A. B.: 1953, Glycine peptides, Part I. The polymerization of piperazine-2,5-dione at 180°C, *J. Chem. Soc.*, 851-855.
- Meggy, A. B.: 1956, Glycine peptides, Part II. The heat and entropy of formation of the peptide bond in polyglycine, *J. Chem. Soc.*, 1444-1454.

- Merlivat, L., Pineau, F. and Javoy, M.: 1987, Hydrothermal vent waters at 13°N on the East Pacific Rise: isotopic composition and gas concentration, *Earth Planet. Sci. Lett.* **84**, 100-108.
- Mesmer, R. E. and Baes, C. F., Jr.: 1974, Phosphoric acid dissociation equilibria in aqueous solutions to 300°C, *J. Soln. Chem.* **3**, 307-322.
- Metzger, J. O., Hartmanns, J., Malwitz, D. and Köll, P.: 1983, Thermal organic reactions in supercritical fluids, in *Chemical Engineering at Supercritical Fluid Conditions* (eds. M. E. Palaitis, J. M. L. Penninger, R. D. Gray, Jr. and P. Davidson), Ann Arbor Science, Ann Arbor, pp. 515-533.
- Mevel, C.: 1987, Evolution of oceanic gabbros from DSDP Leg 82: influence of the fluid phase on metamorphic crystallizations, *Earth Planet. Sci. Lett.* **83**, 67-79.
- Mevel, C.: 1988, Metamorphism in oceanic layer 3, Goringe Bank, Eastern Atlantic, *Contrib. Mineral. Petrol.* **100**, 496-509.
- Michaelis, W., Jenisch, A. and Richnow, H. H.: 1990, Hydrothermal petroleum generation in Red Sea Sediments from the Kebrit and Shaban Deeps, in *Organic Matter Alteration in Hydrothermal Systems - Petroleum Generation, Migration and Biogeochemistry* (ed. B. R. T. Simoneit), *Appl. Geochem.* **5**, 103-114.
- Michard, A., Albarede, F., Michard, G., Minster, J. F. and Charlou, J. L.: 1983, Rare-earth elements and uranium in high-temperature solutions from East Pacific Rise hydrothermal vent field (13°N), *Nature* **303**, 795-797.
- Michard, G., Albarede, F., Michard, A., Minster, J. F., Charlou, J. L. and Tan, N.: 1984, Chemistry of solutions from the 13N East Pacific Rise site, *Earth Planet. Sci. Lett.* **67**, 297-308.
- Miller, S. L.: 1953, A production of amino acids under possible primitive Earth conditions, *Science* **117**, 528-529.
- Miller, S. L.: 1955, Production of some organic compounds under possible primitive Earth conditions, *J. Amer. Chem. Soc.* **77**, 2351-2361.
- Miller, S. L.: 1957a, The mechanism of synthesis of amino acids by electric discharges, *Biochim. Biophys. Acta* **23**, 480-489.
- Miller, S. L.: 1957b, The formation of organic compounds on the primitive Earth, *Annals New York Acad. Sci.* **69**, 260-275.
- Miller, S. L. and Bada, J. L.: 1988, Submarine hot springs and the origin of life, *Nature* **334**, 609-611.
- Miller, S. L. and Bada, J. L.: 1991a, Submarine hot springs were not the site for the origin of life (abstr.), *Geol. Soc. Amer. Abstr. Prog.* **23**, A18.
- Miller, S. L. and Bada, J. L.: 1991b, The origin of life did not take place in submarine hot springs (abstr.), *EOS* **72**, 59.
- Miller, S. L. and Orgel, L. E.: 1973, in *The Origins of Life on Earth* (eds. W. D. McElroy and C. P. Swanson), Prentice-Hall Inc., New Jersey, pp. 83-102.
- Miller, S. L. and Orgel, L. E.: 1974, *The Origins of Life on Earth*, Prentice-Hall, Englewood Cliffs, N.J., pp. 109-112.
- Miller, S. L. and Urey, H. C.: 1959, Organic compound synthesis on the primitive Earth, *Science* **130**, 245-251.

- Miller, S. L., Bada, J. L. and Friedmann, N.: 1989, What was the role of submarine hot springs in the origin of life?, *Origins Life Evol. Biosphere* **19**, 536-537 (abstr.).
- Miller, S. L., Urey, H. C. and Oró, J.: 1976, Origin of organic compounds on the primitive Earth and in meteorites, *J. Molec. Evol.* **9**, 59-72.
- Millero, F. J.: 1970, The apparent and partial molal volume of aqueous sodium chloride solutions at various temperatures, *J. Phys. Chem.* **74**, 356-362.
- Milward, G. R., Ramdas, S. and Thomas, J. M.: 1985, On the direct imaging of offretite, cancrinite, chabazite and other related ABC-6 zeolites and their intergrowths, *Proc. Royal Soc. London, Ser. A* **399**, 57-71.
- Modell, M., Gaudet, G. G., Simson, M., Hong, G. T. and Biemann, K.: 1982, Supercritical water, testing reveals new process, holds promise, *Solid Wastes Management*, August, p. 26.
- Mok, W. S.-L., Antal, M. J., Jr. and Jones, M., Jr.: 1989, Formation of acrylic acid from lactic acid in supercritical water, *J. Org. Chem.* **54**, 4596.
- Molling, P. A. and Sverjensky, D. A.: 1989, Thermodynamic analysis of ore fluids at the Questa Mo-porphyry deposits, *Geol. Soc. Amer. Abstr. Prog.*, **21**, A151.
- Moorbath, S.: 1985, Crustal evolution in the early Precambrian, *Origins of Life* **15**, 251-261.
- Morikawa, T.: 1978, Evolution of hydrogen cyanide during combustion and pyrolysis, *J. Combust. Toxicol.* **5**, 315.
- Mortland, M. M.: 1984, Deamination of glutamic acid by pyridoxal phosphate-Cu²⁺ -ion-smectite catalysts, *J. Molec. Catalysis* **27**, 143-55.
- Mottl, M. J.: 1983, Metabasalts, axial hot springs, and the structure of hydrothermal systems at mid-ocean ridges, *Geol. Soc. Amer. Bull.* **94**, 161-180.
- Mottl, M. J. and Seyfried, W. E.: 1980, Sub-seafloor hydrothermal systems rock- vs. seawater-dominated, in *Seafloor Spreading Centers: Hydrothermal Systems* (eds. P. A. Rona and R. P. Lowell), Hutchinson and Ross, Inc., Dowden, pp. 66-82.
- Muehlenbachs, K.: 1979, The alteration and aging of the basaltic layer of the seafloor: oxygen isotope evidence from DSDP/IPOD Legs 51, 52 and 53, *Initial Reports of the Deep Sea Drilling Project*, U.S. Government Printing Office, Washington, D.C., Vol. **51-53**, 1159-1167.
- Mukhin, L. M.: 1974, Evolution of organic compounds in volcanic regions, *Nature* **251**, 50-51.
- Mukhin, L. M.: 1976, Volcanic processes and synthesis of simple organic compounds on primitive Earth, *Origins Life Evol. Biosphere* **7**, 355-368.
- Mukhin, L. M., Bondarev, V. B. and Safonova, E. N.: 1978, The role of volcanic processes in the evolution of organic compounds on the primitive Earth, *Modern Geology* **6**, 119-122.
- Mukund, S. and Adams, M. W. W.: 1991, The novel tungsten-iron-sulfur protein of the hyperthermophilic archaeobacterium, *Pyrococcus furiosus*, is an aldehyde ferredoxin oxidoreductase, *J. Biol. Chem.* **266**, 14,208-14,216.
- Müller, D., Pitsch, S., Kittaka, A., Wagner, E., Wintner, C. E. and Eschenmoser, A.: 1990, Chemistry of α -aminonitriles. Aldomerization of glycolaldehyde phosphate to *rac*-hexose 2,4,6-triphosphates and (in presence of formaldehyde) *rac*-pentose 2,4-diphosphates: *rac*-allose 2,4,6-triphosphate and *rac*-ribose 2,4-diphosphate are the main reaction products, *Helv. Chim. Acta* **73**, 1410-1468.

- Murray, C. N., Riley, J. P., and Wilson, T. R. S.: 1969, The solubility of gases in distilled water and seawater - I. Nitrogen, *Deep-Sea Res.* **16**, 297-310.
- Murrowchick, J. B., and Barnes, J. B.: 1986, Marcasite precipitation from hydrothermal solutions, *Geochim. Cosmochim. Acta* **50**, 2615-2629.
- Nagayama, M., Takaoka, O., Inomata, K. and Yamagata, Y.: 1990, Diketopiperazine-mediated peptide formation in aqueous solution, *Origins Life Evol. Biosphere* **20**, 249-257.
- Naumann, R.: 1910, Über die Hydrolyse des Cyans, *Z. Elektrochem.* **16**, 772-777.
- Navarro-Gonzalez, R., Negron-Mendoza, A. and Chacon, E.: 1989, The γ -irradiation of aqueous solutions of urea. Implications for chemical evolution, *Origins Life Evol. Biosphere* **19**, 109-118.
- Neal, C. and Stanger, G.: 1984, Calcium and magnesium hydroxide precipitation from alkaline groundwater in Oman, and their significance to the process of serpentinization, *Mineral. Mag.* **48**, 237-241.
- Negron-Mendoza, A. and Ponnampereuma, C.: 1976, Formation of biologically relevant carboxylic acids during the gamma irradiation of acetic acid, *Origins Life Evol. Biosphere* **12**, 427.
- Nehlig, P.: 1991, Salinity of oceanic hydrothermal fluids: a fluid inclusion study, *Earth Planet. Sci. Lett.* **102**, 310-325.
- Nelson, H. D. and De Ligny, C. L.: 1968, The determination of the solubilities of some n-alkanes in water at different temperatures, by means of gas chromatography, *Recueil* **87**, 528-544.
- Nisbet, E. G.: 1986, RNA, hydrothermal systems, zeolites and the origin of life, *Episodes* **9**, 83-90.
- Nisbet, E. G.: 1987, *The Young Earth: An Introduction to Archaean Geology*, Allen & Unwin, Boston, 402 p.
- Nisbet, E. G.: 1989, Origin of life, *Nature* **337**, 23.
- Nisbet, E. G.: 1991, *Living Earth*, Harper Collins Academic, London.
- Nooner, D. W. and Oró, J.: 1979, in *Advances in Chemistry Series, No. 178, Hydrocarbon Synthesis From Carbon Monoxide and Hydrogen* (eds. E. L. Kugler and F. W. Steffgen), American Chemical Society, Washington, p. 159.
- Nooner, D. W., Gilbert, J. M., Gelpi, E. and Oró, J.: 1976, Closed Fischer-Tropsch synthesis over meteoritic iron, iron ore and nickel-iron alloy, *Geochim. Cosmochim. Acta* **40**, 915-924.
- Norton, D. L.: 1984, Theory of hydrothermal systems, *Ann. Rev. Earth Planet. Sci.* **12**, 155-177.
- Norton, D.: 1990, Pore fluid pressure near magma chambers, in *The Role of Fluids in Crustal Processes* (eds. J. D. Bredehoeft *et al.*), National Academy Press, Washington, D.C., pp. 42-49.
- Norton, D. and Knight, J. E.: 1977, Transport phenomena in hydrothermal systems: Cooling plutons, *Amer. J. Sci.* **277**, 937-981.
- Norton, D. and Taylor, H. P.: 1979, Quantitative simulation of the hydrothermal systems of crystallizing magmas on the basis of transport theory and oxygen isotope data: An analysis of the Skaergaard intrusion, *J. Petrol.* **20**, 421-486.
- Noyes, A. A., Kato, Y. and Sosman, R. B.: 1910, The hydrolysis of ammonium acetate and the ionization of water at high temperatures, *J. Amer. Chem. Soc.* **32**, 159-178.

- O'Connell, R. J. and Hager, B. H.: 1980, On the thermal state of the Earth, in *Physics of the Earth's Interior* (ed. A. M. Dziemonski and E. Boschi), Elsevier, New York, pp. 270-317.
- Odom, D. G., Rao, M., Lawless, J. G. and Oró, J.: 1979, Association of nucleotides with homoionic clays, *J. Molec. Evol.* **12**, 365-7.
- Oelkers, E. H. and Helgeson, H. C.: 1988, Calculation of the thermodynamic and transport properties of aqueous species at high pressures and temperatures. Dissociation constants for supercritical alkali metal halides at temperatures from 400° to 800°C and pressures from 500 to 4000 bars, *J. Phys. Chem.* **92**, 1631-1639.
- Oftedahl, Ch.: 1958, A theory of exhalative sedimentary ores, *Geologiska Föreningens i Stockholm Förhandlingar* **80**, 1-19.
- Okazaki, U., Asahara, K., Ikai, T. and Imai, H.: 1974, Cyanuric acid, Japan Patent 49025676, 2 July, 1974: 1974 *Chem. Abstr.* **82**, 112109s.
- Olofsson, G.: 1975, Thermodynamic quantities for the dissociation of the ammonium ion over a wide temperature range, *J. Chem. Thermo.* **7**, 507-514.
- Oparin, A. I.: 1924, *Proiskhozhdienie zhizny*, Izd. Moskovshii Raochii Moscow.
- Oparin, A. I.: 1936, *Origin of Life* (translated from Russian by S. Margolis), Dover Publications, New York, (1953).
- Orgel, L. E.: 1986, Did template directed nucleation precede molecular replication?, *Origins Life Evol. Biosphere* **17**, 27-34.
- Oró, J.: 1965, Stages and mechanisms of prebiological organic synthesis, in *The Origins of Prebiological Systems and of their Molecular Matrices* (ed. S. W. Fox), Academic Press, New York, pp. 137-171.
- Oró, J. and Guidry, C. L.: 1961, Direct synthesis of polypeptides. I. Polycondensation of glycine in aqueous ammonia, *Arch. Biochem. Biophys.* **93**, 166-171.
- Oró, J. and Han, J.: 1966, High-temperature synthesis of aromatic hydrocarbons from methane, *Science* **153**, 1393-1395.
- Oró, J. and Kamat, S. S.: 1961, Amino acid synthesis from hydrogen cyanide under possible primitive Earth conditions, *Nature* **190**, 442-443.
- Oró, J. and Kimball, A. P.: 1961, Synthesis of purines under possible primitive Earth conditions 1. Adenine from hydrogen cyanide, *Arch. Biochem. Biophys.* **94**, 217-227.
- Oró, J. and Kimball, A. P.: 1962, Synthesis of purines under possible primitive Earth conditions II. Purine intermediates from hydrogen cyanide, *Arch. Biochem. Biophys.* **96**, 293.
- Oró, J., Basile, J., Cortes, S., Shen, C. and Yamrom, T.: 1984, The prebiotic syntheses and catalytic role of imidazoles and other condensing agents, *Origins Life Evol. Biosphere* **14**, 237-242.
- Oró, J., Kimball, A., Fritz, R. and Master, F.: 1959 Amino acid synthesis from formaldehyde and hydroxylamine, *Arch. Biochem. Biophys.* **85**, 115-130.
- Oscarson, J. L., Gillespie, S. E., Christensen, J. J., Izatt, R. M. and Brown, P. R.: 1988, Thermodynamic quantities for the interaction of H⁺ and Na⁺ with C₂H₃O₂⁻ and Cl⁻ in aqueous solution from 275 to 320°C, *J. Soln. Chem.* **17**, 865-885.
- Oudin, E. and Constantinou, G.: 1984, Black smoker chimney fragments in Cyprus sulphide deposits, *Nature* **308**, 349-353.

- Paecht-Horowitz, M. and Eirich, F. R.: 1988, The polymerisation of amino acid adenylates on sodium montmorillonite with pre-adsorbed polypeptides, *Origins Life Evol. Biosphere* **18**, 359-387.
- Paecht-Horowitz, M., Berger, J. and Katchalsky, A.: 1970, Prebiotic synthesis of polypeptides by heterogeneous polycondensation of amino acid adenylates, *Nature* **228**, 636-639.
- Palmer, D. A. and Drummond, S. E.: 1986, Thermal decarboxylation of acetate, Part I. The kinetics and mechanism of reaction in aqueous solution, *Geochim. Cosmochim. Acta* **50**, 813-823.
- Park, H. R. and Getoff, N.: 1988, Photoinduced transformation of carbon monoxide in aqueous solution, *Z. Naturforsch.* **43a**, 430-434.
- Parton, H. N. and Gibbons, R. C.: 1939, The thermodynamic dissociation constants of oxalic acid, *Trans. Faraday Soc.* **35**, 542-545.
- Paspek, S. C. and Klein, M. T.: 1990, Shale oil upgrading in supercritical water solutions, *Fuel Science Technol. Int.* **8**, 673-687.
- Paulaitis, M. E., Krukonis, V. J., Kurnik, R. T. and Reid, R. C.: 1982, Supercritical fluid extraction, *Rev. Chem. Eng.* **1**, 179-250.
- Paulaitis, M. E., Penninger, J. M. L., Gray, R. D., Jr. and Davidson, P. (Eds.): 1983, *Chemical Engineering at Supercritical Fluid Conditions*, Ann Arbor Science, Ann Arbor, 543 pp.
- Pearson, D., Copeland, C. S. and Benson, S. W.: 1963a, The electrical conductance of aqueous sodium chloride in the range 300 to 383°, *J. Amer. Chem. Soc.* **85**, 1004-1047.
- Penninger, J. M. and Kolmschate, J. M. M.: 1989, in *Supercritical Fluids Science and Technology - ACS Symposium Series 406* (eds. K. P. Johnston and J. M. L. Penninger), American Chemical Society, Washington, p. 242.
- Penninger, J. M. L., Radosz, M., McHugh, M. A. and Krukonis, V. J. (Eds.): 1985, *Supercritical Fluid Technology*, Elsevier, Amsterdam, 468 pp.
- Peter, J. M.: 1986, Genesis of hydrothermal vent deposits in the southern trough of Guaymas Basin, Gulf of California: A mineralogical and geochemical study, M.Sc. thesis, University of Toronto.
- Peter, J. M., Peltonen, P., Scott, S. D., Simoneit, B. R. T. and Kawka, O. E.: 1991, Carbon-14 ages of hydrothermal petroleum and carbonate in Guaymas Basin, Gulf of California - implications for oil generation, expulsion and migration, *Geology* **19**, 253-256.
- Pflüger, E.: 1875, Über die physiologische Verbrennung in den lebendigen Organismen, *Arch. gesam. Physiol.* **10**, 641-644.
- Phillips, R. D. and Melius, P.: 1974, The thermal polymerization of amino acids: the role and fate of the reactants, *Int. J. Peptide Protein Res.* **6**, 39-319.
- Pinching, G. D. and Bates, R. G.: 1948, Second dissociation constant of oxalic acid from 0 to 50°C, and the pH of certain oxalate buffer solutions, *Jour. Res. Nat. Bur. Stand.* **40**, 405-416.
- Pinnavaia, T. J. and Mortland, M. M.: 1986, Aspects of clay catalysis, in *Clay Minerals and the Origin of Life* (eds. A. G. Cairns-Smith and H. Hartman), Cambridge University Press, Cambridge, pp. 131-135.
- Pirie, N. W.: 1959, Chemical diversity and the origins of life, in *The Origin of Life on the Earth* (eds. F. Clark and R. L. M. Synge), Pergamon, London, pp. 76-83.

- Pitzer, K. S.: 1986, Large-scale fluctuations and the critical behavior of dilute NaCl in H₂O, *J. Phys. Chem.* **90**, 1502-1504.
- Polak, J. and Lu, B. C.-Y.: 1973, Mutual solubilities of hydrocarbons and water at 0 to 25°C, *Can. J. Chem.* **51**, 4018-4023.
- Polak, J. T., Balaban, M., Peplow, A. and Philips, A. J.: 1989, Supercritical carbon dioxide extraction of lipids from algae, in *Supercritical Fluid Science and Technology* (eds. K. P. Johnston and J. M. L. Penninger), American Chem. Soc., Symp. Series 406, Washington, D.C., pp. 449-466.
- Ponnamperuma, C. and Woeller, F. H.: 1967, Alpha-aminonitriles formed by an electric discharge through a mixture of anhydrous methane and ammonia, *Currents Modern Biol.* **1**, 156-158.
- Ponnamperuma, C., Lemmon, R. M., Mariner, R. and Calvin, M.: 1963, Formation of adenine by electron irradiation of methane, ammonia and water, *Proc. Natl. Acad. Sci. U.S.A.* **49**, 737-740.
- Povoledo, D. and Vallentyne, J. R.: 1964, Thermal reaction kinetics of the glutamic acid - pyroglutamic acid system in water, *Geochim. Cosmochim. Acta* **28**, 731-734.
- Prager, B., Jacobson, P., Schmidt, P. and Stern, D.: 1921, *Beilsteins Handbuch der organischen Chemie*, 4th Edition, Vol. III, pp. 74-75.
- Pray, H. A., Schweickert, C. E., and Minich, B. H.: 1952, Solubility of hydrogen, oxygen, nitrogen, and helium in water at elevated temperatures, *Ind. Eng. Chem.* **44**, 1146-1151.
- Price, L. C.: 1976, Aqueous solubility of petroleum as applied to its origin and primary migration, *Bull. Amer. Assoc. Petrol. Geol.* **60**, 213-244.
- Price, L. C., Wenger, L. M., Ging, T. and Blount, C. W.: 1983, Solubility of crude oil in methane as a function of pressure and temperature, *Org. Geochem.* **4**, 201-221.
- Quist, A. S. and Marshall, W. L.: 1968, Ionization equilibria in ammonia-water solutions to 700° and to 4000 bars of pressure, *J. Phys. Chem.* **72**, 3123-3128.
- Ramayya, S., Brittain, A., DeAlmeida, C., Mok, W. and Antal, M. J., Jr.: 1987, Acid-catalyzed dehydration of alcohols in supercritical water, *Fuel* **66**, 1364-1371.
- Rao, M., Eichberg, J. and Oró, J.: 1982, Synthesis of phosphatidylcholine under possible primitive Earth conditions, *J. Molec. Evol.* **18**, 196-202.
- Ratcliffe, H. D. and Drozd, J. W.: 1978, The utilization of L-glutamine and the products of its thermal decomposition by *Klebsiella pneumoniae* and *Rhizobium leguminosarum*, *FEMS Microbiol. Lett.* **3**, 65-69.
- Raulin, F. and Toupance, G.: 1977, The role of sulphur in chemical evolution, *J. Molec. Evol.* **9**, 329-338.
- Read, A. J.: 1982, Ionization constants of aqueous ammonia from 25 to 240°C and to 2000 bar, *J. Soln. Chem.* **11**, 649-664.
- Read, A. J.: 1988, The first ionization constant from 25 to 200°C and 2000 bar for orthophosphoric acid, *J. Soln. Chem.* **17**, 213-224.
- Reddy, T. H. and Suryanarayana, T.: 1988, Novel histone-like proteins in the nucleoid from the acidothermophilic archaeobacterium *Sulfolobus acidocaldarius* that protect DNA against thermal denaturation, *Biochim. Biophysica Acta* **949**, 87-96.

- Reed, M. H.: 1983, Seawater-basalt reaction and the origin of greenstones and related ore deposits, *Econ. Geol.* **78**, 446-485.
- Reid, C. and Orgel, L. E.: 1967, Synthesis of sugars in potentially prebiotic conditions, *Nature* **216**, 455.
- Richardson, C. J., Cann, J., Richards, H. G. and Cowan, J. G.: 1987, Metal-depleted root zones of the Troodos ore-forming hydrothermal systems, Cyprus, *Earth Planet. Sci. Lett.* **84**, 243-253.
- Rickard, D.: 1989, Experimental concentration - time curves for the iron (II) sulphide precipitation process in aqueous solutions and their interpretation, *Chem. Geol.* **78**, 315-324.
- Rickard, D. T., Zweifel, H. and Donnelly, T. H.: 1979, Sulfur isotope systematics in the Åsen pyrite-barite deposits, Skellefte district, Sweden, *Econ. Geol.* **74**, 1060-1068.
- Ringwood, A. E.: 1979, *Origin of Earth and Moon*, Springer-Verlag, New York, 295 pp.
- Ringwood, A. E.: 1990, Earliest history of the Earth-Moon system, in *Origin of the Earth* (eds. H. E. Newsom and J. H. Jones), Oxford University Press, New York, pp. 101-134.
- Rishpon, J., O'Hara, P. J., Lahav, N. and Lawless, J. G.: 1982, Interaction between ATP, metal ions, glycine, and several minerals, *J. Molec. Evol.* **18**, 179-184.
- Roberts, S. J. and Norton, D.: 1992, Prediction of aqueous ion speciation for P-T conditions in mid-ocean ridge hydrothermal systems (abs.), *Ridge Theoretical Institute Short Course*, 37-38.
- Robinson, P. T., Dick, H. J. B. and von Herzen, R.: 1991, Metamorphism and alteration in oceanic layer 3: hole 735B, *Proc. Ocean Drilling Program, Scientific Results* **118**, 541-552.
- Rode, B. M. and Schwendinger, M. G.: 1990, Copper-catalyzed amino acid condensation in water - a simple possible way of prebiotic peptide formation, *Origins Life Evol. Biosphere* **20**, 401-410.
- Rohlfing, D. L.: 1967, Thermal poly- α -amino-acids containing low proportions of aspartic acid, *Nature* **216**, 657-659.
- Rohlfing, D. L.: 1976, Thermal polyamino acids: synthesis at less than 100°C, *Science* **193**, 68-70.
- Rohlfing, D. L. and McAlhane, W. W.: 1976, The thermal polymerization of amino acids in the presence of sand, *Biosystems* **8**, 139-145.
- Rona, P. A.: 1984, Hydrothermal mineralization at seafloor spreading centers, *Earth Sci. Rev.* **20**, 1-104.
- Rona, P. A.: 1988, Hydrothermal mineralization at oceanic ridges, *Can. Mineral.* **26**, 431-465.
- Rona, P. A., Boström, K., Laubier, L. and Smith, K. L., Jr. (Eds.): 1983, *Hydrothermal Processes at Seafloor Spreading Centers*, NATO Conf. Series, Plenum Press, New York, 796 pp. .
- Rona, P. A., Thompson, G., Mottl, M. J., Karson, J. A., Jenkins, W. J., Graham, D., Mallette, M., Von Damm, K. and Edmond, J. M.: 1984, Hydrothermal activity at the Trans-Atlantic Geotraverse hydrothermal field, Mid-Atlantic Ridge Crest at 26°N, *J. Geophys. Res.* **89**, 11,365-11,377.
- Ross, D. S.: 1984, Coal conversion in carbon monoxide - water systems, *Coal Sci.* **3**, 301-337.
- Ross, D. S., Hum, G. P., Miin, T.-C., Green, T. K. and Mansini, R.: 1986, Supercritical water/CO liquefaction and a model for coal conversion, *Fuel Proc. Techn.* **12**, 277-285.
- Russel, N. J. and Fukunaga, N.: 1990, A comparison of thermal adaption of membrane lipids in psychrophilic and thermophilic bacteria, *FEMS Microbiol. Rev.* **75**, 171-182.

- Russell, M. J.: 1978, Downward-excavating hydrothermal cells and Irish-type ore deposits: importance of an underlying thick Caledonian prism, *Trans. Instn. Min. Metall.* **B87**, 168-171.
- Russell, M. J.: 1983, Major sediment-hosted enhalative zinc + lead deposits: Formation from hydrothermal convection cells that deepen during crustal extension, *Mineral. Assoc.*, Canada, Short Course Handbook **9**, 251-282.
- Russell, M. J.: 1988, Chimneys, chemical gardens and feldspar horizons +/- pyrrhotite in some SEDEX deposits: aspects of alkaline environments of deposition, Proc, 7th Quadrennial IAGOD Symposium. E. Schweizerbartsche Verlagsbuchhandlung, Stuttgart, 183-190.
- Russell, M. J. and Daniel, R. M.: 1992, Emergence of life via catalytic hydrothermal colloidal iron sulphide membranes (abstr.), *Annales Geophysicae* **10**, Suppl. III, C.506.
- Russell, M. J., Hall, A. J., Cairns-Smith, A. G. and Braterman, P. S.: 1988, Submarine hot springs and the origin of life, *Nature* **336**, 117.
- Russell, M. J., Hall, A. J. and Duller, P.: 1984, Implications of chemical garden growth to the understanding of certain ore morphologies in the Navan orebody, *Mineral. Soc. Newsletter*, Sept. **64**, 2-3.
- Russell, M. J., Hall, A. J. and Turner, D.: 1989, In vitro growth of iron sulphide chimneys: Possible culture chambers for origin-of-life experiments, *Terra Nova* **1**, 238-241.
- Ruttersmith, L. and Daniel, R. M.: 1991, Thermostable cellobiohydrolase from the thermophilic eubacterium *Thermotoga* sp. strain FJSS3-B1, *J. Biochem.* **277**, 887-890.
- Sagan, C. and Khare, B. N.: 1971, Long-wavelength ultraviolet photoproduction of amino acids on the primitive Earth, *Science* **173**, 417-420.
- Sakai, H., Gamo, T., Kim, E.-S., Tsutsumi, M., Tanaka, T., Ishibashi, J., Wakita, H., Yamano, M. and Oomori, T.: 1990, Venting of carbon dioxide-rich fluid and hydrate formation in mid-Okinawa Trough backarc basin, *Science* **248**, 1093-1096.
- Sakurai, M. and Yanagawa, H.: 1984, Prebiotic synthesis of amino acids from formaldehyde and hydroxylamine in modified sea medium, *Origins Life Evol. Biosphere* **14**, 171-176.
- Samochocka, K., Kawczynski, A. L. and Taube, M.: 1968, High-temperature synthesis of amino acids in the system acetylene/ammonia/carbon dioxide, *Angew. Chem. Internat. Edit.* **7**, 392.
- Samson, I. M. and Russell, M. J.: 1987, Genesis of the Silvermines zinc-lead-barite deposits, Ireland: fluid inclusion and stable isotope evidence, *Econ. Geol.* **82**, 371-394.
- Sanchez, R. A., Ferris, J. P. and Orgel, L. E.: 1966, Cyanoacetylene in prebiotic synthesis, *Science* **154**, 784-785.
- Sanchez, R. A., Ferris, J. P. and Orgel, L. E.: 1967, Studies in prebiotic synthesis II. Synthesis of purine precursors and amino acids from aqueous hydrogen cyanide, *J. Molec. Biol.* **30**, 223-253.
- Sanchez, R. A., Ferris, J. P. and Orgel, L. E.: 1968, Studies in prebiotic synthesis IV. Conversion of 4-aminoimidazole-5-carbonitrile derivatives to purines, *J. Molec. Biol.* **38**, 121-128.
- Sanders, N. D.: 1986, Visual observation of the solubility of heavy hydrocarbons in near-critical water, *Ind. Eng. Chem. Fundam.* **25**, 169-171.
- Sassani, D. C. and Shock, E. L.: 1990a, Speciation and solubility of palladium in aqueous magmatic hydrothermal solutions, *Geology* **19**, 925-928.

- Sassani, D. C. and Shock, E. L.: 1990b, Supercritical mass transfer during aqueous alteration of mafic intrusive rocks, *Geol. Soc. Amer. Abstracts with Programs* **22**, A213.
- Sassani, D. C. and Shock, E. L.: 1992, Estimation of standard partial molal entropies of aqueous ions at 25°C and 1 bar, *Geochim. Cosmochim. Acta* (in press).
- Saunders, M. A. and Rohlfing, D. L.: 1972, Polyamino acids: preparation from reported proportions of "prebiotic" and extraterrestrial amino acids, *Science* **176**, 172-173.
- Saunders, M. A. and Rohlfing, D. L.: 1974, Inclusion of nonproteinous amino acids in thermally prepared models for prebiotic protein, *Biosystems* **6**, 81-92.
- Schafer, T. and Schonheit, P.: 1991, Pyruvate metabolism of the hyperthermophilic archaeobacterium *Pyrococcus furiosus*, *Arch. Microbiol.* **155**, 366-377.
- Schavo, A. and Winkler, C. A.: 1959, The reactions of active nitrogen with acetylene, methylacetylene and dimethylacetylene, *Can. J. Chem.* **37**, 655-659.
- Schiffman, P. and Smith, B. M.: 1988, Petrology and oxygen isotope geochemistry of a fossil seawater hydrothermal system within the Solea Graben northern Troodos Ophiolite, Cyprus, *J. Geophys. Res.* **93**, 4612-4624.
- Schiffman, P., Smith, B. M., Varga, R. G. and Moores, E.M.: 1987, Geometry, conditions and timing of off-axis hydrothermal metamorphism and ore deposition in the Solea graben, *Nature* **325**, 423-425.
- Schiffries, C. M. and Skinner, B. J.: 1987, The Bushveld hydrothermal system: field and petrologic evidence, *Amer. J. Sci.* **287**, 566-595.
- Schimpl, A., Lemmon, R. and Calvin, M.: 1965, Cyanamide formation under prebiotic conditions, *Science* **147**, 149-150.
- Schlesinger, G. and Miller, S. L.: 1983, Prebiotic synthesis in atmospheres containing methane, carbon monoxide and carbon dioxide, *J. Molec. Evol.* **19**, 376-390.
- Schoell, M.: 1988, Multiple origins of methane in the Earth, *Chem. Geol.* **71**, 1-10.
- Schöps, D. and Herzig, P.M.: 1990, Sulfide composition and microthermometry of fluid inclusions in the Leg 111 sheeted dike section of Ocean Drilling Program Hole 504B, Costa Rica Rift, *J. Geophys. Res.* **95**, 8405-8418.
- Schulte, M. D. and Shock, E. L.: 1992, Thermodynamic properties of Strecker synthesis reactions in hydrothermal solutions, in preparation.
- Schwab, G.-M. and Schwab-Agallidis, E.: 1949, On selective catalysis, *J. Am. Chem. Soc.* **71**, 1806-1816.
- Schwartz, A. W. and Bakker, C. G.: 1989, Was adenine the first purine? *Science* **245**, 1102-1104.
- Schwartz, A. W. and Chittenden, G. J. F.: 1977, Synthesis of uracil and thymine under simulated prebiotic conditions, *Biosystems* **9**, 87-92.
- Schwartz, A. W. and Goverde, M.: 1982, Acceleration of HCN oligomerization by formaldehyde and related compounds: Implications for prebiotic synthesis, *J. Molec. Evol.* **18**, 351-353.
- Schwartz, A. W., Van der Veen, M., Bisseling, T. and Chittenden, G. J. F.: 1975, Prebiotic nucleotide synthesis—demonstration of a geologically plausible pathway, *Origins Life Evol. Biosphere* **6**, 163-168.

- Schwartz, A. W., Voet, A. B. and Van Der Veen, M.: 1984, Recent progress in the prebiotic chemistry of HCN, *Origins Life Evol. Biosphere* **14**, 91-98.
- Scott, L. T.: 1982, Thermal rearrangements of aromatic compounds, *Acc. Chem. Res.* **15**, 52-58.
- Scott, S. D.: 1985, Seafloor polymetallic sulfide deposits: Modern and ancient, *Mar. Mining* **5**, 191-212.
- Seewald, J. S. and Seyfried, W. E.: 1990, The effect of temperature on metal mobility in sub-seafloor hydrothermal systems: Constraints from basalt alteration experiments, *Earth Planet. Sci. Lett.* **101**, 388-403.
- Seyfried, W. E.: 1987, Experimental and theoretical constraints on hydrothermal alteration processes at midocean ridges, *Ann. Rev. Earth Planet. Sci.* **15**, 317-335.
- Seyfried, W. and Bischoff, J. L.: 1977, Hydrothermal transport of heavy metals by seawater: the role of seawater/basalt ratio, *Earth Planet. Sci. Lett.* **34**, 71-77.
- Seyfried, W. and Bischoff, J. L.: 1979, Low temperature basalt alteration by seawater: An experimental study at 70°C and 150°C, *Geochim. Cosmochim. Acta* **43**, 1937-1947.
- Seyfried, W. and Bischoff, J. L.: 1981, Experimental seawater-basalt interaction at 300°C, 500 bars, chemical exchange, secondary mineral formation, and implications for the transport of heavy metals, *Geochim. Cosmochim. Acta* **45**, 135-147.
- Seyfried, W. E. and Dibble, W. E.: 1980, Seawater-peridotite interaction at 300°C and 500 bars: implications for the origin of oceanic serpentinites, *Geochim. Cosmochim. Acta* **44**, 309-321.
- Seyfried, W. E. and Mottl, M. J.: 1982, Hydrothermal alteration of basalt by seawater under seawater-dominated conditions, *Geochim. Cosmochim. Acta* **46**, 985-1002.
- Seyfried, W. E., Jr. and Janecky, D. R.: 1985, Heavy metal and sulfur transport during subcritical and supercritical hydrothermal alteration of basalt: Influence of fluid pressure and basalt composition and crystallinity, *Geochim. Cosmochim. Acta* **49**, 2545-2560.
- Seyfried, W. E., Jr., Berndt, M. E. and Janecky, D. R.: 1986, Chloride depletions and enrichments in seafloor hydrothermal fluids: Constraints from experimental basalt alteration studies, *Geochim. Cosmochim. Acta* **50**, 469-475.
- Seyfried, W. E., Jr., Berndt, M. E. and Seewald, J. S.: 1988, Hydrothermal alteration processes at mid-ocean ridges: Constraints from diabase alteration experiments, hot-spring fluids and composition of the oceanic crust, *Can. Mineral.* **26**, 787-804.
- Shanks, W. C. and Seyfried, W. E.: 1987, Stable isotope studies of vent fluids and chimney materials, southern Juan de Fuca Ridge: Sodium metasomatism and seawater sulfate reduction, *J. Geophys. Res.* **92**, 11387-11399.
- Shapiro, R.: 1986, *Origins: a skeptic's guide to the creation of life on Earth*, Summit Books, New York, 332 p.
- Shaw, R. W., Brill, T. B., Clifford, A. A., Eckert, C. A. and Franck, E. U.: 1991, Supercritical water, a medium for chemistry, *Chem. Eng. News* **69** (51, Dec. 23), 26-38.
- Shen, C., Yang, L., Miller, S. L. and Oró, J.: 1987, Prebiotic synthesis of imidazole-4-acetaldehyde and histidine, *Origins Life Evol. Biosphere* **17**, 295-305.
- Shen, C., Yang, L., Miller, S. L. and Oró, J.: 1990, Prebiotic synthesis of histidine, *J. Molec. Evol.* **31**, 167-174.

- Shimizu, M.: 1981, Origin and evolution of the genetic code, in *Origin of Life* (ed. Y. Wolman), Reidel Publishing Co., Dordrecht, Holland, pp. 423-430.
- Shiraki, R., Sakai, H., Endoh, M. and Kishima, N.: 1987, Experimental studies on rhyolite-and andesite-seawater interactions at 300°C and 1000 bars, *Geochem. J.* **21**, 139-148.
- Shock, E. L.: 1988, Organic acid metastability in sedimentary basins, *Geology* **16**, 886-890.
- Shock, E. L.: 1989, Corrections to "Organic acid metastability in sedimentary basins," *Geology* **17**, 572-573.
- Shock, E. L.: 1990a, Do amino acids equilibrate in hydrothermal fluids?, *Geochim. Cosmochim. Acta* **54**, 1185-1189.
- Shock, E. L.: 1990b, Geochemical constraints on the origin of organic compounds in hydrothermal systems, *Origins Life Evol. Biosphere* **20**, 331-367.
- Shock, E. L.: 1991a, The fate of cometary volatiles in hydrothermal systems (abstr.), *Comets and the Origins and Evolution of Life*, University of Wisconsin, pp. 34-35.
- Shock, E. L.: 1991b, Organic synthesis and basalt alteration as coupled irreversible processes (abstr.), *EOS* **72**, 59.
- Shock, E. L.: 1992a, Stability of peptides in high temperature aqueous solutions, *Geochim. Cosmochim. Acta*, in press.
- Shock, E. L.: 1992b, Chemical environments of submarine hydrothermal systems, *Origins Life Evol. Biosphere*, in press.
- Shock, E. L.: 1992c, Application of thermodynamic calculations to geochemical processes involving organic acids, in *Geochemistry of Organic Acids* (eds. M. Lewan and E. Pittman), Springer-Verlag, in press.
- Shock, E. L.: 1992d, Organic acids in hydrothermal solutions: Standard partial molal thermodynamic properties of carboxylic acids and estimates of dissociation constants at high temperatures and pressures, *Amer. J. Sci.*, submitted.
- Shock, E. L.: 1992e, Hydrothermal dehydration of aqueous organic compounds, *Geochim. Cosmochim. Acta*, submitted.
- Shock, E. L.: 1992f, Hydrocarbons in hydrothermal solutions: Standard molal properties of aqueous alkanes, cycloalkanes and aromatics (in prep.)
- Shock, E. L. and Helgeson, H. C.: 1988, Calculation of the thermodynamic and transport properties of aqueous species at high pressures and temperatures: Correlation algorithms for ionic aqueous species and equation of state predictions to 5 kb and 1000 C, *Geochim. Cosmochim. Acta* **52**, 2009-2036.
- Shock, E. L. and Helgeson, H. C.: 1990, Calculation of the thermodynamic and transport properties of aqueous species at high pressures and temperatures: Standard partial molal properties of organic species, *Geochim. Cosmochim. Acta* **54**, 915-945.
- Shock, E. L., Helgeson, H. C. and Sverjensky, D. A.: 1989, Calculation of the thermodynamic and transport properties of aqueous species at high pressures and temperatures: Standard partial molal properties of inorganic neutral species, *Geochim. Cosmochim. Acta* **53**, 2157-2184.
- Shock, E. L., Oelkers, E. H., Sverjensky, D. A., Johnson, J. W. and Helgeson, H. C.: 1992, Calculation of the thermodynamic and transport properties of aqueous species at high pressures

- and temperatures: Effective electrostatic radii to 1000 C and 5 kb, *J. Chem. Soc. Faraday Trans.*, **88**, 803-826.
- Shoor, S. K., Walker, R. D. and Gubbins, K. E.: 1969, Salting out of nonpolar gases in aqueous potassium hydroxide solutions, *J. Phys. Chem.* **73**, 312-317.
- Silant'yev, S. A., Tsameryan, O. P. and Kononkova, N. N.: 1988, Metamorphic and fluid conditions indicated by oceanic and transition-zone metabasite amphibole compositions, *Geochem. Int.* **25**, 1260-1272.
- Silfer, J. A., Engel, M. H. and Macko, S. A.: 1990, The effect of hydrothermal processes on the distribution and stereochemistry of amino acids in Recent Antractic sediments, in *Organic Matter in Hydrothermal Systems - Petroleum Generation, Migration and Biogeochemistry* (ed. B. R. T. Simoneit), *Appl. Geochem.* **5**, 159-167.
- Simoneit, B. R. T.: 1983, Effects of hydrothermal activity on sedimentary organic matter: Guyamas Basin, Gulf of California-petroleum genesis and proto-kerogen degradation, in *Hydrothermal Process at Seafloor Spreading Centers* (eds. P. A. Rona, K. Boström, L. Laubier and K. L. Smith, Jr.), Plenum Press, New York, pp. 451-471.
- Simoneit, B. R. T.: 1984, Hydrothermal effects on organic matter-high vs low temperature components, *Org. Geochem.* **6**, 857-864.
- Simoneit, B. R. T.: 1985a, Hydrothermal petroleum: Genesis, migration and deposition in Guaymas Basin, Gulf of California, *Can. J. Earth Sci.* **22**, 1919-1929.
- Simoneit, B. R. T.: 1985b, Hydrothermal petroleum: Composition and utility as a biogenic carbon source, in *Hydrothermal Vents of the Eastern Pacific: An Overview* (ed. M. L. Jones), *Bull. Biol. Soc. Wash.* **6**, 49-56.
- Simoneit, B. R. T.: 1988, Petroleum generation in submarine hydrothermal systems: An update, *Can. Mineral.* **26**, 827-840.
- Simoneit, B. R. T.: 1990, Petroleum generation, an easy and widespread process in hydrothermal systems: an overview, *Appl. Geochem.* **5**, 3-15.
- Simoneit, B. R. T. (Ed.): 1990, *Organic Matter in Hydrothermal Systems - Petroleum Generation, Migration and Biogeochemistry*, *Appl. Geochem.* **5**, 1-248.
- Simoneit, B. R. T.: 1992, Natural hydrous pyrolysis - petroleum generation in submarine hydrothermal systems, in *Productivity, Accumulation and Preservation of Organic Matter in Recent and Ancient Sediments* (eds. J. K. Whelan and J. W. Farrington), Columbia University Press, New York, pp. 368-402.
- Simoneit, B. R. T. and Galimov, E. M.: 1984, Geochemistry of interstitial gases in Quaternary sediments of the Gulf of California, *Chem. Geol.* **43**, 151-166.
- Simoneit, B. R. T. and Philp, R. P.: 1982, Organic geochemistry of lipids and kerogen and the effects of basalt intrusions on unconsolidated oceanic sediments: Sites 477, 478, and 481, Guaymas Basin, Gulf of California, in *Initial Reports of the Deep Sea Drilling Project* (eds. J. R. Curray, D. G. Moore *et al.*), Vol. 64, U.S. Government Printing Office, Washington, D.C., pp. 883-904.
- Simoneit, B. R. T., Brault, M. and Saliot, A.: 1990, Hydrocarbons associated with hydrothermal minerals, vent waters and talus on the East Pacific Rise and Mid-Atlantic Ridge, in *Organic*

- Matter Alteration in Hydrothermal Systems - Petroleum Generation, Migration and Biogeochemistry* (ed. B. R. T. Simoneit), *Appl. Geochem.* **5**, 115-124.
- Simoneit, B. R. T., Grimalt, J. O., Hayes, J. M. and Hartman, H.: 1987, Low temperature hydrothermal maturation of organic matter in sediments from the Atlantis II Deep, Red Sea, *Geochim. Cosmochim. Acta* **51**, 879-894.
- Simoneit, B. R. T., Kawka, O. E. and Brault, M.: 1988, Origin of gases and condensates in the Guaymas Basin hydrothermal system, in *Origins of Methane in the Earth* (ed. M. Schoell), *Chem. Geol.* **71**, 169-182.
- Simoneit, B. R. T., Kawka, O.E. and Wang, G.-M.: 1992, Biomarker maturation in contemporary hydrothermal systems, alteration of immature organic matter in zero geological time, in *Biological Markers in Sediments and Petroleum* (eds. J. Moldowan, R. P. Philp and P. Albrecht), Chapt. 7, pp. 124-141.
- Simoneit, B. R. T., Philp, R. P., Jenden, P. D. and Galimov, E. M.: 1984, Organic geochemistry of Deep Sea Drilling Project sediments from the Gulf of California - hydrothermal effects on unconsolidated diatom ooze, *Org. Geochem.* **7**, 173-205.
- Simpson, H. D., Haufler, U. R. and Daniel, R. M.: 1991, An extremely thermostable xylanase from the thermophilic eubacterium *Thermotoga*, *J. Biochem.* **277**, 413-417.
- Siskin, M. and Katritzky, A. R.: 1991, Reactivity of organic compounds in hot water: Geochemical and technological implications, *Science* **254**, 231-237.
- Siskin, M., Brons, G., Katritzky, A. R. and Balasubramanian, M.: 1990a, Aqueous organic chemistry. 1. Aquathermolysis - comparison with thermolysis in the reactivity of aliphatic compounds, *Energy & Fuels* **4**, 475-482.
- Siskin, M., Brons, G., Katritzky, A. R. and Murugan, R.: 1990b, Aqueous organic chemistry. 2. Cross-linked cyclohexyl phenyl compounds, *Energy & Fuels* **4**, 482-488.
- Siskin, M., Brons, G., Vaughn, S. N., Katritzky, A. R. and Balasubramanian, M.: 1990c, Aqueous organic chemistry. 3. Aquathermolysis - reactivity of ethers and esters, *Energy & Fuels* **4**, 488-492.
- Siskin, M., Katritzky, A. R. and Balasubramanian, M.: 1991, Aqueous organic chemistry. 4. Cleavage of diaryl ethers, *Energy & Fuels* **5**, 771-773.
- Sleep, N. H. and Windley, B. F.: 1982, Archaean plate tectonics: constraints and inferences, *J. Geol.* **90**, 363-379.
- Sleep, N. H., Zahnle, K. J., Kasting, J. F. and Morowitz, H. J.: 1989, Annihilation of ecosystems by large asteroid impacts on the early Earth, *Nature* **342**, 139-142.
- Smith-Magowan, D. and Wood, R. H.: 1981, Heat capacity of aqueous sodium chloride from 320 to 600 K measured with a new flow calorimeter, *J. Chem. Thermo.* **13**, 1047-1073.
- Smolin, E. M. and Rapoport, L.: 1959, *The Chemistry of Heterocyclic Compounds. S-Triazines and Derivatives*, Interscience, N.Y., a. pp. 26-29, b. pp. 310-315, c. pp. 9-13.
- Snyder, W. D. and Fox, S. W.: 1975, A model for the origin of stable protocells in a primitive alkaline ocean, *Biosystems* **7**, 222-229.

- Sokolova, M. N., Dobrovolskaya, M. G., Organova, N. I., Kazakova, M. E. and Dmitrik, A. L.: 1970, A sulfide of iron and potassium - the new mineral rasvumite, *Vses. Mineralog. Obschch. Zap.* **99**, 712-720.
- Sosnina, I. E.: 1977, Catalytic properties of sodium mordenite in the ketonization of acetic and butyric acids, *Zh. Fiz. Khim.* **51**, 2001; 1977, *Chem. Abstr.* **87**, 151671s.
- Spall, B. C. and Steacie, E. W. R.: 1957, The mechanism of the photolysis of acetamide, *Proc. Roy. Soc. London* **239**, 1-15.
- Spencer, R. J. and Chou, I.-M. (Eds.): 1990, *Fluid-Mineral Interactions: A Tribute to H.P. Eugster*, The Geochemical Society, Special Publication 2, 432 pp.
- Spieß, F. N., MacDonald, K. C., Atwater, T., Ballard, R., Carranza, A., Cordoba, D., Cox, C., Diaz Garcia, V. M., Francheteau, J., Guerrero, J., Hawkins, J., Haymon, R., Hessler, R., Juteau, T., Kastner, M., Larson, R., Luyendyk, B., Macdougall, J. D., Miller, S., Normark, W., Orcutt, J. and Rangin, C.: 1980, East Pacific Rise. Hot springs and geophysical experiments, *Science* **207**, 1421-1433.
- Squires, T. G. and Paulaitis, M. E. (Eds.): 1987, *Supercritical Fluids, Chemical and Engineering Principles and Applications*, ACS Symposium Series 329, American Chemical Society, Washington, DC, 296 pp.
- SRDPG (Ocean Drilling Program Sedimented Ridge Detailed Planning Group): 1990, Sedimented Ridges Drilling Prospectus, *JOIDES Journal* **16**, 40-55.
- Stakes, D. S., Mével, C., Mathilde, C. and Chaput, T.: 1991, Metamorphic stratigraphy of Hole 735B, *Proc. Ocean Drilling Program, Scientific Results* **118**, 153-180.
- Stakes, D. S., Taylor, H. P., Jr. and Fisher, R. C.: 1983, Oxygen isotope and geochemical characterization of hydrothermal alteration in ophiolite complexes and modern oceanic crust, in *Ophiolites and Oceanic Lithosphere* (eds. I. D. Gass, S. J. Lippard and A. W. Shelton), Special Publication of the Geological Society of London, Blackwell Scientific Publishers, pp. 199-214.
- Stanton, R. L.: 1976, Petrochemical studies of the ore environment at Broken Hill, New South Wales: 3 - banded iron formations and sulphide ore bodies: constitutional and genetic ties, *Trans. Instn. Mining Metall.* **85**, b132-b141.
- Stanton, R. L., Roberts, W. P. H. and Chant, R. A.: 1978, Petrochemical studies of the ore environment at Broken Hill, N.S.W.: 5 - major element constitution of the lode and its interpretation, *Proc. Australas. Inst. Min. Metall.* No. **266**, 51-78.
- Staszak, C. N., Malinowski, K. C. and Killilea, W. R.: 1987, The pilot-scale demonstration of the MODAR oxidation process for the destruction of hazardous organic waste materials, *Environ. Progress* **6**(1), 39-43.
- Stearns, R.S., Oppenheimer, H., Simon, E. and Harkins, W.D.: 1947, Solubilization by solutions of long-chain colloidal electrolytes, *J. Chem. Phys.* **15**, 496-507.
- Stephan, E. F., Hatfield, N. S., Peoples, R. S. and Pray, H. A. H.: 1956, The solubility of gases in aqueous uranyl salt solutions at elevated temperatures and pressures, *BMI 1067 Battelle Mem. Inst.*, 54 p.

- Stephenson, R. C. and Clarke, S.: 1989, Succinamide formation from aspartyl and asparaginyll peptides as a model for the spontaneous degradation of proteins, *J. Biol. Chem.* **264**, 6164-6170.
- Stetter, K. O., 1982: Ultrathin mycelia-forming organisms from submarine volcanic areas having an optimum growth temperature of 105°C, *Nature* **300**, 258-260.
- Stetter, K. O.: 1988, *Archaeoglobus fulgidus* gen. nov., sp. nov.; a new taxon of extremely thermophilic archaeobacteria, *System. Appl. Microbiol.* **10**, 172-173.
- Stetter, K. O., Fiala, G., Huber, G., Huber, R. and Seegerer, A.: 1990, Hyperthermophilic microorganisms, *FEBS Microbiol. Rev.* **75**, 117-124.
- Stetter, K. O., König, H. and Stackebrandt, E.: 1983, *Pyrodictium* gen. nov., a new genus of submarine disc-shaped sulphur reducing Archaeobacteria growing optimally at 105°C, *Sys. Appl. Microbiol.* **4**, 535-551.
- Stevenson, D. J.: 1983, The nature of the Earth prior to the oldest known rock record: The Hadean Earth, in *Earth's Earliest Biosphere: Its Origin and Evolution* (ed. J. W. Schopf), Princeton University Press, Princeton, pp. 32-40.
- Stevenson, D. J.: 1987, Origin of the Moon: The collision hypothesis, *Ann. Rev. Earth Planet. Sci.* **15**, 271-315.
- Stoks, P. G. and Schwartz, A. W.: 1981, Nitrogen-heterocyclic compounds in meteorites: Significance and mechanisms, *Geochim. Cosmochim. Acta* **45**, 563.
- Stoks, P. G. and Schwartz, A. W.: 1982, Basic nitrogen-heterocyclic compounds in the Murchison meteorite, *Geochim. Cosmochim. Acta* **46**, 309.
- Storch, H. H., Golumbic, N and Anderson, R. B.: 1951, *The Fischer-Tropsch and Related Syntheses*, John Wiley, New York.
- Suess, E., Simoneit, B. R. T., Wefer, G., Whiticar, M. J., Fisk, M., von Breymann, M., Han, M. W., Wittstock, R., Laban, C., Kadko, D. and Top, Z.: 1992, Hydrothermalism in the Bransfield Strait, Antarctica, *Geologische Rundschau*, in preparation.
- Sverjensky, D.A.: 1991, Trace element partitioning between minerals and hydrothermal fluids in the oceanic lithosphere to 30 km depths, *EOS*, **72**, 538.
- Sverjensky, D. A., Shock, E. L. and Helgeson, H. C.: 1992, Prediction of the thermodynamic properties of aqueous metal complexes to 1000 C and 5.0 kb, in preparation.
- Swanson, M. L., Olson, E. S., Diehl, J. W. and Farnum, S. A.: 1986, Extraction of low-rank coals with supercritical water, *ACS Div. Fuel Chem.* **31**, 43.
- Sylvester-Bradley, P. C.: 1976, Evolutionary oscillation in prebiology: Igneous activity and the origins of life, *Origins Life Evol. Biosphere* **7**, 9-18.
- Takahashi, I. and Ozako, S.: 1974, Isocyanic acid, Japan Patent 48045078, 2 Dec., 1974; 1974, *Chem. Abstr.* **82**, 173,135u.
- Tamaura, Y. and Tabata, M.: 1990, Complete reduction of carbon dioxide to carbon using cation-excess magnetite, *Nature* **346**, 255-256.
- Tanger, J. C. and Helgeson, H. C.: 1988, Calculation of the thermodynamic and transport properties of aqueous species at high pressures and temperatures. Revised equations of state for the standard partial molal properties of ions and electrolytes, *Amer. J. Sci.* **288**, 19-98.

- Taube, M., Zdrojewski, Z., Samochocka, K. and Jezierska, K.: 1967, Formation of amino acids and their precursors from primitive compounds by high-temperature synthesis, *Angew. Chem. Internat. Edit.* **6**, 247.
- Taylor, H. P., Jr.: 1990, Oxygen and hydrogen isotope constraints on the deep circulation of surface waters into zones of hydrothermal metamorphism and melting, in *The Role of Fluids in Crustal Processes* (eds. J. D. Bredehoeft *et al.*), National Academy Press, Washington, D.C., pp. 72-95.
- Taylor, O., Rummery, T. E. and Owen, D. G.: 1979, On the conversion of mackinawite to greigite, *J. Inorg. Nucl. Chem.* **41**, 595-596.
- Taylor, S. R. and Norman, M. D.: 1990, Accretion of differentiated planetesimals to the Earth, in *Origin of the Earth* (eds. H. E. Newsom and J. H. Jones), Oxford University Press, New York, pp. 29-43.
- Temple, K. L. and Colmer, A. R.: 1951, The autotrophic oxidation of iron by a new bacterium: *Thiobacillus ferro oxidans*, *J. Bact.* **62**, 605-611.
- Temussi, P. A., Paolillo, L., Ferrara, L., Benedetti, E. and Andini, S.: 1976, Structural characterization of thermal prebiotic polypeptides, *J. Molec. Evol.* **7**, 105-110.
- Tewari, B., Miller, M. M., Wasik, S. P. and Matire, D.E.: 1982, Aqueous solubility and octanol/water partition coefficient of organic compounds at 25.0°C, *J. Chem. Eng. Data* **27**, 451-454.
- Thompson, W. H. and Snyder, J. R.: 1964, Mutual solubilities of benzene and water. Equilibria in the two-phase liquid-liquid region, *J. Chem Eng. Data* **9**, 516-520.
- Thornton, E. C. and Seyfried, W. E., Jr.: 1987, Reactivity of organic-rich sediment in seawater at 350°C, 500 bars: Experimental and theoretical constraints and implications for the Guaymas Basin hydrothermal system, *Geochim. Cosmochim. Acta* **51**, 1997-2010.
- Tiercelin, J.-J., Boulègue, J. and Simoneit, B.R.T.: 1992, Hydrocarbon, sulphide and carbonate deposits related to sublacustrine hydrothermal seeps in the North Tanganyika Trough, East African Rift, in *Bitumens in Ore Deposits* (Ed. J. Parnell), Springer Verlag, Berlin, in press.
- Tiercelin, J.-J., Thouin, C., Kalala, T. and Mondeguer, A.: 1989, Discovery of sublacustrine hydrothermal activity and associated massive sulfides and hydrocarbons in the north Tanganyika trough, East African Rift, *Geology* **17**, 1053-1056.
- Tissot, B. P. and Welte, D. H.: 1984, *Petroleum Formation and Occurrence: A New Approach to Oil and Gas Exploration*, Springer Verlag, 2nd ed.
- Tivey, M. G. and McDuff, R. E.: 1990, Mineral precipitation in the walls of black smoker chimneys: a quantitative model of transport and chemical reaction, *J. Geophys. Res.* **95**, 12,617-12,637.
- Tödheide, K.: 1982, Hydrothermal solutions, *Ber. Bunsenges. Phys. Chem.* **86**, 1005-1016.
- Townsend, S. H., Abraham, M. A., Huppert, G. L., Klein, M. T. and Paspek, S. C.: 1988, Solvent effects during reactions in supercritical water, *Ind. Eng. Chem. Res.* **27**, 143-149.
- Trent, J. D., Chastain, R. A. and Yayanos, A. A.: 1984, Possible artefactual basis for apparent bacterial growth at 250°C, *Nature* **307**, 737-740.

- Tsonopoulos, C. and Wilson, G. M.: 1983, High-temperature mutual solubilities of hydrocarbons and water. Part 1: benzene, cyclohexane, and n-hexane, *Amer. Inst. Chem. Eng. Jour.* **29**, 990-999.
- Tunnicliffe, V.: 1991, The biology of hydrothermal vents: Ecology and evolution, in *Oceanogr. Mar. Biol. Annual Rev.* (ed. M. Barnes), Aberdeen University Press, **29**, pp. 319-407.
- Ulmer, G. C. and Barnes, H. L. (Eds.): 1987, *Hydrothermal Experimental Techniques*, John Wiley & Sons, New York, 523 pp.
- Urey, H. C.: 1952, *The Planets: Their Origin and Development*, Yale University Press, New Haven, 245 pp.
- Vallentyne, J. R.: 1964, Biogeochemistry of organic matter-II. Thermal reaction kinetics and transformation products of amino compounds, *Geochim. Cosmochim. Acta* **28**, 157-188.
- Vallentyne, J. R.: 1968, Pyrolysis of proline, leucine, arginine and lysine in aqueous solution, *Geochim. Cosmochim. Acta* **32**, 1353-1356.
- van Andel, T.: 1985, *New Views of an Old Planet, Continental Drift and the History of the Earth*, Cambridge University Press, Cambridge.
- van de Meent, D., Brown, S. C., Philp, R. P. and Simoneit, B. R. T.: 1980, Pyrolysis-high resolution gas chromatography and pyrolysis-gas chromatography/mass spectrometry of kerogens and kerogen precursors, *Geochim. Cosmochim. Acta* **44**, 999-1013.
- Van der Velden, W. and Schwartz, A. W.: 1977, Search for purines and pyrimidines in the Murchison meteorite, *Geochim. Cosmochim. Acta* **41**, 961-968.
- Van Trump, J. E. and Miller, S. L.: 1972, Prebiotic synthesis of methionine, *Science* **178**, 859-860.
- Vanko, D. A.: 1988, Temperature, pressure, and composition of hydrothermal fluids, with their bearing on the magnitude of tectonic uplift at mid-ocean ridges, inferred from fluid inclusions in oceanic layer 3 rocks, *J. Geophys. Res.* **93**, 4595-4611.
- Vanko, D. A. and Stakes, D.: 1991, Fluids in oceanic layer 3: Evidence from veined rocks, hole 735B, Southwest Indian Ridge, *Proc. Ocean Drilling Program, Scientific Results* **118**, 181-215.
- Vegotsky, A., Harada, K., and Fox, S. W.: 1958, The characterization of polyaspartic acid and some related compounds, *J. Amer. Chem. Soc.* **80**, 3361-3365.
- Ventilla, M. and Egami, F.: 1977, Formation of amino acids and related oligomers from formaldehyde and hydroxylamine in a solution of transition metal ions, *J. Molec. Evol.* **9**, 105-109.
- Vihinen, M.: 1987, Relationship of protein flexibility to thermostability, *Protein Engr.* **1**, 477-480.
- Viljoen, M. J. and Viljoen, R. P.: 1969, The geology and geochemistry of the lower ultramafic unit of the Onverwacht Group and a proposed new class of igneous rock. *Geol. Soc. S. Africa spec. publ.* **2**: Upper mantle project, 221-244.
- Voet, A. B. and Schwartz, A. W.: 1982, Uracil synthesis via HCN oligomerization, *Origins of Life* **12**, 45-49.
- Voet, A. B. and Schwartz, A. W.: 1983, Prebiotic adenine synthesis from HCN - evidence for a newly discovered major pathway, *Bioorganic Chem.* **12**, 8-17.
- Von Damm, K. L.: 1988, Systematics of and postulated controls on submarine hydrothermal solution chemistry, *J. Geophys. Res.* **93**, 4551-4561.

- Von Damm, K. L.: 1990, Seafloor hydrothermal activity: Black smoker chemistry and chimneys, *Ann. Rev. Earth Planet. Sci.* **18**, 173-204.
- Von Damm, K. L. and Bischoff, J. L.: 1987, Chemistry of hydrothermal solutions from the southern Juan de Fuca Ridge, *J. Geophys. Res.* **92**, 11,334-11,346.
- Von Damm, K. L., Edmond, J. M., Measures, C. I., Grant, B., Trull, T., Walden, B. and Weiss, R. F.: 1985a, Chemistry of submarine hydrothermal solutions at 21°N, East Pacific Rise, *Geochim. Cosmochim. Acta* **49**, 2197-2220.
- Von Damm, K. L., Edmond, J. M., Measures, C. I. and Grant, B. C.: 1985b, Chemistry of submarine hydrothermal solutions at Guaymas Basin, Gulf of California, *Geochim. Cosmochim. Acta* **49**, 2221-2238.
- Von Damm, K. L., Grant, B. and Edmond, J. M.: 1983, Preliminary report on the chemistry of hydrothermal solutions at 21° North East Pacific Rise, in *Hydrothermal Processes at Sea Floor Spreading Centers*, NATO Conference Series, Ser. IV: Marine Sciences, Vol. 12 (eds. P. A. Rona, K. Bostrom, L. Laubier and K. L. Smith, Jr.), Plenum, New York, pp. 391-409.
- Wächtershäuser, G.: 1988a, Before enzymes and templates: Theory of surface metabolism, *Microbiol. Rev.* **52**, 452-484.
- Wächtershäuser, G.: 1988b, Pyrite formation, the first energy source for life: A hypothesis, *System. Appl. Microbiol.* **10**, 207-210.
- Wächtershäuser, G.: 1990a, The case for the chemoautotrophic origin of life in an iron-sulfur world, *Orig. Life Evol. Biosphere* **20**, 173-176.
- Wächtershäuser, G.: 1990b, Evolution of the first metabolic cycles, *Proc. Natl. Acad. Sci. USA* **87**, 200-204.
- Wakita, H. and Sano, Y.: 1983, $^3\text{He}/^4\text{He}$ ratios in CH_4 -rich natural gases suggest magmatic origin, *Nature* **305**, 792-794.
- Wakita, H., Sano, Y., Urabe, A. and Nakamura, Y.: 1990, Origin of methane-rich natural gases in Japan: formation of gas fields due to large-scale submarine volcanism, *Appl. Geochem.* **5**, 263-278.
- Walker, J. F.: 1964, *Formaldehyde*, 3rd Ed., Reinhold, New York, p. 240.
- Walker, J. G. G. and Brimblecombe, P.: 1985, Iron and sulphur in the pre-biologic ocean, *Precamb. Res.* **28**, 205-222.
- Walker, J. and Hambly, F. J.: 1895, Transformation of ammonium cyanate into urea, *J. Chem. Soc.* **67**, 746-767.
- Walsh, K. A. J., Daniel, R. M. and Morgan, H. W.: 1983, A soluble NADH dehydrogenase from *Thermus aquaticus* strain T351, *J. Biochem.* **201**, 427-433.
- Wark, E. E. and Wark, I. W.: 1935, The physical chemistry of flotation. VI. The adsorption of amines by sulfide minerals, *J. Phys. Chem.* **39**, 1021-1030.
- Weast, R. C.: 1964, *The Handbook of Chemistry and Physics*, Vol. 45, Chemical Rubber Co., Cleveland, Ohio.
- Weber, A. L.: 1981a, Formation of the thioester, N,S-diacetylcysteine, from acetaldehyde and N,N'-diacetylcysteine in aqueous solution with ultraviolet light, *J. Molec. Evol.* **17**, 103-107.

- Weber, A. L.: 1981b, Formation of pyrophosphate, tripolyphosphate and phosphorylimidazole with the thioester, N,S-diacetylcysteamine, as the condensing agent, *J. Molec. Evol.* **18**, 24-29.
- Weber, A. L.: 1982a, Formation of the thioester, N-acetyl,S-lactoylcysteine with pyruvaldehyde in aqueous solution, *J. Molec. Evol.* **18**, 354-359.
- Weber, A. L.: 1982b, Formation of pyrophosphate on hydroxyapatite with thioesters as condensing agents, *Biosystems* **15**, 183-189.
- Weber, A. L.: 1989, Thermal synthesis and hydrolysis of polyglyceric acids, *Origins Life Evol. Biosphere* **19**, 7-19.
- Weisser, O. and Landa, S.: 1973, *Sulphide Catalysts, their Properties and Applications*, Pergamon Press and Friedr. Vieweg and Sohn.
- Welhan, J. A.: 1988, Origins of methane in hydrothermal systems, *Chem. Geol.* **71**, 183-198.
- Welhan, J. A. and Lupton, J. E.: 1987, Light hydrocarbon gases in Guaymas Basin hydrothermal fluids: Thermogenic versus abiogenic origin, *Amer. Assoc. Petr. Geol. Bull.*, **71**, 215-223.
- West, M. A. B. and Gray, M. R.: 1987, Pyrolysis of 1,3-butanediol as a model reaction for wood liquifaction in supercritical water, *Can. J. Chem. Eng.* **65**, 645.
- Wetherill, G. W.: 1990, Formation of the Earth, *Ann. Rev. Earth Planet. Sci.* **18**, 205-256.
- Weyl, P. K.: 1968, Precambrian marine environment and the development of life, *Science* **161**, 158-160.
- Whelan, J. K., Simoneit, B. R. T. and Tarafa, M.: 1988, C₁-C₈ hydrocarbons in sediments from Guaymas Basin, Gulf of California - comparison to Peru Margin, Japan Trench and California Borderlands, *Org. Geochem.* **12**, 171-194.
- White, R. H.: 1984, Hydrolytic stability of biomolecules at high temperatures and its implications for life at 250°C, *Nature* **310**, 430-432.
- Whiticar, M. J., Suess, E. and Wehner, H.: 1985, Thermogenic hydrocarbons in surface sediments of the Bransfield Strait, Antarctic Peninsula, *Nature* **314**, 87-90.
- Wiegel, J.: 1990, Temperature spans for growth: hypothesis and discussion, *FEMS Microbiol. Rev.* **75**, 155-170.
- Wilkerson, J. L. and Guillory, W. A.: 1977, Condensed phase photochemistry of acetic acid in the vacuum UV, *J. Photochem.* **7**, 251-261.
- Willis, M. A. and Shock, E. L.: 1991, Titanium speciation in hydrothermal metamorphic and subduction fluids, *EOS*, **72**, 538.
- Wilson, A. C., Caulson, S. S. and White, T. J.: 1977, Biochemical evolution, *Ann. Rev. Biochem.* **46**, 473-639.
- Woese, C. R.: 1987, Bacterial evolution, *Microbiol. Rev.* **51**, 221-271.
- Woese, C. R. and Fox, G. E.: 1977, Phylogenetic structure of the prokaryotic domain: The primary kingdoms, *Proc. Natl. Acad. Sci. U.S.A.* **74**, 5088-5090.
- Woese, C. R., Kandler, O. and Wheelis, M. L.: 1990, Towards a natural system of organisms: proposal for the domains Archaea, Bacteria and Eucarya, *Proc. Natl. Acad. Sci. U.S.A.* **87**, 4576-4579.
- Wöhler, F.: 1828, La formation artificielle de l'urée, *Annal. Chim. Phys.* **37**, 330-334.
- Wöhler, F.: 1828, Über künstliche Bildung von Harnstoff, *Ann. Physik* **12**, 253.

- Wolery, T. J., Isherwood, D. J., Jackson, K. L., Delany, J. M. and Puigdomenech, I.: 1984, EQ3/6: status and applications, UCRL-91884, Lawrence Livermore National Laboratory, 12 p.
- Wood, B. J. and Virgo, D.: 1989, Upper mantle oxidation state: Ferric iron contents of lherzolite spinels by ^{57}Fe Mössbauer spectroscopy and resultant oxygen fugacities, *Geochim. Cosmochim. Acta* **53**, 1277-1291.
- Wood, A. P., Kelly, D. P. and Norris, P. R.: 1987, Autotrophic growth of *Sulfolobus* strains on tetrathionate and the effect of organic nutrient, *Arch. Microbiol.* **146**, 382-389.
- Woodruff, L. G. and Shanks, W. C.: 1988, Sulfur isotope study of chimney minerals and vent fluids from 21°N, East Pacific Rise: Hydrothermal sulfur sources and disequilibrium sulfate reduction, *J. Geophys. Res.* **93**, 4562-4572.
- Wright, J. M., Lindsay, W. T., Jr. and Druga, T. R.: 1961, The behavior of electrolytic solutions at elevated temperatures as derived from conductance measurements, *WAPD-TM204* U.S. Atomic Energy Commission, 31 p.
- Wu, B. J., Paspek, S. C., Klein, M. T. and LaMarca, C.: 1991, Reactions in and with supercritical fluids - a review, in *Supercritical Fluid Technology: Reviews in Modern Theory and Applications* (eds. T. J. Bruno and J. F. Ely), CRC Press, Boca Raton, pp. 511-524.
- Yamagata, Y., Watanabe, H., Saitoh, M. and Namba, T.: 1991, Volcanic production of polyphosphates and its relevance to prebiotic evolution, *Nature* **352**, 516-519.
- Yamanaka, J., Inomata, K. and Yamagata, Y.: 1988, Condensation of oligoglycines with trimeta- and tetrametaphosphate in aqueous solutions, *Orig. Life Evol. Biosphere* **18**, 165-178.
- Yanagawa, H. and Egami, F.: 1980, Formation of organized particles, marigranules and marisomes, from amino acids in a modified sea medium, *Biosystems* **12**, 147-154.
- Yanagawa, H. and Egami, F.: 1981, Is carbon suboxide a new candidate as starting material for the synthesis of biomolecules on the primitive Earth?, *Precamb. Res.* **14**, 75-80.
- Yanagawa, H. and Kobayashi, K.: 1989, Formation of amino acids, peptide-like polymers, and microspheres in superheated hydrothermal environments (abstr.), *Orig. Life Evol. Biosphere* **19**, 540-541.
- Yanagawa, H. and Kobayashi, K.: 1992, An experimental approach to chemical evolution in submarine hydrothermal systems, *Origins Life Evol. Biosphere*, in press.
- Yanagawa, H. and Kojima, K.: 1985, Thermophilic microspheres of peptide-like polymers and silicates formed at 250°C, *J. Biochem.* **97**, 1521-1524.
- Yanagawa, H., Kobayashi, Y. and Egami, F.: 1980a, Genesis of amino acids in the primeval sea: Formation of amino acids from sugars and ammonia in a modified sea medium, *J. Biochem.* **87**, 359-362.
- Yanagawa, H., Kobayashi, Y. and Egami, F.: 1980b, Characterization of marigranules and marisomes, organized particles with elastin-like structures, *J. Biochem.* **87**, 855-869.
- Yanagawa, H., Kobayashi, Y. and Egami, F.: 1981, Genesis of amino acids in the primeval sea: formation of amino acids from sugars and ammonia in a modified sea medium, in *Origin of Life* (ed. Y. Wolman), Reidel Publishing Company, Dordrecht, pp. 181-187.

- Yanagawa, H., Makino, Y., Sato, K., Nishizawa, M. and Egami, F.: 1984a, Novel formation of α -amino acids from α -oxo acids and ammonia in aqueous medium, *Origins Life Evol. Biosphere* **14**, 163-169.
- Yanagawa, H., Nishizawa, M. and Kojima, K.: 1984b, A possible prebiotic peptide formation from glycinamide and related compounds, *Origins Life Evol. Biosphere* **14**, 267-272.
- Yanagawa, H., Makino, Y., Sato, K., Nishizawa, M. and Egami, F.: 1982, Novel formation of α -amino acids and their derivatives from oxo acids and ammonia in aqueous medium, *J. Biochem.* **91**, 2087-2090.
- Yanagawa, H., Ogawa, Y., Kojima, K. and Ito, M.-H.: 1988, Construction of protocellular structures under simulated primitive Earth conditions, *Origins Life Evol. Biosphere* **18**, 179-207.
- Yanagawa, H., Kojima, K., Ito, M. and Handa, N.: 1990, Synthesis of polypeptides by microwave heating: I. Formation of polypeptides during repeated hydration-dehydration cycles and their characterization, *J. Molec. Evol.* **31**, 180-186.
- Yasuda, K.: 1967, Nippon Kagaku Zasshi 88,749; 1967, Thermal decomposition of formamide, *Chem. Abstr.* **69**, 10027c.
- Yoshino, D., Hayatsu, R. and Anders, E.: 1971, Origin of organic matter in early solar system III. Amino acids: Catalytic syntheses, *Geochim. Cosmochim. Acta* **35**, 927-938.
- Yuen, G. U., Lawless, J. G. and Edelson, E. H.: 1981, Quantification of monocarboxylic acids from a spark discharge synthesis, *J. Molec. Evol.* **17**, 43-47.
- Zahnle, K. J.: 1986, Photochemistry of methane and the formation of hydrocyanic acid (HCN, in the Earth's early atmosphere, *J. Geophys. Res.* **91**, 2819-2834.
- Zahnle, K. J. and Walker, J. C. G.: 1982, The evolution of solar ultraviolet luminosity, *Rev. Geophys. Space Phys.* **20**, 280-292.
- Zale, D. E. and Klibanov, A. M.: 1984, Mechanisms of irreversible thermoinactivation of enzymes. *Ann. New York Acad. Sci.* **434**, 20-26.
- Zawisza, A. and Malesinska, B.: 1981, Solubility of carbon dioxide in liquid water and of water in gaseous carbon dioxide in the range 0.2-5 MPa and at temperatures up to 473 K, *J. Chem. Eng. Data* **26**, 388-391.
- Zhao, H., Wood, A. G., Widdel, F. and Bryant, M. P.: 1988, An extremely thermophilic Methanococcus from a deep sea hydrothermal vent and its plasmid, *Arch. Microbiol.* **150**, 178-183.
- Zierenberg, R. A., Shanks, W. C. and Bischoff, J. L.: 1984, Massive sulfide deposits at 21°N, East Pacific Rise: chemical composition, stable isotopes, and phase equilibria, *Geol. Soc. Amer. Bull.* **95**, 922-929.
- Zierenberg, R. A., Shanks, W. C., Seyfried, W. E., Koski, R. A. and Strickler, M. D.: 1988, Mineralization, alteration, and hydrothermal metamorphism of the ophiolite-hosted Turner-Albright sulfide deposit, Southwestern Oregon, *J. Geophys. Res.* **93**, 4657-4674.
- Zillig, W., Ingelore, H., Klenk, H. P., Trent, J., Wundeul, S., Janekovic, D., Imsel, E. and Haas, B.: 1987, *Pyrococcus woesei*, sp. nov. an ultra-thermophilic marine archaeobacterium, representing a novel order, *Thermococcales*, *System. Appl. Microbiol.* **9**, 62-70.

Zillig, W., Holz, I., Janekovic, D., Klenk, H. P., Imseil, E., Trent, J., Wunderl, S., Forjaz, V. H., Coutinho, R. and Ferreira, T.: 1990, *Hyperthermus butylicus*, a hyperthermophilic sulfur-reducing archaebacterium that ferments peptides, *J. Bacteriol.* **172**, 3959-3965.