

# Donald Eugene Canfield

## *Curriculum vitae*

**Name** Donald E. Canfield

**Born** November 14, 1957

**Nationality** American

**Present position** Professor of Ecology, Institute of Biology, University of Southern Denmark, Campusvej 55, 5230 Odense M, Denmark  
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**Education** B.S. in chemistry 1979, Miami University;  
M.Phil. 1984, and Ph.D 1988 in Geochemistry, Yale University,  
New Haven.

**Professional Experience**

Assistant in Research. 1982-1987, Yale University.  
Visiting Assistant Professor. Sept. 1987-May 1988, Univ. of Michigan.  
Research Affiliate. May 1988-Nov. 1988, Yale University.  
NRC Research Associate. Nov. 1988-July 1991, NASA-Ames.  
Visiting Scientist. May 1990-Sept. 1990, Univ. of Århus, Denmark.  
Visiting Lecturer. August 1991-Dec. 1991, Univ. of Århus, Denmark.  
Assistant Professor. Jan 1992-May 1995, Georgia Institute of Technology.  
BAT 1b scientist (permanent position). Sept. 1993-Nov. 1996  
Max Planck for Marine Microbiology, Bremen.  
Professor of Ecology, Odense University, Denmark. Nov. 1, 1996-present.  
Co-director, Danish Center for Earth System Science (DCESS).  
December 1997-2005.  
Director, Nordic Center for Earth Evolution (NordCEE). 2005-present

**Funded research**

Ancient Sulfur Biogeochemistry (5/92-4/95) NASA.  
246,000 USD.  
Biological and Chemical Dynamics of the Oxic/Anoxic Interface (1/97-12/99) Danish National Science Council.  
1,900,000 Dkr.  
Danish Center for Earth System Science (12/97-12/2002) Danish National Research Foundation (w/ Gary Shaffer and J. Ray Bates). 50,000,000 Dkr.  
On-line nitrate analysis machine (Nov. 2002) Danish National Research Council, 300,000 Dkr.

## Special recognition

Danish Center for Earth System Science (12/2002-12/2005)  
Danish National Research Foundation, 9,000,000 Dkr.  
Nordic Center for Earth Evolution (1/8/2005-31/7/2010) Danish  
National Research Foundation, 40,000,000 Dkr.  
NRC Postdoctoral fellowship (1988-1991), NASA-Ames  
Research Center.  
The Royal Danish Academy of Sciences and Letters (foreign  
member, elected 2002)  
ISI Highly-cited researcher, Geosciences  
Paper (Poulton et al., Nature, 2004) chosen as one of 5 most  
important Danish Science breakthroughs in 2004  
Fellow of the Geochemical Society and European Association of  
Geochemists (2007)  
National Academy of Sciences of the United States (2007)  
Fellow of the American Association for the Advancement of  
Science (AAAS) (2007)  
Fellow of the American Association of Microbiologists (AAM)  
(2008)

## Professional activities

Vladimir Vernadsky Prize, EGU (2010=  
Member of Geochemical Society  
Member of ASLO  
Member of American Geophysical Union  
Associate Editor of American Journal of Science (1989-present)  
Associate Editor of Limnology and Oceanography (1997-2002)  
Editor of Geobiology (2003-present)  
Associated Editor of *Geochimica et Cosmochimica Acta* (2001-  
2006)  
Editorial Advisor of *Aquatic Microbial Ecology* (1996-2006)  
Editorial Board of *Chemical Geology* (2004-present)

## Teaching

Teacher of undergraduates and graduates in the Life History of  
the Earth class - BB67, BB502, Experimental Ecology –  
BB15, and Microbial Ecology – BBP84.

## Publications

1. Green, W.J. and Canfield, D.E. (1981) A partial geochemical analysis of the Onyx River. *Antarctic Journal of the U.S.* 16: 42.
2. Canfield, D.E. and Green, W.J. (1983) Aspects of nutrient behavior in Lake Vanda. *Antarctic Journal of the U.S.* 18: 224-226.
3. Canfield, D.E., Green, W.J., Gardner, T.J. and Ferdelman, T. (1984) Elemental residence times in Acton Lake, Ohio. *Arch. Hydrobiol.* 100: 501-533.
4. Green, W.J. and Canfield, D.E. (1984) Geochemistry of the Onyx River (Wright Valley, Antarctica) and its role in the chemical evolution of Lake Vanda. *Geochim. Cosmochim. Acta* 48: 2457-2467.

5. Canfield, D.E. and Green, W.J. (1985) The cycling of nutrients in a closed-basin Antarctic Lake: Lake Vanda. *Biogeochemistry* 1: 233-256.
6. Green, W.J., Canfield, D.E. and Steinly, B.A. (1985) Spatial variations in and controls on the calcite saturation index in Acton Lake, Ohio. *Freshwater Biology* 15: 525-533.
7. Green, W.J., Canfield, D.E., Lee, G.F. and Jones, R.A. (1986) Mn, Fe, Cu and Cd distributions and residence times in closed-basin Lake Vanda (Wright Valley). *Hydrobiologia* 134: 237-248.
8. Canfield, D.E., Raiswell, R., Westrich, J.T., Reaves, C.M. and Berner, R.A. (1986) The use of chromium reduction in the analysis of reduced sulfur in sediments and shales. *Chemical Geology* 54: 149-155.
9. Canfield, D.E. and Berner, R.A. (1987) Dissolution and pyritization of magnetite in anoxic marine sediments. *Geochim. Cosmochim. Acta* 51: 645-659.
10. Canfield, D.E. (1988) Sulfate reduction and the diagenesis of iron in anoxic marine sediments. *Ph.D. dissertation*. Yale Univ., New Haven. 248p.
11. Boudreau, B.P. and Canfield, D.E. (1988) A provisional diagenetic model for pH in anoxic porewaters: application to the FOAM site. *Jour. Mar. Res.* 46: 429-455.
12. Canfield D.E. (1989) Sulfate reduction and oxic respiration in marine sediments: implications for organic carbon preservation in euxinic environments. *Deep-Sea Research* 36: 121-138.
13. Canfield D.E. (1989) Reactive iron in marine sediments. *Geochim. Cosmochim. Acta* 53: 619-632.
14. Berner, R.A. and Canfield, D.E. (1989) A model for atmospheric oxygen over Phanerozoic time. *Amer Jour. Science* 289: 333-361.
15. Green, W.J., Canfield, D.E. and Ferdelman, T.G. (1989) Metal dynamics in Lake Vanda (Wright Valley, Antarctica). *Chemical Geology* 76: 85-94.
16. Canfield, D.E. (1991) Sulfate reduction in deep-sea sediments. *American Journal of Science* 291: 177-186.
17. Canfield, D.E. and Des Marais, D.J. (1991) Aerobic sulfate reduction in microbial mats. *Science* 251: 1471-1473.
18. Canfield D.E. and Raiswell, R. (1991) Pyrite formation and fossil preservation, in: P.A. Allison and D.G. Briggs (eds.), *"Taphonomy: releasing the information locked in the fossil record"*, pp. 337-387, Plenum Press, New York.
19. Canfield D.E. and Raiswell, R. (1991) Carbonate precipitation and dissolution, in: P.A. Allison and D.G. Briggs (eds.), *"Taphonomy: releasing the information locked in the fossil record"*, pp. 411-453, Plenum Press, New York.

20. Canfield, D.E., Raiswell, R., Bottrell, S. (1992) The reactivity of sedimentary iron toward sulfide. *Amer. Jour. Sci.* 292: 659-683.
21. Boudreau, B.P., Canfield, D.E., and Mucci, A. (1992) Early diagenesis in a marine sapropel, Mangrove Lake, Bermuda, *Limnol. Oceanogr.* 37: 1738-1753.
22. Green, W.J., Canfield, D.E., Shengsong, Y., Chave, K.E., Ferdelman, T.G. and Delanois G. (1992) Metal transport and release processes in Lake Vanda: the role of oxide phases, In: W. J. Green "*Antarctic Lake Geochemistry*" AGU Antarctic Series, Wash. D.C.
23. Canfield, D. E. (1993) Organic matter oxidation in marine sediments, in: R. Wollast, L. Chou, and F. Mackenzie "*Interactions of C,N,P and S Biogeochemical cycles*", NATO-ARW. pp. 333-363.
24. Boudreau, B.P. and Canfield, D.E. (1993) A comparison of closed and open system models for porewater pH and calcite saturation state. *Geochimica et Cosmochimica Acta* 57: 317-334.
25. Canfield, D.E., and Des Marais, D.J. (1993) The cycling of carbon, sulfur and free oxygen in a microbial mat. *Geochim. Cosmochim. Acta*, v. 57: 3967-3883.
26. Canfield, D. E., Thamdrup, B. and Hansen, J. W. (1993) The anaerobic degradation of organic matter in Danish coastal sediments: Fe reduction, Mn reduction and sulfate reduction. *Geochim. Cosmochim. Acta*, v. 57: 3971-3984.
27. Canfield, D.E., Jørgensen, B.B., Fossing, H., Glud, R., Gundersen, J., Ramsing, N.B., Thamdrup, B., Hansen, J.W., and Nielsen, L.P. and Hall, P.O.J. (1993) Pathways of organic carbon oxidation in three continental margin sediments. *Marine Geology*, 113: 27-40.
28. Van Cappellen, P., and Canfield, D.E. (1993) Comment on "Lack of evidence for enhanced preservation of sedimentary organic matter in the oxygen minimum of the Gulf of California" *Geology*. 21: 570-571.
29. Raiswell, R., Canfield, D.E. and Berner, R.A. (1994) A comparison of iron extraction methods for the determination of degree of pyritization and the recognition of iron-limited pyrite formation. *Chemical Geology* 111: 101-110.
30. Canfield, D.E. (1994) Factors influencing organic carbon preservation in marine sediments. *Chemical Geology* 114: 315-239.
31. Canfield, D.E. and Des Marais (1994) Cycling of carbon, sulfur, oxygen and nutrients in a microbial mat. In: L.J. Stal and P. Caumette, eds., "*Structure, Development and Environmental Significance of Microbial Mats*" NATO-ARW, Springer-Verlag, pp. 255-263.

32. Des Marais, D.J. and Canfield, D.E. (1994) The carbon isotope biogeochemistry of microbial mats. In: L.J. Stal and P. Caumette, eds., "*Structure, Development and Environmental Significance of Microbial Mats*" NATO-ARW, Springer-Verlag, pp. 289-298.
33. Bebout, B.M., Paerl, H.W., Bauer, J.E., Canfield, D.E. and Des Marais, D.J. (1994) Nitrogen cycling in microbial communities: the quantitative importance of N-fixation and other sources of N for primary production. In: L.J. Stal and P. Caumette, eds., "*Structure, Development and Environmental Significance of Microbial Mats*" NATO-ARW, Springer-Verlag, pp. 265-272.
34. Canfield, D.E. and Thamdrup, B. (1994) The production of  $^{34}\text{S}$ -depleted sulfide during bacterial  $\text{S}^0$  disproportionation. *Science* 266: 1973-1975.
35. Canfield, D.E., Green, W.G., and Nixon, P (1995)  $^{210}\text{Pb}$  and stable Pb geochemistry in Lake Vanda, Antarctica. *Geochim. Cosmochim. Acta* 59: 2459-2468.
36. Fossing, H., Gallardo, V.A., Jørgensen, B.B., Hüttel, M., Nielsen, L.P., Schulz, H., Canfield, D.E., Forster, S., Glud, R., Gundersen, J., Küver, J., Ramsing, N.B., Teske, A., Thamdrup, B., Ulloa, O. (1995) Concentration and transport of nitrate by the mat-forming sulphur bacterium *Thioploca*. *Nature* 374: 713-715.
37. Canfield, D.E. and Thamdrup, B. (1996) Fate of elemental sulfur in an intertidal sediment. *FEMS Microbial Ecology* 19: 95-103 .
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39. Habicht, K.S. and Canfield, D.E. (1996) Sulfur isotopic fractionation in microbial mats and the evolution of the sulfur cycle. *Nature* 382: 342-343.
40. Canfield, D.E. (1996) Evolution of the sulfur cycle. In: S.H. Bottrell, ed. *Fourth International Symposium on the Geochemistry of the Earth Surface*, International Association of Geochemistry and Cosmochemistry, pp. 23-27.
41. Habicht, K.S. and Canfield, D.E. (1996) Sulfur fractionation by natural populations of sulfate reducing bacteria. In: S.H. Bottrell, ed. *Fourth International Symposium on the Geochemistry of the Earth Surface*, International Association of Geochemistry and Cosmochemistry, pp. 59-63.
42. Knoll, A.H., Bambach, R.J., Canfield, D.E., and Grotzinger, J.P. (1996) Comparative Earth history and late Permian mass Extinction, *Science* 273: 452-457.
43. Raiswell, R. and Canfield, D.E. (1996) The kinetics of reaction between silicate iron and dissolved sulfide in Peru margin sediments. *Geochim. Cosmochim. Acta* 60: 2777-2787.
44. Canfield, D.E., Lyons, T.W., and Raiswell, R. (1996) A model for iron deposition

to euxinic Black Sea sediments, *Amer. Jour. Sci.* 296: 818-834.

45. Reimers, C.E., Rittenburg, K.C., Canfield, D.E., Christiansen, M.B., and Martin, J.B. Pore water pH and the earliest diagenesis of the Santa Barbara Basin. (1996) *Geochim. Cosmochim. Acta* 60: 4037-4057.
46. Thamdrup, B., Canfield, D.E., Ferdelman, T.G., Glud, R.N., Gundersen, J.K. A biogeochemical survey of the anoxic basin Golfo Dulce, Costa Rica. (1996) *Revista de Biología Tropical* 44: 19-33.
47. Thamdrup B. and Canfield, D.E. (1996) Pathways of carbon oxidation in continental margin sediments off central Chile. *Limnology and Oceanography* 41: 1629-1650.
48. Canfield, D.E. (1997) The geochemistry of river particulates from the continental United States: major elements. *Geochimica et Cosmochimica Acta* 61: 3349-3365.
49. Canfield, D.E., Thamdrup, B., and Fleischer, S. (1998) Isotope fractionation and sulfur metabolism by pure and enrichment cultures of elemental sulfur disproportionating bacteria. *Limnology and Oceanography* 43: 253-264.
50. Green, W.J., Canfield, D.E. and Nixon, P. (1998) Cobalt cycling and fate in Lake Vanda. In: J. Prisco (ed.), Ecosystem dynamics in a Polar desert: The McMurdo Dry Valleys, Antarctica, AGU, pp. 205-215.
51. Habicht, K.S., and Canfield, D.E. (1997) Sulfur isotope fractionation during bacterial sulfate reduction in organic rich sediments. *Geochimica et Cosmochimica Acta* 61: 5351-5361.
52. Canfield, D.E., Boudreau, B.P., Mucci, A., and Gundersen, J. (1998) The early diagenetic formation of organic sulfur in the sediments of Mangrove Lake, Bermuda *Geochimica et Cosmochimica Acta* 62: 767-781.
53. Habicht, K.S., and Canfield, D.E. (1998) Sulfur isotope fractionation during bacterial reduction and disproportionation of thiosulfate and sulfite. *Geochimica et Cosmochimica Acta* 62: 2585-2595.
54. Raiswell, R., and Canfield, D.E. (1998) Sources of iron for pyrite formation in marine sediments *American Journal of Science* 298: 219-245.
55. Canfield, D.E. (1998) A new model for Proterozoic ocean chemistry *Nature* 396: 450-453.
57. Glud, R.N., Holby, O., Hoffmann, F. and Canfield, D.E. (1998) Benthic mineralisation and exchange in Arctic sediments (Svalbard). *Marine Ecology Progress Series* 173: 237-251.
58. Knoll, A.H., and Canfield, D.E. (1998) Isotopic inferences on early ecosystems.

In: Manger, W.L. and Meeks, L.K. (eds.), *Isotope Paleobiology and Paleoecology*, The Paleontological Society, Pittsburgh, pp. 212-243.

59. Kostka, J.E., Thamdrup, B., Glud, N.R., and Canfield, D.E. (1999) Rates and pathways of carbon oxidation in permanently cold Arctic sediments. *Marine Ecology Progress Series* 180: 7-21.
60. Canfield, D.E. (1999) A breath of fresh air. *Nature* 400: 503-504.
61. Canfield, D.E. and Raiswell, R. (1999) The evolution of the sulfur cycle. *American Journal of Science* 299: 697-723.
62. Nielsen, J.K., Shen, Y. and Canfield, D.E. (1999) Morphology and sulfur isotope composition of early diagenetic pyrite. In Ármannsson, H. (ed.): *Geochemistry of the Earth's surface. Proceedings of the 5<sup>th</sup> International Symposium on Geochemistry of the Earth's Surface*, Reykjavik, Iceland, 16-20 August 1999. A.A. Balkema, Rotterdam, 335-337.
63. Thamdrup, B., and Canfield, D.E. (2000) Benthic respiration in aquatic sediments. In: Sala, O.E., Jackson, R.B., Mooney, H.A. and Howarth, R. (eds.), *Methods in Ecosystem Science* 86-103.
64. Canfield, D., Habicht, K.S. and Thamdrup B. (2000) The Archean sulfur cycle and the early history of atmospheric oxygen. *Science* 288: 658-661.
65. Canfield, D.E., Habicht, K.S. and Thamdrup, B. (2000) Response to The Archean atmosphere and sedimentary sulfides. *Science* 289: 1297-1298.
66. Onstad, G.D., Canfield, D.E., Quay, P.D., and Hedges, J.I. (2000) Sources of particulate organic matter in rivers from the continental USA: Lignin phenol and stable carbon isotope compositions. *Geochimica et Cosmochimica Acta* 64: 3539-3546.
67. Falkowski, P., Scholes, R.J., Boyle, E., Canadell, J., Canfield, D., Elser, J., Gruber, N., Hibbard, K., Höglberg, P., Linder, S., Mackenzie, F.T., Moore III, B., Pedersen, T., Rosenthal, Y., Seitzinger, S., Smetacek, V., Steffen, W. (ICBP Carbon Working Group). (2000) The global carbon cycle: A test of our knowledge of Earth as a system. *Science* 290: 291-296.
68. Shen, Y., Buick, R., Canfield, D.E. (2001) Isotopic evidence for microbial sulphate reduction in the early Archean. *Nature* 410: 77-81.
69. Canfield, D.E. (2001) Isotope fractionation by natural populations of sulfate-reducing bacteria. *Geochimica et Cosmochimica Acta* 65: 1117-1124.

70. Habicht, K.S., Canfield, D.E. (2001) Isotope fractionation by sulfate-reducing natural populations and the isotopic composition of sulfide in marine sediments. *Geology* 29: 555-558.
71. Canfield, D.E. (2001) Biogeochemistry of sulfur isotopes. In J.W. Valley and D.R. Cole, *Stable Isotope Geochemistry, Reviews in Mineralogy and Geochemistry*, v. 43, Mineralogical Society of America, Washington DC, pp. 607-636.
72. Shen, Y., Canfield, D.E., Knoll, A.H. (2002) Middle Proterozoic ocean chemistry: evidence from the McArthur Basin, northern Australia, *American Journal of Science* 302: 81-109.
73. Bjerrum, C.J., Canfield, D.E. (2002) Ocean productivity before about 1.9 Gyr limited by phosphorus adsorption onto iron oxides, *Nature* 417: 159-162.
74. Habicht K.S., Gade M., Thamdrup B., Berg P., Canfield D.E. (2002) Calibration of sulfate levels in the Archean Ocean, *Science*, 298: 2372-2374.
75. Konhauser, K.O., Hamade, T., Raiswell, R., Morris, R.C., Ferris, F.G., Southam, G., Canfield, D.E. (2002) Could bacteria have formed the Precambrian banded iron formations?, *Geology*, 30, 1079-1082.
76. Dalsgaard T., Canfield D.E., Petersen J., Thamdrup, B. Acuña-González. (2003) Anammox is a significant pathway of N<sub>2</sub> production in the anoxic water column of Golfo Dulce, Costa Rica, *Nature*, 422: 606-608.
77. Farquhar, J., Johnston, D.T., Wing, B.A., Habicht, K.S., Canfield, D.E., Airieau, S., Thiemens, M.H. (2003) Multiple sulfur isotope interpretations of biosynthetic pathways: Implications for biological signatures in the sulfur isotope record, *Geobiology*, 1, 27-36.
78. Jetten, M.S.M., Sliemers, O., Kuyvers, M., Dalsgaard, T., van Niftrik, L., Cirpus, I., van de Pas, K., Thamdrup, B., Les Paslier, D., Op den Camp, H., Hulth, S. Nielsen, L.P., Abma, W., Kuenen, J.G., Jørgensen, B.B., Canfield, D.E., Damste, J., Revsbech, N.P., Fuerst, J., Weissenbach, J., Wagner, M., Schmidt, I., Schmid, M., Strous, M. (2003) Anaerobic ammonium oxidation by marine and fresh water planctomycete-like bacteria, *Applied Microbiology and Biotechnology*, 63, 107-114.
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80. Sørensen, K.B., Canfield, D.E., Oren, A. (2004) Salt adaptations of benthic microbial communities in a solar saltern (Eilat, Israel). *Appl. Environ. Microbiol.*, 70, 1608-1616.
81. Bjerrum, C.J., Canfield, D.E. (2004) New insights into the burial history of organic carbon on the early Earth. *Geochemistry Geophysics and Geosystems*, 5,



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83. Canfield, D.E, Sørensen, K.B., Oren, A. (2004) The biogeochemistry of a gypsum-encrusted microbial ecosystem. *Geobiology*, 2, 133-150.
84. Poulton, S.W., Fralick, P.W., and Canfield, D.E. (2004) The transition to a sulfidic ocean ~1.84 billion years ago. *Nature*, 431, 173-177.
85. Canfield, D.E. The evolution of the Earth surface sulfur reservoir. (2004) *American Journal of Science*, 304, 839-861.
86. Poulton, S.W., Canfield, D.E. (2005) Development of a sequential extraction technique for iron: Implications for iron partitioning in continentally-derived particulates. *Chemical Geology*, 214, 209-221.
87. Sørensen, K.B., Canfield, D.E., Oren, A. (2004) Salinity responses of benthic microbial communities in a solar saltern. *Applied and Environmental Microbiology* 70, 1608-1616.
88. Hulth, S., Aller, R.C., Canfield, D.E., Dalsgaard, T., Engström, P., Gilbert, F., Sundbäck, K. and Thamdrup, B. (2005) N removal in marine environments: recent developments and future research challenges. *Marine Chemistry*. 94, 125-145.
89. Habicht, K.S., Salling, L., Thamdrup, B., and Canfield, D.E. (2005) The effect of low sulfate concentrations on lactate oxidation and isotope fractionation during sulfate reduction by *Archaeoglobus fulgidus* strain Z. *Applied and Environmental Microbiology*. 71, 3770-3777.
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91. Dalsgaard, T., Thamdrup, B., and Canfield, D.E. (2005) Mini-review. Anaerobic ammonium oxidation (anammox) in the marine environment. *Research in Microbiology*. 156, 457-464.
92. Poulton, S.W, and Canfield, D.E. (2005) Development of a sequential extraction technique for iron: Implications for iron partitioning in continentally-derived particulates. *Chemical Geology* 214, 209-221.
93. Sørensen, K.B., Canfield, D.E., Teske, A.P., and Oren, A. (2005) Community composition of a hypersaline endoevaporitic microbial mat. *Applied and Environmental Microbiology* 71, 7352-7365.
94. Johnston, D.T., Wing, B.A., Farquhar, J., Kaufman, A.J., Strauss, H., Lyons, T.W., Kah, L.C., Canfield, D.E. (2005) Active microbial sulfur disproportionation in the Mesoproterozoic. *Science*, 310, 1477-1479.

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100. Poulton, S.W., Canfield, D.E. (2006) Co-diagenesis of iron and phosphorus in hydrothermal sediments from the southern East Pacific Rise: Implications for the evolution of paleoseawater phosphate concentrations. *Geochemica et Cosmochimica Acta*, 70, 5883-5898.
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104. Zerkle, A.L., Cox, R.P., House, C. H., Canfield, D. E. (2006) Metal limitation of cyanobacterial N<sub>2</sub> fixation and implications for the Precambrian nitrogen cycle. *Geobiology*, 4, 285-297.
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