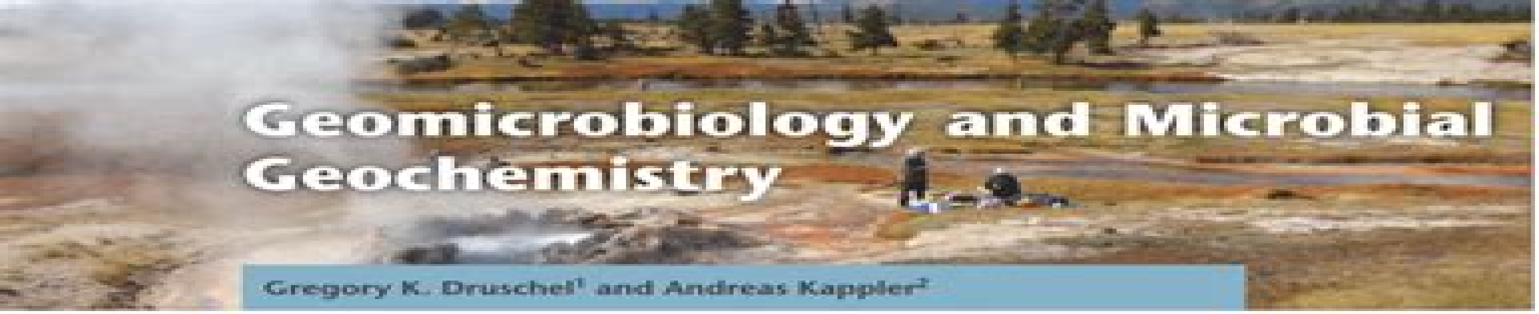

Geomicrobiology and Microbial Geochemistry

Gregory K. Druschel[1] and Andreas Kappler[2]

To understand the biogeochemical cycles of elements and the evolution of life on Earth, one needs to appreciate the interplay between biology, chemistry, and geology.

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Geomicrobiology and microbial geochemistry (GMG) investigates the interaction between Earth, environmental systems, and microbial life. Microbes shape their geochemical surroundings through their metabolic and growth needs and thereby exert significant geochemical and mineralogical control on their local environments. In turn, local geochemical conditions dictate what metabolic processes are possible. These mutual influences mean that microbial evolution has occurred in concert with changing geosphere conditions and that microbes have driven major shifts in ocean, continent and atmospheric chemistry. If one wishes to understand element cycling in any system containing water, one must realize that microbes are critical to the story.

Keywords: geomicrobiology, geochemistry, genetics, redox, biomineralization, evolution

DEVELOPMENT OF GEOMICROBIOLOGY AND MICROBIAL GEOCHEMISTRY

The rapidly developing field of geomicrobiology and microbial geochemistry (GMG) is a subset of the broader disciplines of geobiology and biogeochemistry. GMG overlaps with biology (by studying microbes) but is specifically focused on combining chemical, biological, *and* geological perspectives together to characterize the role of microbes in environmental and geological processes. Geobiochemistry turns this perspective 180°; it establishes the role that geology plays in the development of organismal biochemical processes (Shock and Boyd 2015 this issue). Combined approaches that utilize methods to investigate microbial activity (physiology, genetics, culturing, microscopy) and geochemical processes (aqueous, mineral, isotope geochemistry) have been developed to address the important, and sometimes very complex, interactions between microbes and their (geological) surroundings.

The GMG field owes much to the early work of environmental microbiologists and geochemists. Environmental microbiology has a long history, arguably beginning with the invention and application of the microscope by Leeuwenhoek in the 17th century. However, the link between microorganisms and Earth processes was not fully recognized until Russian microbiologist Sergei Nicholaevitch Winogradsky (1856–1953) formulated the concepts of chemolithotrophy and autotrophy after investigating elemental sulfur transformations by *Beggiatoa spp.* (1887; as reviewed by Dworkin 2012). Russian microbiologist Vladimir Vernadsky (1863–1945) illustrated the temporal dimension of the interaction between life and Earth by arguing that the biosphere has shaped Earth's surface environment throughout geological time (Vernadsky 1926). The Dutch biologist Lourens G. M. Baas Becking (1895–1963) came up with the notion that "everything is everywhere but the environment selects," a novel concept in biology in which a community of organisms is determined by their physicochemical surroundings (see de Wit and Bouvier 2006). Baas Becking also coined the term "geobiology" in an effort to describe the relationships between organisms and the Earth (Quispel 1998).

One of the first to bring together microbiology and geochemistry was Henry Ehrlich (now Professor Emeritus at Rensselaer Polytechnic Institute, New York, USA): his academic training as a microbiologist found a serendipitous union with geology when a colleague piqued his interest in pyrite oxidation caused by bacteria (Ehrlich 2012). His long career has furthered our understanding of the role of microorganisms in a number of element cycles. Other geochemists also blazed the trail towards linking key physical and chemical concepts to microbial processes. The work of American geologist Robert Berner (1935–2015) helped define fundamental concepts of carbon cycling through deep time and the associated formation of metal sulfides and carbonate minerals (both processes that involve microbial activity). Berner also focused discussion on how these small-scale processes might affect the global climate. Other geochemists who have contributed to understanding element cycling through microbial activity (using chemical speciation, energetics, isotope fractionation, kinetics) include Robert Garrels, Harold Helgeson, Samuel Epstein, and Stanley Miller.

Despite these deep historical roots, only in the last 15–20 years has GMG evolved into a robust discipline (Banfield and Nealson 1997). It is not a coincidence that the first generation of truly interdisciplinary scientists—trained at the intersection of microbiology, genetics, geochemistry, mineralogy, and computational approaches—have demonstrated the critical role that microbes play in processes ranging from the molecular to the global scale. From the history of the early Earth to the mobility of elements, new insights are shifting paradigms for how the community thinks about key problems in the field. For example,

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Microbial Geochemistry

Jillian F. Banfield,Kenneth H. Nealson

Microbial Geochemistry:

Microbial Geochemistry Wolfgang E. Krumbein,1983-01-01 Ground-Water Microbiology and Geochemistry Frank Chapelle,1993-02-03 The difficult struggle to protect our valuable ground water resources necessarily involves scientists and engineers from many disciplines To prevail in this effort these practitioners including microbiologists hydrogeologists geoscientists and environmental engineers must have a common understanding of essential ground water quality issues and problems That includes a basic grasp of how microorganisms and microbial processes affect the chemistry of ground water in both pristine and chemically stressed aquifer systems Ground Water Microbiology and Geochemistry marks the first attempt to bridge the historical lack of communication among these disciplines by detailing in language that cuts across specialties the impact of microorganisms and microbial processes on ground water systems To bring these diverse practitioners together the book has been organized in three parts with each section addressing the information needs of specific disciplines The first six chapters of Ground Water Microbiology and Geochemistry provide an overview of microbiology that s geared to geoscientists who may lack formal training in the field Here the book systematically covers the kinds of microorganisms found in subsurface environments focusing on their growth metabolism genetics and ecology The second part of the book which covers four chapters speaks both to geoscientists and to microbiologists It offers a hydrologic perspective on how microbial processes affect groundwater geochemistry in pristine systems an important topic for geochemists since most ground water reservoirs have not been chemically affected by human activities and naturally occurring microbial processes have major impacts on water quality At the same time Part Two introduces microbiologists to the different classes of ground water systems and gives an overview of techniques for sampling subsurface environments In addition microbiologists gain an understanding of biogeochemical cycling in ground water systems in coverage that s unique to this book and of the classic geochemical modeling techniques that are used to study microbial processes The final three chapters of Ground Water Microbiology and Geochemistry focus in on microbial processes in contaminated ground water systems a topic of central concern to environmental scientists In this concluding section microbiologists see how degradation processes depend upon the hydrologic and geochemical environments within which they operate Having achieved a basic knowledge of microbiological and biochemical concepts from the earlier chapters geoscientists are fully prepared for this treatment of microbial acclimation and the biodegradation of petroleum hydrocarbons and halogenated compounds Ground Water Microbiology and Geochemistry is as graphically impressive as it is far reaching High quality computer generated illustrations of particular appeal to visually oriented geoscientists can be found throughout the book Equally important is the book s unusually comprehensive bibliography which like the text itself spans the relevant science and engineering disciplines The importance of Ground Water Microbiology and Geochemistry to geoscientists hydrologists and environmental scientists has been amply documented The book should also be required reading for water planners and lawyers involved in environmental issues It will also serve as a compelling text in upper undergraduate and graduate courses in ground water chemistry **Microbial Metal Respiration** Johannes Gescher,Andreas Kappler,2014-02-21 Microbes can respire on metals This seemingly simple finding is one of the major discoveries that were made in the field of microbiology in the last few decades The importance of this observation is evident Metals are highly abundant on our planet Iron is even the most abundant element on Earth and the forth most abundant element in the Earth s crust Hence in some environments iron but also other metals or metalloids are the dominant respiratory electron acceptors Their reduction massively drives the carbon cycle in these environments and establishes redox cycles of the metallic electron acceptors themselves These redox cycles are not only a driving force for other biotic reactions but are furthermore necessary for initiating a number of geochemically relevant abiotic redox conversions Although widespread and ecologically influential electron transfer onto metals like ferric iron or manganese is biochemically challenging The challenge is to transfer respiratory electrons onto metals that occur in nature at neutral pH in the form of metal oxides or oxihydroxides that are effectively insoluble Obviously it is necessary that the microbes specially adapt in order to catalyze the electron transfer onto insoluble electron acceptors The elucidation of these adaptations is an exciting ongoing process To sum it up dissimilatory metal reduction has wide spread implications in the field of microbiology biochemistry and geochemistry and its discovery was one of the major reasons to establish a novel scientific field called geomicrobiology Recently the discovery of potential applications of dissimilatory metal reducers in bioremediation or current production in a microbial fuel cell further increased the interest in studying microbial metal reduction **Geomicrobiology** S. K. Jain,A. A. Khan,M. K. Rai,2016-04-19 Geomicrobiology is a combination of geology and microbiology and includes the study of interaction of microorganisms with their environment such as in sedimentary rocks This is a new and rapidly developing field that has led in the past decade to a radically revised view of the diversity and activity of microbial life on Earth Geomicrobiology e **The Chemistry of Weathering** J.I. Drever,2012-12-06 Several important developments in our understanding of the chemistry of weathering have occurred in the last few years 1 There has been a major breakthrough in our understanding of the mechanisms controlling the kinetics of sil icate dissolution and there have been major advances in computer modeling of weathering processes 2 There has been a growing recognition of the importance of organic solutes in the weathering process and hence of the inter relationships between mineral weathering and the terrestrial ecosystem 3 The impact of acid deposition acid rain has been widely recognized The processes by which acid deposition is neutral ized are closely related to the processes of normal chemical weathering an understanding of the chemistry of weathering is thus essential for predicting the effects of acid deposition 4 More high qual ity data have become available on the chemical dynamics of smal I watersheds and large river systems which represent the integrated effects of chemical weathering U.S. Geological Survey Bulletin ,1983 **The Petroleum System** Geological Survey (U.S.),1992 **U.S. Geological Survey Bulletin** Margo I. Toth,Max Wyss,Ted G. Theodore,U.S. Geological Survey Library,J. S.

Stacey,Richard Scott Sasscer,Robert Y. Koyanagi,1983 **Links Between Geological Processes, Microbial Activities & Evolution of Life** Yildirim Dilek,Harald Furnes,Karlis Muehlenbachs,2008-07-01 Microbial activities influence water rock interaction processes and chemical transport between the major geochemical reservoirs and the formation transformation of minerals and rocks whereas geological processes and geochemical controls influence the microbial ecology in extreme environments How biological activity influences geological processes and what role these processes played in the geological evolution of the Earth are fundamental questions How do we recognize the ancient microbial activities in the rock record and what analytical methods do we use to document them to better understand the evolution of life Can we detect the existence of microbial life in deep time by studying Archaean rocks Microbial systems in extreme environments and in the deep biosphere may be analogous to potential life on other planetary bodies and hence may be used to investigate the possibilities of extraterrestrial life This book explores these questions in an interdisciplinary approach and examines the mode and nature of links between geological processes and microbial activities and their significance for the origin and evolution of life on the Earth and possibly on other planets A Special Issue on Microbial Geochemistry Lesley A. Warren,2004 *Bacterial Biogeochemistry* Tom Fenchel,Gary M. King,Henry Blackburn,1998-06-02 Bacterial Biogeochemistry Second Edition focuses on bacterial metabolism and its relevance to the environment including the decomposition of soil food chains nitrogen fixation assimilation and reduction of carbon nitrogen and sulfur and microbial symbiosis The scope of the new edition has broadened to provide a historical perspective and covers in greater depth topics such as bioenergetic processes characteristics of microbial communities spacial heterogeneity transport mechanisms microbial biofilms extreme environments and evolution of biogeochemical cycles Key Features Provides up to date coverage with an enlarged scope a new historical perspective and coverage in greater depth of topics of special interest Covers interactions between microbial processes atmospheric composition and the earth s greenhouse properties Completely rewritten to incorporate all the advances and discoveries of the last 20 years **Microbial Ecology** Ronald M. Atlas,Richard Bartha,1987 **Global Ecology** Mitchell B. Rambler,2013-04-25 Public awareness and concern over environmental degradation has reached an all time high as the effect of man s activities on the global environment grows to greater and greater proportions To understand the consequences of these activities it is necessary to understand the fundamental nature of the system that supports life on a planetary scale This book is the first interdisciplinary text on global ecology and is readable to students with only one to two years of science background It contains a glossary of specialized terms which will enable students who are traditionally trained in geology astronomy and chemistry to understand the ecological topics presented It places biogeochemical cycles witin a planetary perspective and ties satellite technology and applications to the earth sciences As such it can be the basis for new courses in planetary ecology as well as being useful for present day ecology courses and seminars in environmental science Contributions in Microbial Geochemistry Geologiska Institutionen (Stockholm),1978 *Geomicrobiology* Jillian

F. Banfield,Kenneth H. Nealson,2018-12-17 Volume 35 of Reviews in Mineralogy defines and explore the topic of geomicrobiology It is organized so as to first introduce the nature diversity and metabolic impact of microorganisms and the types of solid phases they interact with This is followed by a discussion of processes that occur at cell surfaces interfaces between microbes and minerals and within cells and the resulting mineral precipitation dissolution and changes in aqueous geochemistry The volume concludes with a discussion of the carbon cycle over geologic time Basis for this volume was the Short Course on Geomicrobiology presented by the Mineralogical Society of America on October 18 and 19 1997 at the Alta Peruvian Lodge in Alta Utah Arsenic Robert Bowell,Charles Alpers,Heather Jamieson,Kirk Nordstrom,Juraj Majzlan,2014-11-21 Environmental Mineralogy and Bio Geochemistry of Arsenic provides a comprehensive understanding of arsenic geochemistry in the near surface environment Topics covered include the mineralogy thermodynamics geochemistry analysis microbiology and bioavailability of arsenic with emphasis on implications for arsenic toxicity geochemistry in natural ground waters and mine associated impacts and possible mitigation options This volume is useful for those seeking to understand arsenic geochemistry and biological interactions in the near surface environment Clay Minerals does not use an online manuscript tracking submission system as well those working for mining companies the chemicals industry NGO s or government bodies concerned with reducing the impact of arsenic on the environment *Analytical Geomicrobiology* Janice P. L. Kenney,Harish Veeramani,Daniel S. Alessi,2019-07-18 A comprehensive handbook outlining state of the art analytical techniques used in geomicrobiology for advanced students researchers and professional scientists Applied and Environmental Microbiology ,1999 Microbial Biogeochemistry James E. Zajic,1969 Microbial Life of the Deep Biosphere Jens Kallmeyer,Dirk Wagner,2014-04-01 Over the last two decades exploration of the deep subsurface biosphere has developed into a major research area New findings constantly challenge our concepts of global biogeochemical cycles and the ultimate limits to life In order to explain our observations from deep subsurface ecosystems it is necessary to develop truly interdisciplinary approaches ranging from microbiology and geochemistry to physics and modeling This book aims to bring together a wide variety of topics covering the broad range of issues that are associated with deep biosphere exploration Not only does the book present case studies of selected projects but also treats questions arising from our current knowledge Despite nearly two decades of research there are still many boundaries to exploration caused by technical limitations and one section of the book is devoted to these technical challenges and the latest developments in this field This volume will be of high interest to biologists chemists and earth scientists all working on the deep biosphere

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Microbial Geochemistry Introduction

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