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This series aims to report new developments in research and teaching in the interdisciplinary fields of astrobiology and biogeophysics. This encompasses all aspects of research into the origins of life – from the creation of matter to the emergence of complex life forms – and the study of both structure and evolution of planetary ecosystems under a given set of astro- and geophysical parameters. The methods considered can be of theoretical, computational, experimental and observational nature. Preference will be given to proposals where the manuscript puts particular emphasis on the overall readability in view of the broad spectrum of scientific backgrounds involved in astrobiology and biogeophysics.
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- Suitably edited research reports
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Tetsuya Tokano (Ed.)

Water on Mars and Life

With 88 Figures and 9 Tables

Springer

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Preface

This book surveys recent advances made in the research of water on Mars and its astrobiological implication. Meanwhile, the presence of abundant frozen H_2O on present Mars is beyond question and recent spacecraft are unveiling the manifold appearances of Martian water largely hidden from visual inspection. Ground ice in the polar region and water ice in the southern polar cap recently detected by Mars Odyssey and Mars Express, respectively, may be the tip of the Martian iceberg, also in a figurative sense, and encourages the planetary and astrobiological community to strengthen their efforts to follow the water on Mars. Liquid water is generally considered to have played a major role in the evolution of terrestrial-type life. Under this premise, water on Mars inevitably becomes one major subject of astrobiology, which is currently being established as a new interdisciplinary research field.

However, the majority of Martian water is not liquid and has probably not been liquid throughout much of history. Bodies of liquid water at one time are likely to have existed at other times in some another form in different planetary reservoirs, unless they have been lost to space. Therefore, a comprehensive study of all possible forms of water on Mars since the planetary formation and the processes related to them becomes necessary.

This book covers all major aspects related to water on Mars and their possible biological implication that have been discussed in the literature, and consists of 13 chapters written by scientists from various disciplines. New aspects and results are discussed more exhaustively, sometimes in separate chapters, than more "classical" subjects such as outflow channels or valley networks. The assemblage of these separate chapters ultimately merges into a comprehensive story of water on Mars.

Part I (Chapters 1–4) reviews the water on early Mars and its history, and discusses how it may have been involved in the planetary evolution. The story begins with water extracted from Martian meteorites, which can tell us something about the possible origin of Martian water. The following chapter considers how the global inventory of water may have evolved in the course of billions of years as a result of atmospheric and geological processes. In the third chapter we undertake a fascinating palaeontological excursion to early Earth, which may have had some similarities with early Mars. The fourth chapter looks at water-bearing minerals on the surface, which contain clues to the environmental, particularly aqueous, conditions of early Mars.

Part II (Chapters 5–8) deals in detail with various water reservoirs on present Mars as actually evidenced by observations from orbiters, landers and telescopes. The survey begins with the recent detection of subsurface hydrogen by Mars Odyssey, the first firm observational evidence of H_2O in the subsurface. The next chapter discusses the polar caps, which not only represent the largest water reservoir on the surface, but also bear a climatic record of the past. The following chapter reviews ground ice as the largest putative water reservoir on Mars from a geological point of view. Part II concludes with an inspection of the global water

cycle in the atmosphere, which acts as an important medium for the water exchange between the planetary water reservoirs.

Part III (Chapters 9–13) focuses on some particular putative aqueous environments on past or present Mars and their possible terrestrial analogues of possible astrobiological importance. The book first guides the reader to those parts of Artctic and Antarctica which are the most Mars-like environment on Earth and where life still flourishes. The next chapter discusses geological evidences of lakes on early and recent Mars and the environmental conditions relevant for life. Microbial life in impact craters filled with water and salty environments in the subsurface together with their implication for Mars are illustrated in the following two chapters. Finally, we dive into the hydrothermal vents in the deep sea, where early life on Earth may have diversified, and learn about prospects for the future search for life on Mars.

Our knowledge about water on Mars is certainly incomplete and we may gain further new insight in the future through Mars missions as well as by observational, experimental and theoretical studies. Mars Express Orbiter as well as the Mars Exploration Rovers Spirit in Gusev Crater and Opportunity in Meridiani Planum in operation since early 2004 seem to become quite promising. The results of these missions could not be discussed in this book, so the reader is referred to press releases and publications in journals for the most recent findings. However, in this book the reader finds background information as well as a discussion on what potential new results can tell us about the history of water on Mars. I hope that this book can serve as a convenient and representative guide for all those interested in Mars research and astrobiology.

I would like to express my big thanks to all the authors for their tremendous efforts writing a chapter within the framework of this interdisciplinary book. Gerda Horneck of the Editorial Board of this book series “Advances in Astrobiology and Biogeophysics” and Christian Caron of the Springer-Verlag, who both encouraged and assisted me during the entire production process are greatly acknowledged.

Köln, April 2004 *Tetsuya Tokano*

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List of Abbreviations

APXS	Alpha Proton X-Ray Spectrometer
ASCA	Advanced Satellite for Cosmology and Astrophysics
ASPERA	Automatic Space Plasma Experiment with a Rotating Analyser
AWRS	"Arabian water-rich spot"
ATP	adenosine triphosphate
AU	astronomical unit
BIF	banded iron formation
CNRS	Centre national de la recherche scientifique
CRISM	Compact Reconnaissance Spectrometer for Mars
DNA	deoxyribonucleic acid
DSC	differential scanning calorimetry
DTA	differential thermal analysis
EGA	evolved gas analysis
EPS	extracellular polymeric substance
EUVE	Extreme Ultraviolet Spectroscopic Explorer
FUSE	Far Ultraviolet Spectroscopic Explorer
FYSP	faint young Sun problem
Ga	billion years
GCM	general circulation model
GC-MS	gas chromatograph mass spectrometer
GRS	Gamma-Ray Spectrometer
GSH	Gamma Sensor Head
HEND	High Energy Neutron Detector
HRSC	High Resolution Stereo Camera
HST	Hubble Space Telescope
IMP	Imager for Mars Pathfinder
IR	infrared
IRS	Infrared Spectrometer
IRTM	Infrared Thermal Mapper
ISM	interstellar medium; Imaging Spectrometer for Mars
IUE	International Ultraviolet Explorer
ka	thousand years
KHz	Kelvin-Helmholtz
LD	Large Detector
L_s	areocentric longitude of the Sun
LTE	local thermal equilibrium
Ma	million years
MAG/ER	Magnetometer/Electron Reflectometer
MARSIS	Mars Advanced Radar for Subsurface and Ionospheric Sounding
MAWD	Mars Atmospheric Water Detector
MCNPX	Monte Carlo N-Particle code
MD	Medium Detector
MDIM	Mars digital image mosaic
MER	Mars Exploration Rover

MHD	magnetohydrodynamic
MO	Mars Odyssey
MOC	Mars Orbiter Camera
MOLA	Mars Orbiter Laser Altimeter
MPN	most probable number method
MSL	Mars Science Lab
NCAR	National Center for Atmospheric Research
NPR	Northern permafrost region
NS	Neutron Spectrometer
OMEGA	Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité (Visible and Infrared Mineralogical Mapping Spectrometer)
PCR	polymerase chain reaction
PIXE	particle induced X-ray emission
PVO	Pioneer Venus Orbiter
RH	relative humidity
RNA	ribonucleic acid
ROSAT	Röntgen Satellite
SD	Small Detector
SEM	scanning electron microscope
SMOW	standard mean ocean water
SNC	Shergotty, Nakhla and Chassigny
SPR	Southern permafrost region
TEGA	Thermal Evolved Gas Analyzer
TEM	transmission electron miscroscope
TES	Thermal Emission Spectrometer
TF	terrestrial fractionation
TGA	thermogravimetric analysis
THEMIS	Thermal Emission Imaging System
TSW	terrestrial seawater
UV	ultraviolet
VL	Viking lander
VNIR	visible/near-infrared
wt %	weight %
XRD	X-ray diffraction
XRF	X-ray fluorescence
XUV	extreme ultraviolet
ZAMS	zero age mean sequence