



SEDIMENTARY GEOLOGY AT MERIDIANI PLANUM, MARS

Editors

S.W. SQUYRES and A.H. KNOLL



Sedimentary Geology At Meridiani Planum Mars

Nathalie A. Cabrol, Edmond A. Grin



Sedimentary Geology At Meridiani Planum Mars:

Sedimentary Geology at Meridiani Planum, Mars S.W. Squyres, Andrew H. Knoll, 2006-01-17 In January of 2004 twin robotic explorers Spirit and Opportunity landed on Mars Expected to last for 90 days the two rovers explored the Martian surface for nearly two years Their objective was to search for evidence of ancient water on Mars and to determine if Mars ever had conditions that would have been suitable for life Opportunity landed on Meridiani Planum a smooth plateau near the Martian equator coming to rest in a small impact feature named Eagle Crater After leaving Eagle Crater Opportunity drove eastward to Endurance Crater a much larger crater that allowed access to deeper and older rocks At these locations Opportunity found strong evidence for ancient water on Mars This evidence includes blueberries small concretions rich in hematite that precipitated from water Other evidence includes rocks that were made largely of sulphate salts deposited when water evaporated and rocks that preserve ancient ripples that formed billions of years ago as water flowed over sand on Mars The conditions long ago at Meridiani Planum could have been suitable for some simple forms of life Whether life could have developed there however is a more difficult question

Treatise on Geochemistry, 2013-10-19 This extensively updated new edition of the widely acclaimed Treatise on Geochemistry has increased its coverage beyond the wide range of geochemical subject areas in the first edition with five new volumes which include the history of the atmosphere geochemistry of mineral deposits archaeology and anthropology organic geochemistry and analytical geochemistry In addition the original Volume 1 on Meteorites Comets and Planets was expanded into two separate volumes dealing with meteorites and planets respectively These additions increased the number of volumes in the Treatise from 9 to 15 with the index appendices volume remaining as the last volume Volume 16 Each of the original volumes was scrutinized by the appropriate volume editors with respect to necessary revisions as well as additions and deletions As a result 27% were republished without major changes 66% were revised and 126 new chapters were added In a many faceted field such as Geochemistry explaining and understanding how one sub field relates to another is key Instructors will find the complete overviews with extensive cross referencing useful additions to their course packs and students will benefit from the contextual organization of the subject matter Six new volumes added and 66% updated from 1st edition The Editors of this work have taken every measure to include the many suggestions received from readers and ensure comprehensiveness of coverage and added value in this 2nd edition The esteemed Board of Volume Editors and Editors in Chief worked cohesively to ensure a uniform and consistent approach to the content which is an amazing accomplishment for a 15 volume work 16 volumes including index volume

Comparative Climatology of Terrestrial Planets Stephen J. Mackwell, Amy A. Simon-Miller, Jerald W. Harder, Mark A. Bullock, 2014-01-25 The early development of life a fundamental question for humankind requires the presence of a suitable planetary climate Our understanding of how habitable planets come to be begins with the worlds closest to home Venus Earth and Mars differ only modestly in their mass and distance from the Sun

yet their current climates could scarcely be more divergent Only Earth has abundant liquid water Venus has a runaway greenhouse and evidence for life supporting conditions on Mars points to a bygone era In addition an Earth like hydrologic cycle has been revealed in a surprising place Saturn s cloud covered satellite Titan has liquid hydrocarbon rain lakes and river networks Deducing the initial conditions for these diverse worlds and unraveling how and why they diverged to their current climates is a challenge at the forefront of planetary science Through the contributions of more than sixty leading experts in the field Comparative Climatology of Terrestrial Planets sets forth the foundations for this emerging new science and brings the reader to the forefront of our current understanding of atmospheric formation and climate evolution Particular emphasis is given to surface atmosphere interactions evolving stellar flux mantle processes photochemistry and interactions with the interplanetary environment all of which influence the climatology of terrestrial planets From this cornerstone both current professionals and most especially new students are brought to the threshold enabling the next generation of new advances in our own solar system and beyond Contents Part I Foundations Jim Hansen Mark Bullock Scot Rafkin Caitlin Griffith Shawn Domagal Goldman and Antígona Segura Kevin Zahnle Part II The Greenhouse Effect and Atmospheric Dynamics Curt Covey G Schubert and J Mitchell Tim Dowling Francois Forget and Sebastien Lebonnois Vladimir Krasnopolsky Adam Showman Part III Clouds Hazes and Precipitation Larry Esposito A M tt nen K P rot F Montmessin and A Hauchecorne Nilton Renno Zibi Turtle Mark Marley Part IV Surface Atmosphere Interactions Colin Goldblatt Teresa Segura et al John Grotzinger Adrian Lenardic D A Brain F Leblanc J G Luhmann T E Moore and F Tian Part V Solar Influences on Planetary Climate Aaron Zent Jerry Harder F Tian E Chassefiere F Leblanc and D Brain David Des Marais

3D Digital Geological Models Andrea Bistacchi, Matteo Massironi, Sophie Viseur, 2022-04-05 3D DIGITAL GEOLOGICAL MODELS

Discover the practical aspects of modeling techniques and their applicability on both terrestrial and extraterrestrial structures A wide overlap exists in the methodologies used by geoscientists working on the Earth and those focused on other planetary bodies in the Solar System Over the course of a series of sessions at the General Assemblies of the European Geosciences Union in Vienna the intersection found in 3D characterization and modeling of geological and geomorphological structures for all terrestrial bodies in our solar system revealed that there are similar datasets and common techniques for the study of all planets Earth and beyond from a geological point of view By looking at Digital Outcrop Models DOMs Digital Elevation Models DEMs or Shape Models SM researchers may achieve digital representations of outcrops topographic surfaces or entire small bodies of the Solar System like asteroids or comet nuclei 3D Digital Geological Models From Terrestrial Outcrops to Planetary Surfaces has two central objectives to highlight the similarities that geological disciplines have in common when applied to entities in the Solar System and to encourage interdisciplinary communication and collaboration between different scientific communities The book particularly focuses on analytical techniques on DOMs DEMs and SMs that allow for quantitative characterization of outcrops and geomorphological features It also highlights

innovative 3D interpretation and modeling strategies that allow scientists to gain new and more advanced quantitative results on terrestrial and extraterrestrial structures 3D Digital Geological Models From Terrestrial Outcrops to Planetary Surfaces readers will also find The first volume dedicated to this subject matter that successfully integrates methodology and applications A series of methodological chapters that provide instruction on best practices involving DOMs DEMs and SMs A wide range of case studies including small to large scale projects on Earth Mars the 67P Churyumov Gerasimenko comet and the Moon Examples of how data collected at surface can help reconstruct 3D subsurface models 3D Digital Geological Models From Terrestrial Outcrops to Planetary Surfaces is a useful reference for academic researchers in earth science structural geology geophysics petroleum geology remote sensing geostatistics and planetary scientists and graduate students studying in these fields It will also be of interest for professionals from industry particularly those in the mining and hydrocarbon fields

Lakes on Mars Nathalie A. Cabrol, Edmond A. Grin, 2010-09-15 On Earth lakes provide favorable environments for the development of life and its preservation as fossils They are extremely sensitive to climate fluctuations and to conditions within their watersheds As such lakes are unique markers of the impact of environmental changes Past and current missions have now demonstrated that water once flowed at the surface of Mars early in its history Evidence of ancient ponding has been uncovered at scales ranging from a few kilometers to possibly that of the Arctic ocean Whether life existed on Mars is still unknown upcoming missions may find critical evidence to address this question in ancient lakebeds as clues about Mars climate evolution and its habitability potential are still preserved in their sedimentary record Lakes on Mars is the first review on this subject It is written by leading planetary scientists who have dedicated their careers to searching and exploring the questions of water lakes and oceans on Mars through their involvement in planetary exploration and the analysis of orbital and ground data beginning with Viking up to the most recent missions In thirteen chapters Lakes on Mars critically discusses new data and explores the role that water played in the evolution of the surface of Mars the past hydrological provinces of the planet the possibility of heated lake habitats through enhanced geothermal flux associated with volcanic activity and impact cratering The book also explores alternate hypotheses to explain the geological record Topographic morphologic stratigraphic and mineralogic evidence are presented that suggest successions of ancient lake environments in Valles Marineris and Hellas The existence of large lakes and or small oceans in Elysium and the Northern Plains is supported both by the global distribution of deltaic deposits and by equipotential surfaces that may reflect their past margins Whether those environments were conducive to life has yet to be demonstrated but from comparison with our planet their sedimentary deposits may provide the best opportunity to find its record if any The final chapters explore the impact of climate variability on declining lake habitats in one of the closest terrestrial analogs to Mars at the Noachian Hesperian transition identify the geologic morphologic and mineralogic signatures of ancient lakes to be searched for on Mars and present the case for landing the Mars Science Laboratory mission in such an environment First review on the subject by

worldwide leading authorities in the field New studies with most recent data new images figures and maps Most recent results from research in terrestrial analogs Martian Aeolian Geomorphology Zhibao Dong,Chao Li,Ping Lü,2025-06-14 This book covers Martian Aeolian Geomorphology and is organized around three main foci The first focus is about advancing our understanding of aeolian geomorphology through research on Martian aeolian landforms Chapters 1 through 4 provide essential knowledge for understanding the aeolian geomorphology of Mars Among them Chapters 1 and 2 provide readers with a clear understanding of the significance scientific status and methodology of the study of aeolian geomorphology on Mars Chapters 3 introduces the physics of aeolian geomorphology and Chapter 4 presents an overview of Mars Chapters 5 and 6 are devoted to the Martian atmosphere and Martian sediments respectively constituting the dynamic conditions and the material basis for the formation of aeolian landforms their basic characteristics the processes that control their formation and evolution and comparisons with Earth Chapters 7 and 8 discuss the geomorphological types morphology and distribution of dunes on Mars and extract information on the developmental environment and processes that control dune landforms The second focus of this book concerns the unique characteristics of Martian aeolian landforms Chapters 9 and 10 provide thorough introductions to several unique Martian aeolian landforms The third focus is to provide a textbook for graduate students To facilitate understanding of Martian aeolian landforms and deepen the reader's comprehension of current aeolian geomorphological theories we connect the characteristics of various aspects of Martian aeolian landforms with the relevant theories and especially the classical theories that have stood the test of time At the same time we try to present different viewpoints and hypotheses on relevant scientific issues leaving readers with wide room for innovative thinking The book's 12 chapters are ordered to start with an overview of fundamental knowledge Chapters 1 to 4 continue Chapters 5 to 11 by describing the book's core content and conclude Chapters 12 by relating what we believe about Mars to what we know about Earth **The International Atlas of Mars Exploration: Volume 2, 2004 to 2014** Philip J. Stooke,2016-04-07 Beginning with the landing of the Spirit and Opportunity rovers in 2004 and concluding with the end of the Curiosity mission in 2014 this second volume of The International Atlas of Mars Exploration continues the story of Mars exploration in spectacular detail It is an essential reference source on Mars and its moons combining scientific and historical data with detailed and unique illustrations to provide a thorough analysis of twenty first century Mars mission proposals spacecraft operations landing site selection and surface locations Combining a wealth of data facts and illustrations most created for this volume the atlas charts the history of modern Mars exploration in more detail than ever before Like the first volume the atlas is accessible to space enthusiasts but the bibliography and meticulous detail make it a particularly valuable resource for academic researchers and students working in planetary science and planetary mapping **Volatiles in the Martian Crust** Justin Filiberto,Susanne P. Schwenzer,2018-08-30 Volatiles in the Martian Crust is a vital reference for future missions including ESA's EXO Mars and NASA's Mars2020 rover looking for evidence of life on Mars and the potential for habitability

and human exploration of the Martian crust Mars science is a rapidly evolving topic with new data returned from the planet on a daily basis The book presents chapters written by well established experts who currently focus on the topic providing the reader with a fresh up to date and accurate view Organized into two main sections the first half of the book focuses on the Martian meteorites and specific volatile elements The second half of the book explores processes and locations on the crust including what we have learned about volatile mobility in the Martian crust Coverage includes data from orbiter and in situ rovers and landers geochemical and geophysical modeling and combined data from the SNC meteorites Presents information about the nature relationship and reactivity of chemical elements and compounds on Mars Explores the potential habitability of Mars Provides a comprehensive view of volatiles in the Martian crust from studies of actual samples as well as from the variety of landed missions including the MER and Curiosity rovers Delivers a vital reference for ongoing and future missions to Mars while synthesizing large data sets and research on volatiles in the Martian atmosphere Concludes with an informative summary chapter that looks to future Mars missions and what might be learned

Treatise on Geophysics, Volume 10 Tilman Spohn, 2010-05-20 Planets and Moons covers topics relating to the physics of the major planetary bodies in the solar system starting with an introductory description of the solar system and collection of pertinent data continuing with a discussion of the early history of the planets and finishing with articles about planet dynamics thermal evolution of planets and satellites and descriptions of their magnetic fields and the processes that generate them In addition to providing a review on the solid planets and the satellites this volume addresses the interactions of solid surfaces and atmospheres as well as the roles of water and ice in shaping the surfaces of planetary bodies Self contained volume starts with an overview of the subject then explores each topic with in depth detail Extensive reference lists and cross references with other volumes to facilitate further research Full color figures and tables support the text and aid in understanding Content suited for both the expert and non expert

Geochemical Sediments and Landscapes David J. Nash, Sue J. McLaren, 2011-07-18 This state of the art volume reviews both past work and current research with contributions from internationally recognized experts The book is organized into fourteen chapters and designed to embrace the full range of terrestrial geochemical sediments An up to date and comprehensive survey of research in the field of geochemical sediments and landscapes Discusses the main duricrusts including calcrete laterite and silcrete Considers deposits precipitated in various springs lakes caves and near coastal environments Considers the range of techniques used in the analysis of geochemical sediments representing a significant advance on previous texts

Fundamentals of Geobiology Andrew H. Knoll, Don E. Canfield, Kurt O. Konhauser, 2012-03-30 2012 PROSE Award Earth Science Honorable Mention For more than fifty years scientists have been concerned with the interrelationships of Earth and life Over the past decade however geobiology the name given to this interdisciplinary endeavour has emerged as an exciting and rapidly expanding field fuelled by advances in molecular phylogeny a new microbial ecology made possible by the molecular revolution increasingly sophisticated new techniques for

imaging and determining chemical compositions of solids on nanometer scales the development of non traditional stable isotope analyses Earth systems science and Earth system history and accelerating exploration of other planets within and beyond our solar system Geobiology has many faces there is the microbial weathering of minerals bacterial and skeletal biomineralization the roles of autotrophic and heterotrophic metabolisms in elemental cycling the redox history in the oceans and its relationship to evolution and the origin of life itself This book is the first to set out a coherent set of principles that underpin geobiology and will act as a foundational text that will speed the dissemination of those principles The chapters have been carefully chosen to provide intellectually rich but concise summaries of key topics and each has been written by one or more of the leading scientists in that field Fundamentals of Geobiology is aimed at advanced undergraduates and graduates in the Earth and biological sciences and to the growing number of scientists worldwide who have an interest in this burgeoning new discipline Additional resources for this book can be found at <http://www.wiley.com/go/knoll/geobiology>

Fluvial Megafans on Earth and Mars Justin Wilkinson, Yanni Gunnell, 2023-05-18 Megafans are partial cones of river sediment that reach unexpectedly large dimensions with the largest on Earth being 700 km long Due to recent developments in space based observations global mapping efforts have shown that modern megafan features cover vast landscapes on most continents This book provides a new inventory of nearly 300 megafans across five continents Chapters focus on regional studies of megafans from all continents barring North America and Antarctica The major morphological attributes of megafans and multi megafan landscapes are discussed and the principal controls on megafan development are examined The book also compares megafans with alluvial fans deltas floodplains and the recently recognised major avulsive fluvial system MAFS The final part of the book discusses the application of megafan research to economic geology aquifers and planetary geology including layered deposits on Mars This is an invaluable reference for researchers in geomorphology sedimentology and physical geography

From Habitability to Life on Mars Nathalie A. Cabrol, Edmond A. Grin, 2018-06-29 From Habitability to Life on Mars explores the current state of knowledge and questions on the past habitability of Mars and the role that rapid environmental changes may have played in the ability of prebiotic chemistry to transition to life It investigates the role that such changes may have played in the preservation of biosignatures in the geological record and what this means for exploration strategies Throughout the book the authors show how the investigation of terrestrial analogs to early Martian habitats under various climates and environmental extremes provide critical clues to understand where what and how to search for biosignatures on Mars The authors present an introduction to the newest developments and state of the art remote and in situ detection strategies and technologies that are being currently developed to support the upcoming ExoMars and Mars 2020 missions They show how the current orbital and ground exploration is guiding the selection for future landing sites Finally the book concludes by discussing the critical question of the implications and ethics of finding life on Mars Edited by the lead on a NASA project that searches for habitability and life on Mars leading to the Mars 2020 mission

Presents the evidence questions and answers we have today including a summary of the current state of knowledge in advance of the ESA ExoMars and NASA Mars 2020 missions Includes contributions from authors directly involved in past current and upcoming Mars missions Provides key information as to how Mars rovers such as ExoMars and Mars 2020 will address the search for life on Mars with their instrumentation *Sand* Michael Welland,2009-01-15 From individual grains to desert dunes from the bottom of the sea to the landscapes of Mars and from billions of years in the past to the future this is the extraordinary story of one of nature s humblest most powerful and most ubiquitous materials Told by a geologist with a novelist s sense of language and narrative *Sand* examines the science sand forensics the physics of granular materials sedimentology paleontology and archaeology planetary exploration and at the same time explores the rich human context of sand Interwoven with tales of artists mathematicians explorers and even a vampire the story of sand is an epic of environmental construction and destruction an adventure in staggering scales of time and distance yet a tale that encompasses the ordinary and everyday *Sand* in fact is all around us it has made possible our computers buildings and windows toothpaste cosmetics and paper and it has played dramatic roles in human history commerce and imagination In this luminous kinetic revelatory account we do indeed find the world in a grain of sand *Extremophiles as Astrobiological Models* Joseph Seckbach,Helga Stan-Lotter,2021-01-13 The data in this book are new or updated and will serve also as Origin of Life and evolutionary studies Endospores of bacteria have a long history of use as model organisms in astrobiology including survival in extreme environments and interplanetary transfer of life Numerous other bacteria as well as archaea lichens fungi algae and tiny animals tardigrades or water bears are now being investigated for their tolerance to extreme conditions in simulated or real space environments Experimental results from exposure studies on the International Space Station and space probes for up to 15 years are presented and discussed Suggestions for extraterrestrial energy sources are also indicated Audience Researchers and graduate students in microbiology biochemistry molecular biology and astrobiology as well as anyone interested in the search for extraterrestrial life and its technical preparations *Planetary Crusts* S. Ross Taylor,Scott McLennan,2009 *Planetary Crusts* explains how and why solid planets and satellites develop crusts Extensively referenced and annotated it presents a geochemical and geological survey of the crusts of the Moon Mercury Venus Earth and Mars the asteroid Vesta and several satellites like Io Europa Ganymede Titan and Callisto After describing the nature and formation of solar system bodies the book presents a comparative investigation of different planetary crusts and discusses many crustal controversies The authors propose the theory of stochastic processes dominating crustal development and debate the possibility of Earth like planets existing elsewhere in the cosmos Written by two leading authorities on the subject this book presents an extensive survey of the scientific problems of crustal development and is a key reference for researchers and students in geology geochemistry planetary science astrobiology and astronomy Issues in Earth Sciences, Geology, and Geophysics: 2011 Edition ,2012-01-09 *Issues in Earth Sciences Geology and Geophysics 2011 Edition*

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Geomorphology of Desert Dunes Nicholas Lancaster,2023-03-23 Sand dunes are a globally important depositional landform and sedimentary system Their origins and dynamics are important in understanding how deserts have evolved in response to climate change and changes in sand supply and mobility and how they will continue to evolve in the future This book provides a state of the art review of the characteristics of desert dunes and their sediments and explores their dynamics on timescales from days to millennia as they respond to changes in wind speed and direction precipitation and sand supply This extensively revised edition reflects the advances in our understanding of desert dunes their dynamics and history and covers recent developments including the luminescence dating revolution ground penetrating radar and advances in numerical modeling Also covering dunes on Mars and Titan this authoritative reference is a must have for researchers and graduate students working on desert dunes and aeolian geomorphology

Dynamic Mars Richard Soare,Susan Conway,Stephen M. Clifford,2018-08-07 Dynamic Mars Recent and Current Landscape Evolution of the Red Planet presents the latest observations interpretations and explanations of geological change at the surface or near surface of this terrestrial body These changes raise questions about a decades old paradigm formed largely in the aftermath of very coarse Mariner mission imagery in the 1960s suggesting that much of the interesting geological activity on Mars occurred deep in its past eons ago The book includes discussions of 1 Mars ever changing atmosphere and the impact of this on the planet s surface and near surface 2 the possible involvement of water in relatively new if not contemporary gully like flows and slope streaks i e recurring slope lineae and 3 the identification of a broad suite of agents and processes i e glacial periglacial aeolian meteorological volcanic and meteoric that are actively revising surface and near surface landscapes landforms and features on a local regional and hemispheric scale Highly illustrated and punctuated by data from the most recent Mars missions Dynamic Mars is a valuable resource for all levels of research in the geological history of Mars as well as of the three other terrestrial planets Utilizes observational and model based data as well as geological context to frame the understanding of the dynamic surface and near surface of Mars Presents a broad spectrum of highly regarded experts and themes to discuss and evaluate the geological history of late and current Mars Includes extensive and detailed imagery to clearly illustrate

these themes discussions and evaluations River, Coastal and Estuarine Morphodynamics. RCEM 2009, Two Volume Set
Carlos Vionnet, Marcelo H. García, E.M. Latrubesse, G.M.E. Perillo, 2018-10-03 Coastal estuarine fluvial and submarine
morphodynamics encompass some of the leading processes shaping our planet They stem mainly but not only from the
interaction of water in motion and movable sediment boundaries resulting in morphological changes produced by erosion
transport and deposition of sediments that generate a variety of landsca

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