Preface

"What are extreme environmental conditions?" Most of the answers that one gets from undergraduate students confirm a rather anthropocentric view: An environment that humans perceive as unpleasant is classified as extreme.

De facto, many of Earth's ecosystems are characterized by "extreme" environmental conditions, because they deviate from those conditions that humans would consider "normal" with regards to temperature, water availability, pressure, salinity, nutrient supply and so on. Despite being considered extreme, these habitats are colonized by a large number of organisms that thrive under the given conditions.

The definition of an extreme habitat is based on our anthropocentric view, but as a more general approach, microorganisms can be considered extremophilic when they thrive under physical and chemical conditions that destroy cellular components of most nonextremophilic organisms. In recent times, more and more scientists from various disciplines have become interested in the topic 'Life in Extreme Environments'. Through multidisciplinary research, completely new concepts were developed of how extremophiles can possibly survive and even thrive in extreme ecosystems.

Based on these recent advances, the book series 'Life in Extreme Environments' publishes topical volumes in the rapidly growing research field of microbial life in extreme environments. This includes all habitats at the edge of survivability, ranging from equatorial to polar regions, from marine to terrestrial environments and from surface to deep ecosystems. Environmental niches that are, for instance, characterized by extraordinarily hot, cold, acidic, alkaline or dry conditions, or subjected to high salinity, radiation or pressure.

The extremophilic microorganisms living in these environments represent numerous and diverse lineages from across all three domains of life: *Bacteria*, *Archaea* and *Eukarya*. Special emphasis is placed on the understanding of the structure and function of microbial communities in extreme environments, their life strategies and adaptation mechanisms as well as their reaction to changing environmental conditions.

This book series will be a useful reference for advancing our understanding of the origin of life and for exploring the biotechnology potential of these fascinating microorganisms.

The first volume of this series presents a broad overview of our current knowledge of microbial life in deep subsurface environments. Over the last decade, this so-called deep biosphere research has expanded quite dramatically. Since the early days of Morita and Zobell (1955), who set the limit of life at 7.47 meters below the sea floor, the maximum depth to which life reaches into the Earth has been set deeper and deeper and is now exceeding 3 km on land and 1.5 km in marine sediments. Active microbial communities were found in areas that were considered devoid of life, for example, the oceanic crust. Still, we have not seen the true limits of life yet. Despite major technical advances in the last few years, subsurface life exploration is still heavily depending on technical improvements because quite often the abundance and activity of subsurface microbes is orders of magnitude lower than in surface sediments.

When compiling this volume, we wanted to cover the diversity of this young but rapidly growing field of research. The first section is devoted to the different major habitats. The chapter of Parkes et al. provides us with a much-awaited update of their review paper about subseafloor sediment microbiology from 2000. There is hardly any publication about deep subseafloor sediment that does not cite this classic. This chapter allows us to follow the development of the field from a small niche subject into an important research field.

Microbial life in subseafloor environments is not restricted to sediments, there are new and exciting findings of life in the oceanic crust, and these are presented by Biddle et al.

Of course, research in terrestrial subsurface environments has made a similar leap forwards, and Karsten Pedersen provides us with an update on the state-of-the-art. When searching for life elsewhere in the Universe, one should need to know what to look for. Charles Cockell argues that Earth's subsurface might be a good analogue for habitats on, or rather, in other planetary bodies.

After these more general chapters, the book focuses on several special topics that are currently under much debate. Andreas Teske's chapter about archaea in deep marine subsurface sediments gives an overview of the current knowledge about this largely uncultivated group of organisms. Although modern molecular techniques have become increasingly popular in recent years, classical cultivation still is very important. Toffin and Alain summarize recent advances in this field with specific remarks about high-pressure cultivation, and other high-tech methods that allow us to grow microbes that would otherwise remain uncultured. Not only microbes, i.e. prokaryotes live in the subsurface. Eukaryotes are also present and might play a much more important role than previously thought. Edgcomb et al. inform us about the current state of knowledge in this area.

One of the main drawbacks of molecular techniques is the apparent disconnection between phylogenetic and metabolic information. Only through novel techniques that allow measuring multiple information simultaneously from the same sample can we now actually see which microbe is doing what. Morono et al. present us their recent advances in NanoSIMS research and the challenges that are still lying ahead. This part of the book is closed by a chapter of Karen Lloyd who shows us how just minor differences in sample preparation can have huge impacts on the final results. This should be a note of caution to everybody working in this field and a friendly reminder that there are still many technical challenges ahead of us.

The subsurface biosphere is not just of purely scientific interest. As many geotechnological applications are affected by subsurface microbial activity, there is also a growing industrial interest in this field of research. Ollivier et al. introduce us to microbial activity in hydrocarbon reservoirs. Of course, not only hydrocarbons are affected by microbes, Alawi shows us their effects on hydrothermal systems and subsurface storage of carbon dioxide.

Even with the most sensitive techniques, metabolic activity might be so low that it cannot be detected and many turnover processes occur over geologic time scales, vastly exceeding the timespan that humans can observe. While LaRowe and Amend focus on thermodynamical controls on subsurface life, DiPrimio introduces basin modeling as a valuable tool to understanding ultraslow abiotic reactions that run over geologic time scales. Røy shows us how to use actual measurements of downcore profiles to quantify metabolic rates.

We hope that this volume will provide you with a broad overview of this exciting and rapidly developing field of research and stimulates the debate on this fascinating research field in the near future.

March 2014 — Dirk Wagner & Jens Kallmeyer