SUBSURFACE MICROBIOLOGY AND BIOGEOCHEMISTRY
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SUBSURFACE MICROBIOLOGY AND BIOGEOCHEMISTRY

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During the past decade, the subsurface environment has represented a true frontier for microbiological research. Until recently, our understanding of microorganisms in the subsurface was largely a matter of speculation and based on sparse and sometimes anecdotal data. Much of the region below the terrestrial surface was believed to be hostile to microorganisms and essentially devoid of living organisms. However, enormous strides have been made in investigating the presence and characteristics of subsurface microorganisms, and we have come to appreciate these environments for their microbiological and chemical complexity and potential for harboring novel bacteria of environmental and, possibly, industrial importance.

Scientific investigations into the microbiology of deep subsurface environments early in this past century were stimulated by demands for petroleum and subsequent exploration for and study of oil fields and oil-bearing rocks. One of the first indications that microorganisms inhabited deep subsurface environments emerged in the 1920s when a geologist at the University of Chicago, Edson Bastin, examined the source of hydrogen sulfide and bicarbonate in water from deeply buried oil fields in Illinois. In an experiment reported in *Science* in 1926, Bastin and several colleagues at the University of Chicago submitted samples to bacteriological analysis and were successful in culturing sulfate-reducing bacteria (SRB) from groundwater samples collected from oil fields at depths of 150–600 m. These results suggested that microorganisms were responsible for the *in situ* reduction of sulfate to sulfide. Years later, investigations by Russian scientists also indicated that diverse microbial populations were associated with hydrocarbon-bearing rocks and waters. Many scientists at the time viewed the existence of microorganisms in deep terrestrial environments with skepticism due to the considerable uncertainty as to the origins of the microorganisms cultured from groundwaters collected from developed wells. The process of drilling and well development unavoidably introduced organisms into the deep strata, and the practice of flooding with water to enhance oil recovery led to further contamination and stimulation of indigenous and nonindigenous microorganisms. Although such early studies suggested the presence of microorganisms in the deep subsurface, these findings would not be verified until later in the century.
In the late 1970s and early 1980s, emerging groundwater quality issues in the United States stimulated scientists to further investigate the possibility that microorganisms inhabited shallow water-yielding formations as well as relatively deep aquifers. Moreover, technological and methodological advances were made that allowed researchers to collect deep groundwater, sediment, and rock samples while minimizing microbial contamination and chemical changes. Many researchers also employed various types of tracers during sampling that allowed measurement of the degree of contamination. Initial studies, focused primarily on microbiological characterization, revealed that active and diverse communities of microorganisms were present in shallow and deep (> 50 m) groundwaters and sediments. Most of these studies employed traditional microbiological methods involving culturing of microorganisms, visualization using direct microscopic techniques, or, in some cases, isolation and physiological and/or phylogenetic characterization. Despite the limitations of these techniques, important information was obtained on the presence and distribution of microorganisms, including aerobic heterotrophic bacteria, fungi, protozoa, and on total numbers of microbial cells in subsurface environments. However, the in situ activities of subsurface microorganisms and the biogeochemical processes they catalyzed remained poorly understood. The results of many of these early studies were biased by the limitations of techniques available at the time for studying microbial ecology and by the lack of robust methods for probing in situ microbial activities and community structure. Researchers were heavily dependent on laboratory cultures, introducing a potentially severe bias into results. It is now widely recognized that only a fraction, often less than 1% of the total microbial population, is typically cultured from environmental samples. Moreover, microorganisms cultured and studied under laboratory conditions may exhibit phenotypes quite different from those expressed in the environment. Regardless of these limitations, many novel aerobic and anaerobic microorganisms with interesting biochemical and genetic traits have been isolated from subsurface environments.

The results of these deep subsurface microbiology studies greatly spurred the interest of scientists from other disciplines, including geology, hydrology, geochemistry, and environmental engineering. Multidisciplinary teams and approaches and more robust analytical methods were increasingly applied to the study of deep subsurface microbiology. These approaches greatly extended the range of subsurface environments that microorganisms were shown to inhabit and allowed exploration of relationships between microbial abundance, physiology, taxonomy, and activity, and the subsurface environment, including geochemical, geological, and hydrological properties. Now it is clear that the subsurface environment provides numerous opportunities for microbial growth and survival, and, through this book, we have endeavored to capture this new understanding of the broad range and diversity of the previously “hidden” subterranean organisms.

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