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Introduction

Geobiology–a holistic scientific discipline

In less than a decade, a new scientific discipline, "geobiology", has been defined. Rapidly, geobiological studies are published, geobiological research institutions are established, and journals are founded that deal exclusively with this new, pulsing research branch. What is geobiology, and what makes it so fascinating?

Geobiology understands Earth as a system, and life as part of it. In space and time, life influences Earth's development, and Earth's changing environments moulds life. Although geobiology appears new and yet to unfold, its objectives have been focus of research already of the earliest geologists. James Hutton discussed in 1788 the interaction of organisms with geological processes, and described how life affected the history of Earth (Knoll, 2003). Later generations of scientists proved him right. Today, geobiology experiences an enormous expansion and popularity. Why?

One reason lies in the development of science itself. During the past centuries, the increase of knowledge about nature's laws, their development, and their various applications lead to the definition of more and more scientific branches. This diversification was supported by progress in technology. Today, we understand Earth as a holistic system, and we are challenged by the interwoven complexity of nature. In response to this new understanding, and equipped with our highly developed technological abilities, we demand a more appropriate scientific approach: a complex, but holistic system Earth can be understood only by a holistic, interdisciplinary concept of research. The tool of choice is not the diversification, but the fusion of the disciplines of life sciences. Geobiology is one example of this modern trend.

Geobiology mirrors not only a new development in sciences, but also responses to the new challenges and demands imposed by today's world and society. The three domains of geobiological research are (i) to understand environmental problems of global scale, and to predict unforeseen damages in the future; (ii) to reconstruct the history of our planet, analyzing causes and consequences of life–environment interactions during the joint evolution of life and Earth; and (iii) to explore extraterrestrial worlds by studying analogue environments on Earth. But, how do geobiologists approach this great variety of research topics? How does the concept of a holistic scientific discipline look like?

In order to understand the complex interactions of life in system Earth, geobiologists must determine coupled biological and geological processes across different spatial and temporal scales. That is, they investigate macro- and micro-scale changes in the present (the today's Earth and its biota), but also in the fossil record. The fossil record is provided by million year old rocks, which constitute an archive of ancient life in former and unfamiliar environments. In response to this twofold approach, geobiological studies comprise a specific, dual concept that mirrors the nature of the parent disciplines biology and geology (Noffke, 2002). How can geobiology been seen in the context of its parent disciplines?

Biology and geology are basic research disciplines. Traditionally, their objectives and methodological approaches have different foci and rarely overlap.

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Biology predominantly studies present life forms and their interactions with their environments. In consequence, most of the methods of investigations have direct access in the field, and in laboratory experiments. Only short-termed processes can be considered, and biologists seldom have access to data bases that cover more than the last 100 years. Biology does structure and describe nature today, but does not detect or observe long-term processes.

Geoscientists focus on ancient life forms, the reconstruction of the strange environments of Earth's past, and on processes that last millions of years. But in comparison to biology, the geological methods of investigations can only access fossils, sedimentary structures, or minerals that are witnesses of ancient processes manifested in rock. Large-scale geological processes may take very long, so that commonly we cannot observe them during our life time. One example would be the formation of orogens. But the study of the fossil record allows us to conclude on such slow processes, to decipher their causes, and finally to understand, what effects they have on today's nature and the future. The disadvantage of the geological methods is that they require subjective interpretation. Why? The reason is that the fossil record is a history of gaps. Long periods of the Earth history are not recorded simply because rock successions are incomplete. For example, the oldest portion of Earth's history, the Archean eon, comprises 2000 Ma of time, but is represented only by rock successions of a few kilometers thickness. In addition, taphonomy, that is the change of an organism to a lithified fossil, is very selective, and only parts of organisms, or only parts of ancient ecological communities become preserved. And finally, the diagenetic and tectonic alteration of rocks in course of time also overprints information. In all those cases, the biological understanding of life processes of the modern system Earth, help to fill in the gaps of the geological past. For example, we study metabolic cycles of bacterial communities to reconstruct former life conditions of ancient environments not documented in lithologies.

Clearly, we can observe the traditional gap between the objectives and concepts of the parent disciplines. Geobiology bridges this traditional gap. How? The question of geobiologists is that of the interface of life and Earth's environments. This question frames each hypothesis, which originate either from a more biological or from a more geological root (Fig. 1). To answer this question, geobiology combines both direct and indirect methodologies of the parent disciplines, and employs the multifold technologies provided by the pool of their subdisciplines such as microbiology, biogeochemistry, geomicrobiology, astrobiology, paleontology, mineralogy, and many others. For geobiological studies, it is fundamental, that results of investigations in the laboratory or in the modern environment are compared with studies on rocks, and vice versa. This dualism in objective, and methodological approach is the core of geobiology, mirroring its parentage. The twofold research concept permits the synthesis of data, and the fusion of a theoretical

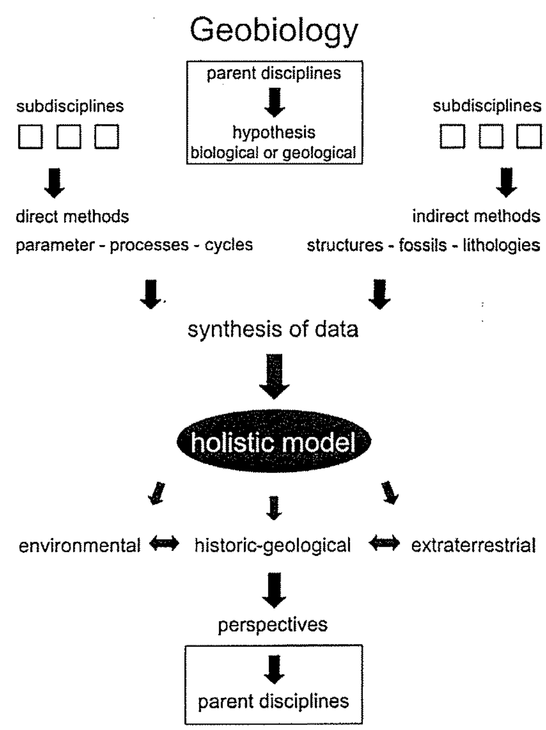

Fig. 1. Geobiology investigates life in the context of system Earth, past and present. The research discipline reflects the trend in modern sciences to study system Earth by fusion of disciplines, not by their diversification. Geobiology bridges the traditional gap between its parent disciplines biology and geology. Its dual concept of approach and methodology creates a holistic model of system Earth, which gives insight into past, present, and future changes. Environmental, historic-geological, and extraterrestrial aspects are topics of geobiological research. Further explanation in text.

model of Earth's environment and life (Fig. 1). This holistic model does not document a present and rigid status. Rather, it reflects flexibilities or weaknesses of the living system Earth, and documents triggering and feed-back effects in global changes over time. The holistic model of system Earth serves to simulations with different parameters. Our understanding of past and present joins causes and consequences, and enables us to predict the future. But then, do we still need the traditional research disciplines?

The core disciplines of biology and geology (including their subdisciplines) are not replaced by geobiology, but continue to exist and function as sources of basic knowledge. Rather, the parental research disciplines get support from a new methodological approach that provides exciting perspectives in environmental, historic-geological, and extraterrestrial research (Fig. 1). In consequence, the term geobiology reflects earlier fruitful combinations of geology with other disciplines, such as physics (geophysics), chemistry (geochemistry), or mathematics (geomathematics). Geobiology touches various subdisciplines of geology and biology in many ways (Olszewski, 2001). This new scientific discipline will serve biogeochemists, paleontologists, biomineralogists, astrobiologists, geomicrobiologists, and many others as a forum for critical discussion and as an opportunity to determine future directions in research. Indeed, geobiology can be understood as a holistic science.

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