Geobiology and Geomicrobiology: Frontier areas in Earth System Science by Prof. Ramanathan Baskar (*Email:* rbaskargjuhisar@yahoo.com)

One of the great exciting moments in science during this century will be the discovery of life on another planet. The recent discoveries of microbes in extreme environments (such as hydrothermal vents/ deep ocean floor) have improved our understanding about origin of life on earth, and have strengthened the perceived probability that similar kinds of micro-organisms/life forms may exist on other planets. Such grand scientific goals and exciting scientific discoveries are now within reach, because of rapid advances in the fields of geobiology and geo-microbiology during the last two decades. Geomicrobiology requires varied expertise in subjects ranging from geology, geo-chemistry, mineralogy to microbiology, and microbial ecology. Current and future geobiological investigations will improve our ability to understand the relevant records, interpret them and make predictions, and, thereby, have a more detailed understanding of the complete history of the earth.

It is well known fact that the Earth's physical and biological processes continuously interact and influence one another, but we have classified the geological and biological sciences as separate entities in the academic world. There is no doubt that both the disciplines have grown and matured independently but certainly lack of geobiological approach has led to poor understanding of the coupled earth-biosphere interactions. It is only in the past decade that geologists, microbiologists, geohydrologists and geochemists have recognized the significance of these microbial activities. At present, there is general agreement about the importance of microbiological activities in shaping the earth's hydrosphere and atmosphere. Microbes affect and are affected by virtually all geochemical processes that occur at the earth's surface, as well as deep within its subsurface. Microbes have lived at the earth's surface for most (about 85%) of the time since the earth was formed.

There are many potential practical and scientific benefits that might arise from the study of geobiology, some of which are outlined below:

Understanding Biogeochemical cycles: Microorganisms are an essential part of the bio-geocycling of elements (example C, N and S) between the surface of the earth and the surrounding atmosphere.

Waste cleaning: Bacteria are used to clean up oil spills and polychlorinated biphenols in water/soil.

Metal mobility/Bioleaching: Certain microbes have proven ability to transform toxic, soluble metals into insoluble ones by their mediation by affecting the redox process. *Bioleaching* is a biochemical process by which specific metals in the ores can be concentrated.

Enhancing understanding the Science of Climate Change: Some part of the puzzle relating to global warming are likely to lie inside microbial cells, since multitudes of these tiny organisms emit and deplete enormous amounts of gases (e.g. carbon dioxide and methane) that trap heat around the earth.

Cave geomicrobiology: This field deals with the microscopic life that resides in caves and its interactions with minerals, including mineral dissolution/precipitation.

Possible solutions for achieving Energy security: Microbes in the organic-rich sediments beneath the ocean floor produce huge amounts of methane gas, which exists in crystalline form; combines with water in the form of methane hydrates.

Extraterrestrial matter: Biosignatures discovered in earth may be important tools in astrobiological studies.

Viewing the earth processes through geomicrobiological lens has changed some of our perceptions. Some examples are discussed, which are by no means exhaustive.

For example, banded iron formations (BIFs) are one of the most abundant chemical precipitates from the Precambrian period. The unique feature of BIFs is that these sedimentary rocks are no longer formed like during the Precambrian period, and consist of repeated thin layers of iron oxides with bands of shale and chert. Some geochemists believe that BIFs could form by direct oxidation of iron by autotrophic (non-photosynthetic) microbes. The conventional concept is that the banded iron layers are the result of oxygen released by photosynthetic cyanobacteria, combining with dissolved iron in the earth's oceans to form insoluble iron oxides.

Another example of such a geological puzzle is the mineral dolomite. There was a time in geological history, when dolomite was formed on the earth in great quantities, e.g. the Dolomite Mountains in the Italian Alps. Dolomite precipitation is mediated by a group of sulphate-reducing bacteria. Currently, dolomite is formed in only a few selected locations such as salt flats and lagoons. Its mineral composition includes magnesium, calcium and carbonate ions, which are common enough in sea water, but the conditions necessary for arranging these components in the ordered, alternating layers that form dolomite are not common today. These conditions and the group of sulphate-reducing bacteria may once have been far more prevalent.

Another important contribution by geomicrobiology, is the recognition the role microbes play as geochemical agents in cave ecosystems. Cave environment being relatively free from weathering and erosional processes, make apparent the subtle chemical changes made by microorganisms. Cave geomicrobiology has also contributed in understanding the pathways of microbial metabolism and biotransformation in geochemical environments. It has helped in understanding the roles microbes play in the formation of caves. It can be as subtle as the generation of CO_2, which forms the carbonic acid that is responsible for the formation of the vast majority of the world's carbonate caves, to sulphuric acid from sulphate reducing bacteria, a mechanism recently reported that can form caves, hundreds of kilometers in length.

The action of corrosive agents in chemical weathering of rock has been long appreciated by geologists but it still remains unappreciated that microbes can play an important role as weathering agents or its ability to act as catalysts in the weathering process. Microbes are known to excrete chemical agents that corrode the rock through chemical interaction/ by oxidizing/ reducing a rock component that leads to mineral diageneis or dissolution.

In the Western world, rapid advances are taking place in the field of geobiology/ geomicrobiology. There are many institutions where geobiological and geomicrobiological research has been given prime focus. There are many Universities where formal courses in geobiology/ geomicrobiology are offered and many centers of research in geobiology/ geomicrobiology are established.

In the Indian scenario, geologists are not trained in microbiology and vice versa. This pioneer field should be recognized as a thrust area by the Department of Science and Technology and Ministry of Earth Sciences, New Delhi and should be strongly supported as one of the new, important frontier areas of knowledge. There is also an urgent need to offer formal programs in geobiology/geomicrobiology at the postgraduate level with the support of University Grants Commission, New Delhi, so that the Indian students have the opportunity to explore this frontier area of research. New discoveries can be expected from such cross-disciplinary approaches, which can lead to advances in basic research, of course with huge possibility of applied outcome. Even INSA vision document for Indian Science (2010) supports cross-disciplinary science and suggest that the Indian bio- and geo- sphere could provide an overall background for exciting research and teaching, which overlaps a wide range of fields, as an example.

We may conclude that geobiology is a tool which can be applied to address fundamental questions in geology, biology, microbiology, ecology with vast applications in earth and beyond. Formal courses in geobiology and geomicrobiology should be launched. We should ensure that the casual dating between geology and biology (microbiology) should be solemnized into a solid marriage, without any further delay.

Summary of the lecture to be delivered at the monthly meeting of the Geological Society of India on 30th January 2013.

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