suggested the compilation of a book containing the proceedings of the conference; this might serve as a 'first step' towards reviewing the Indian position with regard to commercialization of HGR and so on. But is a useful conversation between the 'two cultures' really possible, when even a common understanding of terms as apparently simple as 'human' or 'life' is hard to come by? Peter Glasner (pers. commun.) says, 'Clearly a meeting of minds is difficult, but what is important is to establish that the categories being used are socially constructed and not just "given". Many senior scientists are happy to recognize this, and science after all progresses by knocking theories/concepts down in the face of advancing knowledge. Nothing is set in stone, either for natural or for social scientists – the danger is in reifying concepts so they take on a life of their own'.

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MEETING REPORT

Geomicrobiology – an Indian perspective*

What molecular-scale interactions underpin geochemical cycles? What are the links between the abundance and structure of microbial communities and rock/sediment geochemistry? What are the effects of microbiota on landform evolution, climate and ecosystem performance? Many such and other fundamental questions regarding the role that microbes play in geological processes controlling the chemical composition of our planet are the realm of geomicrobiology. This interdisciplinary field of research has received attention recently due to the tremendous potential it offers to understand and control our environment, decipher the conditions during emergence of life on our planet and the diverse chemical transformations that can sustain life[1].

To evolve an effective national-level programme by identifying key issues and relevant questions to be addressed for geomicrobiological research in India, a brainstorming workshop was held recently under the aegis of the interdisciplinary 'Science of the Shallow Subsurface (SSS)' programme that was launched by the Department of Science and Technology (DST), New Delhi to bring together scientists specialized in different disciplines to obtain an accurate description of subsurface properties and processes using geological, geochemical, geophysical and geobiological, including microbiological approaches (http://www.dst.gov.in/scientific-programme/ser-ssss.htm). The unique SSS programme, both in terms of magnitude and interdisciplinary nature, supports research by geologists, geophysicists, zoologists, botanists, microbiologists, chemists, geographers, hydrologists and others, and includes scientists affiliated to premier research institutions, university departments and colleges from all over India.

The workshop included lead talks and project concept proposals by about 20 scientists from different institutions/universities of the country. It was also attended by several scientists participating in the SSS programme and a number of experts in microbiology, biochemistry, molecular biology and geology from the country.

V. Rajamani (Jawaharlal Nehru University, New Delhi); also the Chairman, Programme Advisory and Monitoring Committee for the DST–SSS programme, in his inaugural address highlighted the importance of integration of Earth and life sciences. He pointed out that it is the interaction of minerals and microbiota that controls air and water chemistry, climate and ecosystem, and an integrated study will help manage and guide changes in the surface environment for sustainable development. M. Mohanty (DST) emphasized the importance of geomicrobiological research in India and the prominent role that DST and the Ministry of Earth Sciences could play in promoting such research.

In the opening session, G. Archana (Maharaja Sayajirao University of Baroda (MSU), Vadodara; also the event coordinator) pointed out that while the origins of geomicrobiology could be traced to early studies by pioneering soil microbiologists of the first half of the last century, recognition of this field as an independent, new, interdisciplinary, scientific area happened in the last decade or so, from the emergence of specialized journals and review series dedicated to the subject. Advances in molecular biological tools to study bacterial communities

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without culturing them in the laboratory have helped elucidate the manner in which the environment determines the architecture of microbial communities, and also the genes and molecular mechanisms by which microbes mediate chemical transformations, giving rise to the concept of 'molecular geomicrobiology'[2]. The work carried out in her laboratory under the DST–SSS programme has demonstrated the correlation of sediment characteristics with microbial activity and molecular diversity in sediments of the Mahi River basin, Gujarat. According to Archana, 'The coming together of scientists from different disciplines in the SSS programme not only made collaboration easy, but also helped in lateral transfer of ideas and concepts between people of different specializations'.

Archana also presented a concept proposal on nutrient cycling in the mudflats of the Ranns of Kutch, a hostile environment subjected to high stresses such as hyper-arid climate, high salt content, seasonal waterlogging and extremes of temperature. The vast stretch of the Ranns, being devoid of vegetation, raises the question of primary productivity for the sustenance of microbiota. Studying sediment–microbe interactions in an environment considered unparalleled on the globe[3] would provide information about physiological basis of survival in such an inhospitable environment and has tremendous implications on understanding early life on Earth.

V. Purnachandra Rao (National Institute of Oceanography, Goa) gave a lead talk about his findings on the influence of microbes on the formation of mineral deposits such as phosphorites and dolomites from the coastal areas of India. He described the importance of mineral deposits of stromatolitic (formed due to sediment-trapping and precipitation because of microbial activity, principally cyanobacteria) origin in understanding the conditions of early earth and pointed out that microscopic, isotopic and other multiproxy approaches of modern (Quaternary) deposits can document the role of microorganisms in their formation[4]. He further highlighted the importance of studies on biogeochemical processes in microenvironments and chemistry of microbial surface polymers in understanding the formation of sedimentary minerals. 'Geomicrobiology, an emerging field with wide applications in different areas, is a multidisciplinary study, with not only geology and microbiology, but also strong component of geobiochemistry', concluded Rao.

The lead talk was followed by project concept presentations by scientists from various organizations. The project ideas ranged from understanding of microbial community diversity and functions in specialized environmental settings such as mangroves, sodic soils, hot springs, caves and alluvial delta plains, to experimental geomicrobiology that deals with the study of geochemical processes with pure cultures of microorganisms in artificial microcosms.

Shailesh Dave (Gujarat University, Ahmedabad), with several years of experience in diversity and physiology of acid mine drainage microbes, pointed out the importance of studying bacterial activity (particularly, sulphur-oxidizing bacteria) in the acidification of the mine drainage and also how another group of bacteria (sulphur-reducing bacteria) could be used to remediate the acidity of the drainage water. S. Sinha-Roy (Birla Institute of Scientific Research, Jaipur) emphasized the importance of studies of 'critical zone', where the microbe–soil–landform trinity relations are established. A holistic study comprising geomorphological maps, land-use and soil properties in conjunction with microbial biomass, activity and diversity to identify linkages would help interpret the complex microbial ecosystem with soil formation dynamics. Such a study would help in land-use planning and resource management.

R. Baskar (Guru Jambheshwar University, Hisar) emphasized on the importance of studying cave microbiology. Not only do the cave ecosystems provide a wide spectrum of fascinating life-forms, the microbes also play an important role in dissolution and precipitation of minerals. His group, in collaboration with scientists from Norway and Germany, has carried out pioneering work on Indian cave ecosystems, including the role of microorganisms in speleotherm formations in Meghalayan caves[5] and propose that a wealth of new information about microbial involvement in biogeochemical processes could be obtained from studying microflora of these environments.

The function of microorganisms in mineral dissolution and oxidation, and the industrial applications of these processes formed the basis of proposals on biometallurgy and metal beneficiation. One such application proposed was the use of microbial metabolites or whole cells for enrichment of rare earth elements from their ores. Deliberations on several other important aspects of research that were discussed include understanding the basis of granite weathering, study of heterotrophic potential of Arctic microflora and understanding the biogeochemical cycling of N and P in the Arctic environment. The talks were followed by a panel discussion and significant areas and strategies for research were outlined. These included geomicrobiology of hot springs, caves, polar regions, mangroves, alluvial delta plains and deserts such as the Ranns of Kutch; landform–soil–microbe trinity relationships; weathering of rocks and metal bio-transformations. Research in these areas would focus on microbiological activities underlying geological processes and be carried out as collaborative initiatives between geologists and microbiologists. A decision was made to submit a detailed document to DST highlighting the importance, present status and future research directions in the thrust areas identified.

To summarize, microbes, by catalysing a myriad of chemical reactions in nature, control the chemistry of our environment. How microbes direct the major biogeochemical pathways, their metabolic capabilities involved, and what are the limits of microbial adaptations to environmental factors, are aspects that are yet to be thoroughly understood. Practical applications of geomicrobial processes and how microbial life has affected Earth's environment through geological times are significant and exciting areas of research that will provide insights to help restore the environment.

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