Foreword

The unique "isotopic signatures" that characterise the various Earth and Planetary reservoirs make "Isotope Cosmo-Geochemistry" a powerful tool to study the past and contemporary physical, chemical and dynamical processes governing the evolution of the planet Earth and other Solar System objects. New ideas coupled with major advances in the detection and measurement of these isotopic signatures have led to significant strides in this field over the past couple of decades. Research in "Isotope Geochemistry" in India was initiated in the mid 1950s with a focus on the applications of Cosmic Ray produced isotopes to understand the time scales of atmospheric and marine processes and studies of Sr-isotopes to characterise crustal silicates. Over the years, the scope of studies in this newly emerging area has been considerably expanded through the use of additional isotope tracers in diverse fields of research, such as, the early evolution of the solar system objects, cosmic ray prehistory, origin and evolution of the continental flood basalts, geochemical cycles of elements, geomorphology, ocean circulation, palaeoclimate and catastrophic events in the Earth's history.

This special issue of the Proceedings of the Indian Academy of Sciences (Earth and Planetary Sciences) contains some of the important papers (three plenary and sixteen invited) presented at the International Conference on "**Isotopes in the Solar System**" held at the Physical Research Laboratory at Ahmedabad in November 1997. These papers demonstrate the unique power of isotopes in the study of some of the dramatic transformations that have taken (or are taking) place in the extra-terrestrial and terrestrial settings. The first five contributions cover topics in isotope geology and geochemistry, followed by several papers on palaeoclimate records on different time scales and on the chemistry and dynamics of the river-ocean system. A series of papers dealing with isotopic studies of meteorites that have a direct bearing on the origin and early evolution of the solar system, pre-solar processes and cosmic ray prehistory completes the volume.

The article "Cosmic ray produced isotopes in the terrestrial system" by **D Lal** is a brief summary of current researches in this field with emphasis on the major advances made recently, thanks mainly to the newly developed Accelerator Mass Spectrometry (AMS) technique that allows precise measurements of minute quantities of long-lived cosmogenic isotopes in terrestrial samples. This new technique has opened up several novel applications of cosmogenic nuclides as tracers for quantitative studies in Earth and Planetary Sciences, which hitherto could not be made using conventional techniques. Chemical and biological changes at geological boundaries and their probable causes is the central theme of the paper by **N Bhandari**, who reviews the salient features of various chemical and isotopic tracers in samples representing the Cretaceous/Tertiary, the Permo/Triassic and the Eocene/Oligocene boundaries from Indian sites. The results attest to an extra-terrestrial impact as the cause for the extinction of species at the K/T boundary, while terrestrial causes appear to be responsible for the biological changes observed at the P/T boundary. Analysis of K/T sections in the Deccan inter-trappeans coupled with their chronology further suggest that the major phase of eruption of the voluminous Deccan trap predate the K/T boundary event by ~ 2 Ma; this rules out Deccan volcanism as the major cause for extinction observed at this boundary.

The study of past climate and its variability continues to be an intriguing subject, of considerable interest among scientists, as it is a topic of direct relevance to the continued wellbeing and survival of mankind. The availability of source and process specific isotopic and elemental tracers along with highly sensitive techniques for their measurements have yielded excellent sets of high-resolution palaeoclimatic data from several types of archives. The review by **R J Delmas** provides an overview of the global climate and environmental changes retrieved from the Greenland and Antarctic ice cores. These studies provide a framework for investigating the teleconnections in climate change between the Northern and the Southern Hemispheres, an essential ingredient for a better understanding of the global climate system. The paper by **T L Ku and H C Li** demonstrates the utility of speleothems (a cave limestone deposit) as a high-resolution palaeoclimate recorder. Through the measurements of oxygen and carbon isotopes and trace elements, these authors have been able to reconstruct regional changes in precipitation,

Proc. Indian Acad. Sci. (Earth Planet. Sci.), **107**, No. 4, December 1998, pp. 237–239

temperature and vegetation in northeastern China. **S Chakraborty and R Ramesh** discuss the oxygen and carbon isotope records in a coral from the Gulf of Kutch, and conclude that $\delta^{18}O$ variations in it can be used to qualitatively reconstruct the regional rainfall variations.

One of the most conspicuous transformations of the Earth's surface during the Cenozoic is the uplift of the Himalayan mountain belt. **K K Sharma** provides an extensive review of the spatial and temporal evolution of the Himalaya both in terms of geology and tectonics. Has this uplift influenced changes in the global climate through enhanced aluminosilicate weathering and drawdown of atmospheric CO_2? This is a contentious issue. From the synthesis of global data on fluvial Sr and $^{87}Sr/^{86}Sr$, which is often used as a proxy for silicate weathering, **Y Huh and J M Edmond** conclude that there is no obvious climatic influence on weathering rates from the Tropics to the high Arctic and that the flux of dissolved load and CO_2 consumption for the Himalayan rivers are comparable to those of the Americas. **S Krishnaswami and Sunil K Singh** address the issue of carbonate-vs-silicate weathering in determining the Sr isotope composition of the head-waters of the Ganga. Through a comparison of $^{87}Sr/^{86}Sr$ and Sr/Ca in river waters, carbonates and silicates and inter-relation between Sr isotope composition and silicate derived cations in rivers, they argue that silicate weathering exerts a dominant control on the $^{87}Sr/^{86}Sr$ of these rivers.

Four papers in the volume are devoted to chemical and isotopic studies of sea-water. **W S Moore** through his studies of Ra isotopes in coastal waters off South Carolina brings out the importance of submarine groundwater discharge to the sea and suggests a possible approach to estimate its magnitude. The role of groundwater discharge to the oceans in contributing to the water and chemical budgets has been a topic of interest among hydrologists for some time. The approach presented in this paper shows a way to probe this issue. **E Maier-Reimer and G Handerson** discuss the basic requirements for successful modeling of particle reactive tracers in the ocean using ^{210}Pb as a test case. The ^{210}Pb distribution they obtain through a coupled general circulation-biogeochemical cycle model, is consistent with direct observations. **D S Alibo, M Amakawa and Y Nozaki** present two methods for the determination of indium in natural waters by flow injection inductively coupled plasma mass spectrometry. Their results from the Atlantic and the Pacific show that the inter-oceanic variations by and large mimic the behaviour of Al and that particle scavenging plays an important role in the distribution of indium in sea water. **S W A Naqvi *et al*** present data on the nitrogen isotope composition of various species of nitrogen (molecular N_2, nitrate and nitrous oxide) and $\delta^{18}O$ in N_2O in the suboxic water column of the Arabian Sea and suggest that microbially mediated reduction of NO_3^- to N_2 (denitrification) in the oxygen minimum zone greatly affects the natural isotopic abundances. They also observe that coupling between nitrification and denitrification is an important mechanism for N_2O production.

Of late, the isotopic studies of meteorites has progressed at a very rapid pace and contributed significantly to our current understanding of the origin and evolution of the early solar system. In fact laboratory studies of interstellar dust is now possible, thanks to the identification of diamond, silicon carbide and graphite grains in samples of primitive meteorites. Isotopic studies of these grains have confirmed their interstellar origin and provide new insight into the stellar environments in which they formed. Finally, isotopic studies of meteorites and lunar samples provide the only window to look at the intensity and composition of energetic particles of solar and galactic origin that have been present in the interplanetary space for aeons. All these aspects are discussed in a series of seven papers in the current volume. **U Ott** reviews the source and origin of interstellar grains found in meteorites and discusses new results that provide additional information on the origin of interstellar diamonds. **H Vanhala** presents results obtained from numerical simulation studies that suggest the possibility of a triggered origin of the solar system. The time scale for the collapse of the protosolar cloud to form the Sun, inferred from isotopic studies of meteorites, could be accommodated in this model. The presence of short-lived nuclides in the early solar system is discussed at length by **J N Goswami**, who considers the various suggestions regarding the source(s) of these nuclides and concludes that the current experimental data are consistent with their stellar origin. The time scales for the protosolar cloud collapse, for the formation of some of the first solar system solids and for thermal metamorphism and differentiation of meteorite parent bodies in the early solar system, that can be inferred from the data on short-lived nuclides in meteorites, are also discussed. The validity of the I-Xe dating technique to infer relative time scales of the early solar system processes is the theme of the paper by **C M Hohenberg *et al***. They present recent experimental data to show that this dating approach can give meaningful information on the time scale for secondary processes such as aqueous alteration, thermal metamorphism, and shock, experienced by the meteorites on their parent bodies. **K Marti and K J Mathew** summarize the presently available data for noble gas isotopic compositions in solar wind, meteorites and planetary atmospheres and their possible interrelations, using Xe isotopes. The usefulness of the noble gas isotopic composition in understanding the processes affecting the evolution of

planetary atmosphere has also been discussed in this paper.

The last two papers in the volume present the progress made in understanding the energetic particle environment in the interplanetary space from studies of their interaction records in lunar samples and meteorites. **R C Reedy** reviews the data on the intensity of the contemporary solar energetic particles gathered from spacecraft observations, and compares them with those obtained from isotopic studies of lunar samples, that provide similar data, averaged over time scales of thousands to millions of years. Suggestions for further refinement of this data set to confirm the trends seen in the long-term behaviour of the solar activity are also presented. **R Michel and S Neumann** discuss the progress made in laboratory simulation studies of cosmic ray interactions with meteoroids in space and in analytical studies that attempt to model such interactions. Both these aspects are important for the interpretation of cosmogenic isotope data in meteorites in terms of cosmic ray intensity and their spatial and temporal variations. The need for further studies of pertinent nuclear reaction cross sections has been emphasized in both the papers.

The broad canvas of topics included in this volume amply demonstrates the wide scope of application of the isotopic records preserved in the Earth and Planetary materials, to gain a quantitative understanding of the various processes operating in the planet Earth and other solar system objects during different epochs in their evolutionary history. It is hoped that the contents of this volume will provide an impetus to students and scientists alike in specific areas in Earth and Planetary sciences and serve as a meaningful source of current research for pursuing further work in these areas. We are grateful to all the contributors to this volume and also to the international panel of reviewers for their diligent and painstaking review of the manuscripts. We are grateful to Prof. V K Gaur, Editor-in-Chief, Proc. Indian Academy of Sciences, (EPS), for advice and encouragement received during the preparation of this volume. We thank Mr. P G Thomas, Mr. K R Nambiar, Mr. A D Shukla and Ms. K K Marhas of the Physical Research Laboratory for help during the various stages of its preparation, and the staff of the Indian Academy of Sciences for a commendable job in bringing out this volume within a short period of time. We gratefully acknowledge the financial assistance received from the Dept. of Space and the Dept. of Science and Technology, Govt. of India, for supporting this endeavour.

J N Goswami
S Krishnaswami
Guest Editors