GOALS FOR EARTH SCIENCE ACTIVITIES IN THE NINETIES

Proceedings of the Workshop

Bangalore, 17-18, June 1989

GEOLOGICAL SOCIETY OF INDIA
BANGALORE

PARTICIPANTS IN THE WORKSHOP

Standing top row (from left to right)

T. D. Mahabaleswar *(Bangalore)*, S. Jithendra Kumar *(Bangalore)*, R. H. Sawkar *(Bangalore)*, B. Mahabaleswar *(Bangalore)*,

Standing 1st row (from left to right)

Ashok Sahni *(Chandigarh)*, Arvind K. Jain *(Roorkee)*, R. Vaidyanadhan *(Waltair)*, K. R. Gupta *(New Delhi)*, K. V. Subbarao *(Bombay)*, M. Ramakrishnan *(Bangalore)*, G. V. Anantha Iyer *(Bangalore)*, A. G. B. Reddy *(Bangalore)*, S. K. Tandon *(Delhi)*, A. S. Janardhan *(Mysore)*, B. P. Radhakrishna *(Bangalore)*.

Sitting (from left to right)

Ashok K. Singhvi *(Ahmedabad)*, S. S. Samprathi *(Bangalore)*, Mallikarjuna Joshi *(Naini Tal)*, Vivek S. Kale *(Pune)*, Kurien Jacob *(Bangalore)*, Vishwas S. Kale *(Pune)*, S. Balakrishnan *(Roorkee)*, Rajiv Nigam *(Goa)*, T. Radhakrishna *(Trivandrum)*, Kanchan Pande *(Ahmedabad)*.

Proceedings of the Workshop on 'Goals for Earth Science Activity in the Nineties'

17-18 June 1989

INTRODUCTION

There is a growing feeling among earth scientists in the country that the research effort as reflected in the publications suffers in comparison with the level of publication at the international level and that steps have to be taken to build a healthy climate for promoting innovative thinking so as to make significant contribution to our understanding of earth history. Indian continent presents some of the best geological sections and exposures which can stand comparison to any in the world. The Himalayan Mountain Belt, the Deep Continental Crust of South India, the Proterozoic Sedimentary Basins and the Deccan Flood Basalts—all these belong to the world class and it should be possible to be in the frontline of research and contribute significantly to our knowledge in a few selected fields at least, if only we could effectively plan and implement inter-disciplinary and inter-institutional research on certain challenging areas to be identified and goals set for achieving tangible results in the nineties.

Since young scientists in the age group of 30 to 35 years were expected to possess a freshness of outlook and innovative thinking, it was felt desirable to tap this talent and ascertain their own assessment of priorities in research.

With this end in view, the Department of Science and Technology in co-operation with the Geological Society of India, organised a two-day workshop on the 17th and 18th of June, 1989 at Bangalore on 'Goals for Earth Science Activity in the Nineties'. Invitations were sent to about seventeen young scientists with a proven record of high quality research as reflected by their publications in standard journals. They were requested to send extended abstracts outlining their view points. Only fifteen responded and actually ten participated in the workshop.

The contributed extended abstracts received from the young scientists were compiled, edited, bound as a separate volume and distributed to the participants beforehand.

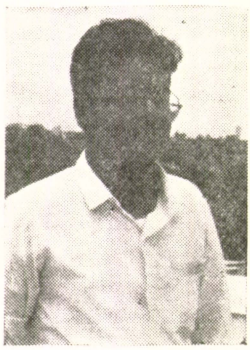
President of the Geological Society of India, Dr. Kurien Jacob welcomed the invited scientists and Dr. M. N. Qureshy, Adviser, Department of Science and Technology, Dr. S. K. Tandon and Dr. B. P. Radhakrishna offered opening remarks outlining the origin and scope of the workshop.

FIRST DAY'S PROCEEDINGS

The first day was devoted to hearing the view points of the young scientists, while the second day concentrated on identifying certain challenging areas in the field of earth science for further study.

Suture zones in the Archaean

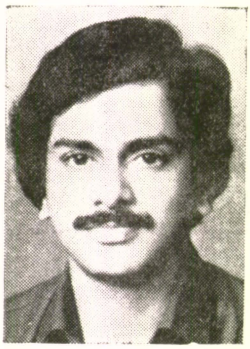
The first speaker to present his views on the opening day was S. BALAKRISHNAN, of the Roorkee University. He is a young scientist who has been closely associated with V. Rajamani of the Jawaharlal Nehru University and has been carrying out exceptionally good geochemical work on the schistose rocks of the Kolar Schist Belt and the gneisses to the east and west of it. This work carried out in close collaboration with the group of scientists at Stonybrook, New York, headed by the noted geochemist G. N. Hanson, has extended the operation of plate tectonic processes into the Archaean. Detailed geochemical work on the different lithologies of the schist belt has demonstrated that these lithologies on the eastern and western parts are distinct in their major, and trace element and isotopic compositions. Balakrishnan felt that this was a problem of great significance as earth processes can be quantified and a thorough insight gained in understanding the geodynamics of a particular terrain. He recommended an integrated approach involving detailed geological, geochemical, structural and geophysical studies.



He also felt that such studies should be undertaken simultaneously with studies of established suture zones as in the Himalaya. Such a comparative study, he felt, would provide a unique opportunity for recognizing signatures left behind by processes like accretion, subduction, and collision and help in a better understanding of global geodynamism through time.

Fluid inclusion studies

The second presentatian was by M. SANTOSH of the Centre of Earth Science Studies, Trivandrum. He is a young man who has to his credit several publications on the subject of fluid inclusions. In his talk, he stressed on the importance of understanding the character of mineral-forming fluids and on the wealth of valuable information that such studies can provide on aspects like depth of emplacement of magma, identification of the source of volcanic rocks, diagenesis, and metamorphism. South India provided best opportunities for studying rocks of the deep continental crust. The existence side by side of gneisses and granulitic rocks indicated that pressure and temperature increase alone cannot explain transformation to granulites and that it was necessary to involve a mechanism which permitted flushing by fluids. He pleaded for a more intensive study of the subject by developing newer techniques like



Raman spectroscopy and Laser Raman spectroscopy for the study of fluid inclusions. It was also necessary to create awareness among Earth Scientists of the wide application of fluid inclusion research, especially its importance in the characterization of mineralizing fluids.

Study of deep continental crust

G. R. RAVINDRA KUMAR, another young scientist, also from the Centre for Earth Science Studies, Trivandrum, who has concentrated his attention on older granulites and establishing P-T conditions of their formation, stressed the importance of carrying out geological and geochemical research on older granulite-grade-sediments, recognized as forming a separate group in the Indian Precambrian. He felt that a N-S geophysical transect, cutting across the granite-greenstone terrain and the high-grade terrain, with a transition zone in between and with numerous large-scale transcurrent ductile zones would provide answers for understanding the geological evolution of the southern Indian shield. This would necessitate detailed geological, petrological, geochemical, isotopic and geochronologic studies, involving different institutions within the country. It should be possible, according to him, to provide answers to many fundamental problems relating to the origin of the deep continental crust.

Seismic Reflection Profiling of Sedimentary Basins

MALLIKARJUN JOSHI, who hails from the Himalayan region and presently working at the Kumaun University, Naini Tal, stressed the importance of establishing field relationship first, especially by carrying out geomorphologic and neotectonic studies in the Himalaya with a view of testing the theory of continental movement and horizontal tectonics in operation. He emphasized the need for carrying out seismic reflection profiling over the different sedimentary basins in order to understand the disposition of thrust sheets which have affected the sediments.

Study of mafic dyke swarms

T. RADHAKRISHNA, basically a geologist but is currently taking interest in palaeomagnetic studies, especially of dyke rocks. The main point made out by him was the existence in India of mafic dyke swarms of diverse ages characteristic of various tectonic regimes. According to him, Indian continent represented a classical terrain to unravel the entire gamut of geological processes like deformation, metamorphism, magmatism, sedimentation pattern, creation and destruction of ocean floor, etc. He felt that modern methods of interpretation to evaluate crustal contamination should be attempted. The dyke swarms were considered particularly significant as their occurrence is a consequence of intrusion of magmatic material into fracture systems generated through stresses built up in the crust. He advocated use of High Resolution Space Imagery for delineation of the dyke swarms and palaeomagnetic and geochronological studies

to establish the position of the Indian continent during different stages of its evolution.

He also emphasized the need for the study of the major shear zones identified in Peninsular India and the suture zone in Himalaya, especially in the north-eastern region where geochemical information was lacking.

Transects across the Indian contnent

He presented an EW coast-to-coast crustal transect across Peninsular India correlating geological and geophysical data and suggested that similar transects over crustal sections where geophysical data is available be taken up to answer specific problems.

Isotopic study of magmatic processes in the crust

KANCHAN PANDE who had his geological training in Kumaun University, Naini Tal, joined the Physical Research Laboratory at Ahmedabad and received good training in isotopic and geochronological research under K. Gopalan at Ahmedabad and the Scripps Institution of Oceanography, La Jolla, California under J. D. Macdougall. His approach to the problem posed by the workshop was from the geochronological angle. He pointed out how the concept of chemical and isotopic geodynamism provided a framework for the study of the evolution of the variety of geological features presented by India. He wanted to concentrate on the study of the oldest crustal components as well as on the spectacular Proterozoic fold belts in order to characterize the changes in the nature of Archaean and Proterozoic crusts. He would also like to continue his studies aimed at establishing the time and duration of Deccan trap activity by ^{40}Ar-^{39}Ar method.

He emphasized the need to study basic magmatism in the Himalaya, a much neglected field. Such a study would considerably help in erecting models for the origin and evolution of the Himalaya.

Antarctic studies

ANIL JOSHI of the Antarctic Division of the Geological Survey of India and MANOJ SHUKLA of the Birbal Sahni Institute of Palaeobotany, Lucknow, did not attend the workshop but, provided informative abstracts giving expression to their views. The emphasis of JOSHI was on Antarctic studies—particularly the study of the Proterozoic high-grade terrain and associated anorthosites, as well as the study of glaciers and meteorites.

Importance of palaeobiological studies

MANOJ SHUKLA's interest was palaeobiological, in trying to unearth traces of the oldest fossils in the geological record and in defining precisely

the Precambrian-Cambrian transition. Origin and early evolution of life, according to him, should form a major thrust area and efforts at understanding the transition from chemical evolution to biological evolution should receive attention. The study of microbiota responsible for the formation of stromatolites, so common in the Precambrian of India, was another field of research holding good promise. India possessed some of the best Precambrian terminal sequences both in the Himalaya as well as in the Peninsula and, therefore, ideally suited for establishing stratigraphic biochronology.

Studies relating to changes of climate in the past

RAJIV NIGAM, of the National Institute of Oceanography, who has to his credit considerable amount of research on certain aspects of marine geology was the next to present his views. He emphasized the importance of marine biological studies as indicative of changes of climate in the past. He pointed out that India had a coast-line extending to nearly 6000 km and Exclusive Economic Zone (EEZ) of no less than 2 million km^2. The exploration and identification of resources in this very large area was a major challenge before earth scientists in the coming decade. His particular emphasis was on the study of the inner shelf with a view to gaining knowledge about changes in palaeo-climate and sea-level changes. The study of sediments being deposited rapidly in the shallow seas shed light on climatic changes in the last few thousands of years. He furnished details of a pilot study he had undertaken based on foraminiferal variation. His study indicated a cyclicity of about 77 years in the incidence of draught. This was to a certain extent corroborated by a study of rainfall pattern over the last 100 years.

Proterozoic Sedimentary Basins—importance of sedimentological studies

VIVEK S. KALE and VISHWAS S. KALE, both from the University of Poona, Pune, were the next two speakers. VIVEK KALE, who was the youngest among the young earth scientists assembled, gave an excellent resume of the Proterozoic sedimentary basins of India. A series of well-chosen slides in colour and good delivery carried his message across. He pointed out how India possessed a complete and continuous sedimentation record from Middle to very late Proterozoic (perhaps including even the early Palaeozoic). He was somewhat harsh on the previous workers who had confined their attention to mapping just lithological variations. There was need for detailed sedimentological studies on modern lines. The Proterozoic basins of India were an encyclopaedic collection of sedimentary structures requiring detailed study.

Kale felt there was need for a complete reorganization of stratigraphic classification presently in vogue for the Proterozoic sedimentary basins of

India. He particularly illustrated the case of Bhima Basin with well-chosen examples of lateral facies transitions. According to him, it was not correct to delink stratigraphy from sedimentological parameters.

On the precise age of the various basins, he was sceptical of the different methods adopted. According to him, there was utter confusion in linking lithostratigraphy with biostratigraphy based on the study of stromatolites. He was of the opinion that the study of trace fossils and stromatolites which had hardly received attention should be pursued with greater vigour. There was again, he emphasized, an urgent need to define the precise isotopic age of the basement, interlayered volcanics and of the authigenic minerals like glauconite, tourmaline and feldspar.

There was also a mistaken impression, he told the audience, that these sequences were least disturbed. In fact, all the basins had suffered from moderate deformation and it was necessary to distinguish between what was penecontemporaneous as against post-depositional episodes of deformation. The close association of these basins with the mobile belts was another subject requiring detailed study.

It was refreshing to follow the arguments of this young crusader demolishing one after another some of the entrenched beliefs relating to Proterozoic sedimentation and at the same time demonstrating what a heavy agenda of work remained to be carried out in understanding the sedimentation history of the unique Proterozoic Basins of India. His extempore delivery, his marshalling of arguments, his care in the preparation of illustrative material, and the quiet confidence with which he presented his case elicited the admiration of those assembled. His performance was easily the best among the several presentations.

Morphometric study of river basins

VISHWAS KALE, of the Geography Department of the University of Poona, dwelt on the importance of carrying morphometric studies of rivers in the western upland region of Deccan. He showed some excellent views of Deccan landscape. His treatment was mathematical and somewhat difficult to follow by some of us. He advocated a multidisciplinary approach to the problem of understanding the basic causes of catastrophic floods and the role of lithology and tectonics in disturbing the grade condition. This was another aspect of Quaternary Geology requiring study.

Study of environmental changes in the past

R. RAMESH, another bright young scientist from the Physical Research Laboratory, was unfortunately unable to be present but he sent an informative abstract in which he dwelt on his pet subject of studying climatic and environmental changes by examining shallow ocean sediments from the sea, tree rings, sand dunes and glaciers on land. This is another

fascinating realm of interdisciplinary study opening up new challenges in which our country can be expected to contribute substantially to the reservoir of knowledge on the changing patterns of environment during the recent past. These studies do provide invaluable clues in the palaeo reconstruction of climate on a global scale.

Some aspects of Quaternary research

The last of the speakers was ASHOK SINGHVI, again from the Physical Research Laboratory. He is a mature scientist with considerable research experience to his credit as reflected from the numerous publications in his name and that of his associates. His interest was mainly in Quaternary geology, the elucidation of climatic events during the past hundred kilo years. There is no doubt that this is an important field of research, much neglected by earth scientists. New isotopic and geochemical methods have enabled securing precise data about the climatic changes in the past. Taking the example of desert sands of Rajasthan, Singhvi pointed out how it was possible to get an insight into aspects like mobility and stabilisation of sand, mechanism of development of dune systems, aeolian activity on global and regional scale, development of gypsum crust and calcrete. The main thrust of his talk was to relate how laboratory data could be utilized in understanding the processes responsible for climatic changes in the past and in dating recent sediments.

India is predominantly an agricultural country. Its soil and water resources are of the greatest importance. A clearer understanding of the processes giving rise to the weathered crust would greatly add to our knowledge about soils. Significant new lines of research could be developed and geologists with their field knowledge could interact more closely with physicists and chemists in the laboratory. The talk of Singhvi was an eye opener pointing to the wide field of cooperation before earth scientists and physicists in solving current problems of great relevance to the needs of the country.

The first day's presentation thus, proved to be extraordinarily good pointing to the hidden sources of talent available in the country, awaiting encouragement and sympathetic understanding. It became clear that, if only opportunities to interact freely with more experienced members of the earth science profession and scientists of other disciplines are provided to these young minds there could be a significant spurt in research activities.

FORENOON SESSION ON THE SECOND DAY

The morning session of the second day was centered round a discussion of the points made out the previous day by the young scientists. The

senior scientists were asked to give their reactions to the problems posed. Free exchange of ideas then followed with several suggestion of new approaches to the solution of problems posed.

Inadequacy of our data base

The most important point which emerged was the faulty and insufficient data base. The availability of maps was one such inadequacy. Speaker after speaker emphasized the need for base geological maps on a sufficiently large scale (1:50,000). Geophysical data, especially gravity and aeromagnetic coverage and their presentation on the same scale was considered essential for any significant advance to be made. There was unanimity of opinion on concentrating attention on detailed mapping of suspected suture zones. The main points made out by individual speakers are summarized in the following pages.

Study of suture and shear zones

Continental collision is an elegant model, but its consequences require to be tested in the field and laboratory. It was felt that structural geologists having first-hand knowledge about collision tectonics in the Himalaya should be provided with opportunities to study the spectacular Proterozoic shear zones in the Peninsula (A. S. Janardhan, A. K. Jain). Proterozoic mobility had brought different crustal blocks of diverse character and piled them up one upon another. The evidence so far adduced by the group working at JNU was of a geochemical character. This had to be supplemented by detailed field studies, and structural mapping (M. Ramakrishnan and B. P. Radhakrishna).

Developing Raman Spectroscopy for study of fluid inclusions

Since fluids constituted a unifying theme for understanding diverse geologic processes operating in the crust, studies of fluid inclusions, it was emphasized, should be pursued more vigorously. The help of the Physics Departments of the Indian Institute of Technology at Madras, Kanpur and Bombay and the BARC should be sought in introducing Raman Spectrometry and Laser Raman Spectrometry to the study of fluids trapped in metamorphic rocks (A. K. Singhvi). It was suggested that in order to pursue this matter further, an exclusive workshop should be organized inviting earth scientists carrying out fluid inclusion studies in different laboratories and physicists from Indian Institutes of Technology, Bhabha Atomic Research Centre and enable them to interact with each other. A blue print of coordinated research in understanding the role of fluids in metamorphism and related processes could possibly come out of such a multidisciplinary and multi-institutional approach (B. P. Radhakrishna).

Study of Proterozoic sedimentary basin configuration

Seismic reflection profiling should be attempted to map the configuration of the different Proterozoic Basins. Their hydrocarbon potential

should not be lost sight of (B. P. Radhakrishna). A suggestion was made for carrying out deep resistivity sounding to characterize the floor of sedimentary basins. This was a simpler method for which equipment is already available at NGRI and GSI. By adopting this technique it should be possible to obtain basic information on basin configuration (A. G. B. Reddy). Structural studies are needed to ascertain the extent to which basins had subsided (A. K. Jain). Detailed sedimentological studies should be attempted at least on one basin where exposure quality was excellent. Palaeobiological record was likely to be preserved far more completely in these peninsular sedimentary basins than anywhere else and they were, therefore, ideal for the recognition of the first metazoan fossils. Specialists with experience in recognizing trace fossils should be closely associated in the detailed study of these sedimentary basins (S. K. Tandon).

Need for geomorphological maps of drainage basins

While morphometric studies of the type attemped by Viswas Kale with mathematical output was welcome, there was need for geomorphological maps of drainage basins as a prerequisite to morphometric studies (R. Vaidyanadhan).

Studies on water, energy and soil resources

Intensive studies on our water, energy and soil resources should be attempted as a piece of relevant research of great significance. Basic research in respect of these resources have been sadly neglected by earth scientists. In the coming decade we should concentrate on a detailed study of weathering processes, and the study of soils. It would be helpful if persons like Singhvi could attempt a review paper giving details of the several ways in which adoption of modern analytical techniques could come to the aid of earth scientists in solving problems relating to weathering and soil formation (B. P. Radhakrishna).

Specialists of PRL, Subbarao of IIT, Bombay, and Shankardas who is now retired from BARC, and a few others could sit together and formulate a project for the study of weathering and soil formation processes (M. N. Qureshy).

The study of geology of clays, the manner in which silicates weather and give rise to clays is a fascinating subject. Such a study can throw light on changing climatic conditions (G. V. Ananta Iyer).

Intensive study of the granulite belts of India

The status of the older group of Archaean metasediments and volcanics, older than the widespread thermal event around 3000 m.y., should be established (M. Ramakrishnan). A comparative study of the granulites of S. India, the granulites of the Himalaya and the granulites of Central and Eastern India should be undertaken (A. S. Janardhan). There were cratonic granulites in Central India unconnected with regions of mobility. These should be examined (M. Ramakrishnan).

Seismic reflection profiling

The need for developing capability of carrying out seismic profiling of Proterozoic and younger sedimentary basins was particularly emphasized. The possibility of utilizing telluric currents and magneto-telluric studies to outline the resistivity and magneto-stratification of the sedimentary basins was suggested as a cheaper alternative to seismic profiling (A. G. B. Reddy).

Study of mafic dyke swarms

There was unanimity of opinion regarding intensive study of the spectacular dyke swarms of India. Detailed petrographic study of the dyke rocks should be taken up. There is distinct possibility of identifying diamond-bearing lamproits (B. P. Radhakrishna). The dyke rocks offered the best material for carrying out geochronological studies. ^{40}Ar-^{39}Ar dating of the dyke rocks could be taken up and a faster flow of data attempted (K. Pande). A simpler alternative, in the first instance, was to determine rock magnetic properties of the dyke rocks in a routine way. Recent work had established a close relation between rock magnetism, the state of iron and age. This could provide a rapid method for distinguishing dykes belonging to the different age groups (K. V. Subbarao). Mass spectrometry could furnish quantitative estimate of the status of iron (A. K. Singhvi). Since Rb-Sr data had failed to identify older events because of the widespread thermal impress around 2500 m.y., it may be worthwhile to extend the ^{40}Ar-^{39}Ar method into the Archaean and find out what type of results we get (M. Ramakrishnan).

Geochemical characterization of Deccan Flood Basalts

There was need for continuation of the geochemical characterization of the Deccan flood basalts. Deccan basalts have the distinction of becoming prototypes for tracing crustal contamination. Boron should be used as an indicator element in establishing crustal contamination in subduction zones. Detailed geochemical studies on the intertrappeans particularly in terms of the presence of iridium, is likely to offer challenging opportunities to delineate, the C/T Boundary. Use of computer-aided techniques proved to be of immense use in genetic models for the Deccan as a whole (K. V. Subbarao). Equipment for the determination of Rhenium-Osmium was being set-up at PRL, Ahmedabad and it is expected that data emerging from this unit could throw light on crustal contamination processes (K. Pande).

Earth scientists to become information conscious

Recent years have witnessed spectacular advances in computational technology. Instrumentational techniques are making available enormous quantity of data. Storing of this data, its retrieval and graphical portrayal are essential parts of this new culture. Earth Science community in the

country is to a large extent unaware of these developments. The information available has to be utilized. There should be a continuous effort at making the ON LINE facilities available to earth scientists (B. P. Radhakrishna).

AFTERNOON SESSION ON THE SECOND DAY

The afternoon of the second day under the chairmanship of S. K. Tandon was devoted to hearing of the view points of some of the seniors participating in the workshop.

K. R. GUPTA, of the Department of Science and Technology at the outset gave a brief resume of the different thrust areas funded by the DST and the extent of funding in recent years. He stated that nearly 70% of the funding related to the procurement of instruments. The utilization of instruments was not optimal and there yet remained many problems to be overcome in ensuring fuller and satisfactory utilization. Effective monitoring and promotion of interaction between individuals and institutions had yet to be achieved.

ASHOK SAHNI, from Panjab University Chandigarh and a member of the Project Advisory Committee of the DST, dealt at length on the philosophy behind the identification of thrust areas. Some, like the stratigraphic boundary problems, the problem of granulites, the Deccan traps, were of global significance. Some others, like the Himalayan structures, the Indo-Gangetic plain, were regional in character. Others like coastal geomorphology, water resources, soils, earthquake prediction, were of national significance. All these had to be taken into consideration in identifying problems and in fixing up priorities.

A. K. JAIN, of Roorkee University, emphasized the pivotal role which DST had played during the last decade in liberally funding scientific research. The present decade had seen the emergence of quantitative modelling in understanding crustal problems. These developments should be projected into the coming decade. There was need for Nodal Research Centres where sophisticated instrumental facilities should be provided. It is only then, dependence on foreign collaboration can be avoided. There should be generous funding on a long-term basis. We should concentrate on two items—one, the study of crustal processes—the geodynamics of the lithosphere— and two, surficial processes—which covered aspects of Quaternary geology.

J. A. K. TAREEN of the Mysore University spoke about the culture which developed during the last decade of collecting samples and getting them analyzed in outside laboratories which brought forth certain significant results. The Indian scientists, although deeply involved in the programmes, performed the role of sample gatherers. In order to overcome

this type of culture which was tending to grow into a habit, the establishment of Regional Sophisticated Instrument Centers was thought of and liberally funded by DST. Experience had shown that for various reasons these units attached to some of the IIT's had not been much of a success. The sharing of knowledge and experience with others was not taking place. The labs did not run all the 24 hours, as in western countries. Bureaucratic procedures played havoc in proper functioning of the centres. One solution is to have small autonomous centres detached from major institutions with a two-tier system of management: a technical component taking care of the instruments and an academic component devoted to pursuit of research. These aspects were engaging attention.

A. S. JANARDHAN, also from the Mysore University stated that it was only during the last one or two years University Earth Science departments had been equipped with sophisticated instruments. They should be given time to produce results. Hasty condemnation of a useful system was not justified.

S. BALAKRISHNAN of the University of Roorkee deprecated too much dependence on technicians. It was the scientist's duty to get trained in all aspects of electronics and instrumentation, and be in a position to operate the instrument himself, and be sure of the results. It was necessary to build the facilities around a University, as it was only then that graduate students who are going to be the future leaders could get trained in modern methods.

B. MAHABALESWAR of the Bangalore University wanted information about the types of instruments available in different parts of the country to be made known to all. There should be a provision in the scheme of DST to allow others to utilize these facilities.

The afternoon session thus provided a forum for the expression of differing viewpoints on the identification of thrust areas and the process of funding by DST.

CONCLUDING SESSION

B. P. Radhakrishna, Geological Society of India, who chaired the session, recalled how initially he was reluctant to seek governmental assistance for developing the Geological Society. It was Dr. Gupta, who, influenced by the impact of the article 'Twenty-five years of progress', persuaded him to make an application to the DST for assistance. This assistance which started as a trickle in 1985 had gradually grown in volume and had enabled the Society to have a habitation of its own, increase the number of pages in the Journal and launch on an ambitious programme of publishing state-of-art reports, guide books, seminar volumes, etc. It had also enabled it to organise national and

international seminars on topics of world-wide geological interest. Young scientists should take courage from this example. They should count on DST as their biggest benefactor. No worthwhile project will fail to get support. What is required is hard and sustained work. The Geological Society too would strive to play an important role in bringing persons working in different disciplines and different regions of the country together and promote interaction between them. He assured the young scientists that the society will go all out to help them in their research problems. It felt confident that by so doing, it would help accelerate the tempo of research in the country.

Taking due note of the different views expressed during the course of the two-day workshop, the Chairman listed the following programmes as challenging fields deserving further study during the coming decade.

Understanding of the Plate tectonic processes in the Himalaya and their extension to the Proterozoic and the Archaean

The pre-eminance of Himalaya as the classic ground for the study of collision tectonics was emphasized. Much team work and sustained effort were necessary to unravel the complicated geological history of the terrain. Palaeomagnetism plays a vital role in the study of these areas. All Earth Science Institutions in the country should get involved in the study. Transects of all collision zones should be attempted. Exchanges of visits and ideas between geologists working in the younger terrain and the considerably older terrains in the south should be encouraged. This will enable a clear perception to be gained of the changing patterns of Plate Tectonic processes through time.

Understanding of the role of fluids in geological processes

The important role fluids play in metamorphism and mineralization processes has come into prominence in recent years. This field is yet new in India and requires to be pursued with vigour. The help of physicists in IIT's., BARC should be availed of in venturing on studies of fluids by adopting the latest techniques of Raman spectroscopy and Laser Raman spectroscopy. Group of individuals and institutions engaged in this study should be identified and given encouragement to pursue the subject more intensively and contribute to our knowledge of metamorphic and mineralization processes.

Study of Proterozoic Sedimentary Basins

The study of Proterozoic sedimentary basins of India has not received much attention so far. They are a fantastic store-house of sedimentary structures. Detailed sedimentological studies should receive urgent attention. Geophysical input in defining subsurface characterization, mapping of the basement and seismic profiling to outline the structure are essential. Since in some sections at least, the sedimentary record as preserved in these

basins transgresses the Precambrian-Cambrian boundary, a detailed palaeo-biological study should be undertaken. Geologists working in the Himalaya should get deeply involved in the study of these basins in Peninsular India.

Study of Mafic Dyke Swarms

India has a priceless heritage of a vast variety of dyke swarms of different kinds and different ages which required to be studied from all angles – petrographical, geochemical, geochronologcal, palaeomagnetie and structural. They are sure to throw considerable light on the evolution of the Indian lithosphere.

Geochemical characterization of Deccan Flood Basalts

This is an on-going research project which has yielded good results. Geochemical characterization and establishment of stratigraphy for the entire Deccan trap region should be attempted. Petrological and isotopic study should be intensified, as the Deccan Flood Basalts represent the best candidates for studying crustal contamination in continental flood basalts and continental lithosphere. ^{40}Ar-^{39}Ar age determination should enable precise fixture of the time and duration of the eruption. Correlation of flood basalt eruption with mass extinction is a fruitful field of research which must receive attention. Another fascinating and challenging problem relates to the study of the processes and causes of uplift of the Western Ghats and its possible effect on the drainage pattern of the Peninsula.

Studies on groundwater, soil and weather

As a piece of relevant research which has a great bearing on the welfare of the people, Earth Scientists will have to take greater interest in carrying out basic research in respect of groundwater, weathering and soil formation and on the changing patterns of climate.

Groundwater: Processes which cause fluctuation in water table, the manner of recharge and the consequences of large-scale withdrawal, the role played by the vadose zone in transfering water, groundwater contamination which is posing a serious threat—all these aspects should receive immediate attention.

Soils: A clear understanding of the chemistry of the weathering process in relation to soil formation is another important field on which research has to be concentrated. Valuable soil is getting rapidly eroded. Studies should be aimed at controlling this menace, through geomorphological appraisal, terracing, contour bunding, afforestation of watersheds and such other constructive measures.

Weather: Studies on the changing aspects of climate are equally important. All investigations, like the study of shallow oceanic sediments in

the shelf region, tree rings, sand dunes, loess and glaciers should be intensified and knowledge gathered from a study of these aspects periodically synthesized.

Formation of small working groups

A recommendation was made that small working groups in respect of each challenging area should be formed whose task will be to identify individuals and institutions who are likely to be involved in this study and get project reports prepared. It should also be the duty of these working groups to monitor the progress achieved in their respective areas and send periodical reports. Timely corrective action, it was emphasized, should be taken to set right deficiencies.

The above, represented some of the challenging areas on which it would be worthwhile to concentrate attention in the coming decade. The Chairman expressed the hope that the process of interacting with young minds will develop in future, and the Society will involve them more and more in its meetings and give the more intelligent and enterprising among them a pride of place in its deliberations. Such efforts, he felt, should get multiplied in different centres and a new awareness and a new interest generated. If such a development does take place and there is greater interaction between scientists of different regions and scientists of other disciplines, the efforts at organizing such workshops will not have been in vain.

EPILOGUE

Thus concluded one of the very successful workshops which the Geological Society has conducted in recent years. The group was small but of an optimum size which generated close interaction between participants who were all deeply involved in the subject. They spent every minute of their stay during the two days in intimate conversation with their peers and came to have a better perception of the other man's point of view. The discussion and the happy team-spirit which prevailed, provided the seed for many a collaborative programme of research between individual scientists and scientists working in different institutions. A general consensus emerged as to the future course of action of research on some of the aspects discussed. All participants, benefited by their participation and went enriched with their enthusiasm kindled. It is hoped that this enthusiasm will last and a spirit of adventure will motivate these young brains to greater effort.

B. P. RADHAKRISHNA