The 'Vision 2005: Earth Sciences' document of the Department of Science and Technology was recently printed in the pages of this journal (Curr. Sci., 1996, 71, 820–823). An alternative view, espoused by one of India's leading geologists is reproduced below.

– Editors

Priorities in earth science research

B. P. Radhakrishna

'If we want the world to pay greater attention to geology, and if we want decision makers to allocate more resources for geology, then we need to demonstrate the importance of geology in public affairs and we must accept our public obligation to be good citizen geologists.'

E - an - Zen

As the twentieth century is drawing to a close, scientific institutions in the country have taken to the exercise of presenting 'vision papers' outlining the goals of research to be pursued by them. The United Front Government at the Centre too has come out with a Common Minimum Programme (CMP) to be followed during the coming years. It is worthwhile to examine the relevance of these programmes and the role of Earth Science in the present context.

One of the vision documents lists the following areas of opportunities for research in the field of Earth Science: (1) Evolution of the Indian Crust, (2) Himalayan Orogenic Belt, (3) Earthquake Problems, (4) Reconstruction of Palaeoenvironments and (5) Earth Science Application for Societal Needs.

Are these the priority areas of our research? What are we really going to achieve? Do these in any way contribute to the welfare of our people? If such questions are posed, it will be seen that a good part of our research effort is aimless and that we are trying to answer questions which nobody is asking.

The trouble with our research programmes appears to be that our top research personnel occupying senior positions in our universities and research institutions have received training in universities of UK, Europe and America. So trained they cannot but pursue the type of research that is being practised in those countries. Their vision has seldom extended to finding solutions to the problems faced by this country. Science and Technology have yet to become effective tools for national growth and economic development. The time appears ripe for introspection and rethinking.

The glaring fact remains that this country, even after fifty years of independence continues to be one of the poorest nations in the world. It is not as if we are lacking in resources. For its size, India has a variety of mineral and metal resources to satisfy many of its needs. Compared to other parts of the world it receives copious amounts of rainfall. Its soil is fertile. Hill slopes are covered with evergreen forests. The country is populated not by aborigines but by intelligent people with thousands of years of culture behind them. Its human resources are second to none. And yet, in spite of all these plus points, we remain poor. The reasons are not far to seek. It is because we seem to be wasting our time in imitative and aimless research and serious problems facing the country have been largely ignored. Have we tried to identify gaps in our knowledge and pose the right questions? First and foremost there is need for educating the public and those who are occupying seats of power as to what the scope of Earth Science is and what it can do to better our economic well-being.

Energy needs

As a consequence of the big boost given to the growth of the automobile industry, there has been an alarming increase in the number of vehicles and consequently in oil consumption which stands at 65 million tonnes per year. Indigenous production has remained stationary at around 35 million tonnes, necessitating import of the balance quantity of 30 million tonnes per year! This drain is likely to increase in the years to come, causing a big hole in foreign exchange resources amounting to over 7 billion dollars, or nearly 25,000 crore rupees.

Sedimentary basins having a good potential for oil cover an area of 1,400,000 km^2 on land and 720,000 km^2 offshore. This is an indication of the magnitude of the work before earth scientists – geologists and geophysicists alike – in carrying out detailed exploration of these sedimentary basins with a view to identifying favourable structures for test drilling. No concerted effort is yet evident in this direction. We seem to be waiting for others to come and do the job for us. The zeal and enthusiasm which were in evidence at the time of the formation of the Oil and Natural Gas Commission are lacking today. If goals are set and our scientists motivated and encouraged, there is no reason why India should lag behind in attaining self-sufficiency in respect of her oil requirements. One need not always be on the look out for giant fields, the many smaller fields also require attention.

The same lack of will is evident in the development of natural gas resources. Adequate attention is yet to be directed towards wise utilization of the identified reserves. In any agenda for research in the coming years, the identification of fresh resources of hydrocarbons should, therefore, occupy the first place. Geophysicists and geologists have a challenging task before them in these areas alone.

There is quite a bit of loose money in the country as is revealed by the insatiable thirst for possessing gold. Annually not less than 25,000 crores are being diverted in this way for want of better avenues for investment. Government policies and private initiative should aim at providing incentives to wean people away from investing their surplus money in gold and divert it for nation-building activities.

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Mineral resources

We do not yet have a comprehensive volume on the Mineral Deposits of India to enthuse our young men about the immense possibilities that exist in the development of our mineral resources. The Mineral Year Book brought out by the Indian Bureau of Mines falls very short of what is actually required. The geological setting of the country holds great promise for a boom, in mineral production and in order to usher in such a boom, regional mapping programmes have to be accelerated in order to stimulate mineral exploration. Proving extension of known ore bodies, identifying new ore zones and discovering new satellite ore bodies are items of research which should be encouraged and adequately funded.

Gold production has remained at a miserably low level. There is no urge or incentive to produce more. Hundreds of promising occurrences which should be humming with activity are left undeveloped, denying large-scale employment opportunities to the rural poor.

Utilization of resources

The practice of exporting large quantities of iron ore, manganese ore, chromite, barite, etc., without any processing to add to their value is still continuing unabated. This will not bring any prosperity to the country and requires to be stopped. The setting up of iron and steel production units is a step in the right direction and these industries have to be helped in obtaining an assured supply of suitable raw materials. This in itself is a major task which could provide unlimited employment opportunities to earth scientists.

Decentralization of powers

The CMP of the Government of India does not make any reference to the development of mineral resources. It, however, recommends devolution of powers to the States. This is a welcome move, as at present all power is centered in Delhi. Decision making is avoided at all levels, making the task of obtaining a mineral concession a most frustrating and exasperating exercise. The spate of applications received as a result of the liberalization policy announced by Government more than two years ago are still lying in cold storage with absolutely no action taken on any of them. There is no reason why State Governments, which are keen on developing the resources of their respective States should not be empowered to decide on the grant of mineral concessions subject to strict observance of rules and regulations in this regard.

Close association with industry essential

Official Survey Organizations, Universities and Research Institutions should forge greater links with industry and not function in isolation. Considerable amounts are being spent by several government organizations on exploration without first identifying the exploiting agency and follow-up action on mining and mineral processing is conspicuous by its absence. There is great apathy both in government and the private industrial sector, towards mining and exploitation of mineral resources. Need-based research should receive greater emphasis and be financially supported. Projects undertaken by research institutes and universities should be oriented towards providing the industry with new and more efficient technologies.

Subsequent exploration and exploitation should be in the hands of a large number of private companies and individuals and not in the hands of governments as at present. Official survey organizations can play an important role providing the industry with detailed geological information, maps, and conceptual models, which will prove helpful in these areas and help the quest for new exploration concepts and in the discovery of new ore bodies. Key centres of research in economic geology should be developed where Government, Universities and Industry shall work in close co-operation. Increasing amounts should be made available for research in this field.

Every project undertaken by the official survey organizations should end with a detailed report, which should be readily available to interested exploratory organizations and persons and not kept in cold storage as at present. Official survey organizations should also provide effective, responsive and efficient customer service. There is no harm in throwing open the country, with adequate safeguards, to international exploration, as all efforts at resource identification and exploitation should be encouraged. It is a never-ending process which, fuelled by its own successes, will gain momentum.

This does not mean that basic research should not be encouraged, but that is best confined to a few specialist groups. Repetitive and imitative research on the same type of problem by different Institutes and University Departments will not produce results commensurate with the time and money spent.

Significant progress possible

That India can make significant contributions in the field of science and technology is borne out by the spectacular results achieved by agricultural scientists in bringing about the green revolution and making the country self-sufficient in its requirements of food grains. Earth scientists too, can make an equally striking contribution if only they go about it in the right way, identifying resources and developing the skills for utilizing them to satisfy the Nation's requirements.

If spectacular progress can be achieved in highly specialized fields like software technology, cold fusion, and adventures in space, there is no reason why India should lag behind in developing her mineral industries and produce real wealth. What is needed is massive co-ordinated research programmes with the provision of adequate financial support unhampered by bureaucratic control. It is not the lack of instruments that is retarding progress but the lack of a will to succeed. Making a start is half the battle won.

Water-related problems

The ugly spectacle of feuds that are raging between States over sharing river waters is before us as a standing warning as to what is in store for us in the near future. Most of the problems that the country is presently facing appear to be the result of mismanagement rather than lack of resources. There is enough water to satisfy our needs but, who can place a limit to human greed?

Our knowledge about the water resources of the country and the extent of their utilization is far from satisfactory: Take the water needs of a city like Bangalore – we have no information on what percentage of population of the city depends on municipal water supply, how many depend on groundwater for their needs and how many live by purchasing water from dealers? State Groundwater Boards do not have correct records of the number of bore-wells that exist and the quantity of water pumped each day. No limit is placed on the exploitation of this essential and precious resource. Every day we hear of large sums being sanctioned for sinking new bore-wells without first considering the effect of large-scale withdrawal on a shrinking resource. An alarming decline in the water table has not in any way dampened the zeal for new wells, and hardly any attention is given to the replenishment of the resource through recharge. Forests which had the effect of arresting rainwater run-off and recharging groundwater reservoirs are being destroyed, leading to floods and severe soil erosion. River channels and surface water reservoirs are getting choked with silt. No effort is made to impound rain water and allow it to percolate down and recharge the groundwater reservoir. The extent of work awaiting the attention of geohydrologists is enormous.

Nature has provided a vast interconnected reservoir of water below ground. Ways of replenishing this reservoir should be our main concern. Attention has to be given to terracing, contour bunding, creation of farm ponds and afforestation of catchment areas. Such practices have the aim of arresting the free flow of rainwater and allowing it to infiltrate below ground and enrich the groundwater reservoir. Scientific knowledge has to be put into practice in demonstration plots and the message of water conservation conveyed to the public. The scope for service in this field is unlimited.

The advent of down-the-hole hammer rigs capable of drilling rapidly, even through hard rock, and the deep-well turbine pumps capable of lifting enormous quantities of water have revolutionized agriculture. They have, at the same time, allowed unlimited withdrawal of groundwater far in excess of annual recharge. Technology, while helping the farmer, has tended to jeopardize and possibly ruin a precious resource through overuse.

Withdrawal of groundwater in excess of the annual recharge should not be permitted under any circumstances. It will lead to a lowering of the water table and result in every other well in the region going dry. This is already happening in many parts of the country and if this practice of unrestricted utilization continues, there will be a water crisis in the not-too-distant future. When that happens, water will not be available even for drinking, let alone for irrigation.

The extent to which surface water and groundwater are increasingly polluted as a result of the use of pesticides and fertilizers is another major problem. Remedial measures to prevent chemical pollution of the precious resource must be taken without delay.

Educating the intelligent farmer, making him understand the problems he has to face and acquaint him with appropriate remedial measures he has to take to protect this resource is the paramount need of the hour.

It is earth scientists who are primarily concerned with the study of all aspects of groundwater – its occurrence, quality, exploitation and conservation. Unfortunately Research Institutes, and University Geology Departments have given a low priority to the study of groundwater-related problems. This is the one field where they can come into close contact with the people and in which, they can, by the application of their scientific knowledge, contribute to public welfare. Earth scientists can have all the job satisfaction they need, when they realize that they are of some service to their fellow men.

Surface water resources

Surface water resources too are not being used wisely. Vast sums of money have been spent in building high dams and storing large quantities of water. In this process, very large expanses of valuable agricultural land have got submerged, causing wholesale displacement of local populations and consequent untold misery. While engineering skill of a high order is evident in the construction of major reservoirs, the same technological skill has not been displayed when it comes to the proper utilization of the stored water. Methods presently adopted for conveying water are the most primitive and wasteful, in no way different from the practices followed thousands of years ago. Irrigation, as a result of such wasteful practices, remains the largest sick industry in India today with hardly any return on the huge capital invested. Major irrigation projects stand as examples of wasteful utilization of a precious resource, with no regulatory structures and measuring devices for supply of water. No value is fixed for the water supplied, resulting in wasteful utilization, far in excess of what is actually required. In this process, fertile land is also getting degraded, waterlogged and saline.

In matters of water conservation much can be learnt from Israel. Water in that arid country is an exceedingly precious commodity calling for maximum conservation. It is conveyed through pipes to prevent loss through seepage and evaporation and meters are installed to regulate supply with no wastage permitted. Sprinkler and drip irrigation are practised on a large scale in order to obtain maximum benefit from the water. We, on the other hand, by continuing obsolete and wasteful practices, are conveying water in open cut trenches using only 30% of the stored water in crop production. In the face of a rapidly growing population and the need for growing more food, we can ill afford such amateurish and unscientific utilization of water.

Water is the most precious of our natural resources and has to be conserved and used with great care. Effecting improvements in our irrigation practices is a realizable goal which has to be implemented without delay. Yields under flood irrigation, as practised in India, are too low, less than one tonne per hectare, while Japan, with controlled irrigation, has been able to produce 5.5 tonnes and in some cases as much as 8 tonnes per hectare. This is an indication of what is possible.

There is, again, a craze for planting water intensive crops like sugarcane. It should be remembered that water required for one hectare of sugarcane crop can irrigate 10 hectares of wheat. Scientific planning is necessary in making use of limited water resources and drawing maximum benefit.

Surface storage even in our largest dams is far from dependable. Dams can at best store one year's supply only and cannot safeguard against years of drought. Greater attention has to be given to groundwater reservoirs as their storage capacity is considerable and they can help tide over years of poor rainfall.

Those who benefit from major irrigation works are the richer and more articulate sections of society. The water need of the large majority of the population, living in regions far away from perennial sources and affected by droughts almost every year, is sadly neglected. No single Research Institute, to my knowledge, has specialized in water resource management and the country may have to pay a heavy penalty for neglecting this most important field of research.

Land use planning

It is estimated that there are 142 million hectares of arable land, of which only 46 million hectares have been brought under agriculture, the rest lying barren. The country cannot afford to allow such vast extents of land to lie barren. Science and technology aided by the intelligent use of modern mechanical devices should bring much of this land lying fallow under the plough. Terracing of land, excavation of contour ditches, erection of bunds, afforestation and all such land-use practices aimed at arresting free surface flow of rain water and making it percolate into the ground are needed.

Private industry and business establishments should take to farming and organize agriculture as an industry. Large investments are needed for developing infrastructure like roads, wells, drip irrigation pipe lines, pump houses, fencing and drainage. Modern technology has to be adopted with a view to seeing that every drop of water is utilized and the precious resources never allowed to run waste. Such development can bring about a major revolution in irrigation through planned groundwater exploitation.

Research on a variety of topics related to use of surface and groundwater can be suggested. Soil geochemistry, soil productivity, estimation of optimum requirement of water for different crops, estimation of evapo-transpiration losses, soil fertility, effect of irrigation on groundwater regime, conjunctive use of surface and groundwater, efficient water management, irrigation water-use efficiency, formulation of irrigation methods aimed at water conservation, salinity, prevention of soil degradation through excess irrigation – all these need expert attention. The problems are complex and require the combined efforts of hydrogeologists, irrigation engineers, and soil scientists. What is more important is that the results of research should be continuously communicated to the farmers, making it easy for them to grasp the details and enabling them to adopt new technology for better water management and improving agricultural efficiency.

Agricultural scientists have shown a better sense of responsibility. Instead of wasting their time in inappropriate research, they have adopted down-to-earth policies and deviced innovative measures to improve the conditions of the farmer. There has been a phenomenal increase in food production and very soon the country may become an important exporter of food grains. The most advanced research is being directed to produce hybrid seeds and step up food production. This is because, the large majority of agricultural scientists are engaged not in aimless academic research but on practical research oriented towards finding solutions to the problems faced by the farmer.

Environmental problems

There are several environmental problems which only geoscientists can solve, for they have the necessary geoscientific knowledge gathered over a period of years. Areas of special interest are: waste disposal, threat of natural hazards like floods, landslides, earthquakes, desertification, coastal erosion, etc.

How to improve the quality of life of our people should be the primary concern of present and future geoscientists. Geology, it should be emphasized, is a social science and not a laboratory oriented discipline. The whole earth is its laboratory and human welfare its goal. Playing down field work and glorifying laboratory-oriented research has been the root cause for the decline in pubic appreciation of the value of geologist's services.

Environmental considerations should not, however, come in the way of progress by putting obstacles in the development of resources aimed at improving the quality of life of the common people. A balance has to be struck between stepping up mineral production and preservation of environmental quality.

Quaternary studies

Processes which have operated on the earth, especially during the last 10,000 years (Holocene), need special study. Information on rates of erosion, sediment transport and accumulation in standing bodies of water, is lacking. Sediment cores from silted-up reservoirs offer the best material for study as they preserve a faithful record of environmental changes.

The Himalayan terrain, which is environmentally fragile, requires special attention on the part of earth scientists. The evidence afforded by river terraces and the distribution of plant and animal life point to uplift of the terrain even after the advent of man. Rivers have changed their courses, transforming fertile lands into deserts and *vice versa*. Deformation as a result of uplift and movement along faults has made the area particularly prone to landslides. Floods are causing enormous havoc almost every year. Earth scientists, through detailed field studies, should be in a position to develop prognostic capability, identify areas prone to natural hazards and forewarn the people. This is another field of research in earth science which should be undertaken on a priority basis.

Study of soils and soil forming processes

India has the largest accumulation of fertile black soils, specially in the States of Maharashtra, Madhya Pradesh, Karnataka and Andhra Pradesh. The role of parent rock and changing climatic conditions in soil formation has not been clearly understood. A clear understanding of processes leading to soil formation, reasons for degradation of soil and scope for regeneration and in-

creasing soil productivity, should form an important branch of earth science research.

More important than dating rocks formed thousands of million years ago is the dating of geologically young materials like soils. Information on the time required for soil formation is lacking at present. New techniques, using isotopes produced by cosmic radiation, being applied elsewhere to solving current problems can also be attempted here for better soil management and conservation.

Palaeontological studies

Palaeontology, the study of ancient forms of life, is at the very core of earth science studies. The main contribution of geology and its greatest triumph has been the decipherment of earth history during the past 600 million years. In spite of this enviable past record, palaeontology is today a neglected field of study.

The zonal classification of strata, using macro and micro fossils, ought to be a continuous process refining the stratigraphic record. Such studies of samples collected from off-shore wells and cores recovered from the ocean bottom and deep drilling projects have great practical importance in the exploration for hydrocarbons. Modern technological aids like electronic imaging system and electronic data bases have greatly enhanced the value of palaeontological studies. Palaeontology combined with seismic stratigraphy can be a powerful tool in providing chronological control. Major global environmental events can be recognized more precisely by the appearance and disappearance of organisms.

Geological Survey Organizations at State level and University Departments teaching earth science should take the initiative in organising natural history museums, with ancient life forms on display, kindling interest in the minds of children and the lay public. The success of *Jurassic Park* and the crowds of visitors attracted to view life-size, models of dinosaurs indicate the extent to which the public can be made to realize the importance of geology in understanding the history of the evolution of the earth and its inhabitants.

The foremost need of the hour is to do everything possible to increase productivity in our agricultural land and in our industrial establishments. The all-pervading bureaucracy should reorient its thinking and develop a helpful, instead of an obstructionist, attitude. The inferiority complex that is apparent in many of our young men should be replaced by confidence in our ability to develop our resources to our advantage.

My main object in drafting these notes is to focus attention on the need for geoscientists to bestir themselves and strive their utmost to increase their knowledge about land, mineral and water resources and be of service to the people. Societal obligations should gain precedence over purely professional recognition. Subsidies are not going to improve the living conditions of the rural poor but will kill all initiative and condemn them to live on perpetual doles. What is needed is employment opportunities and assurances of adequate income. This is possible only through development of land, mineral and water resources on a scientific basis.

The President of the Geological Society of America in his recent Presidential Address posed the question 'If geoscientists went on strike, would anybody notice?' Our geoscientists should likewise ask themselves – 'how relevant is my research to the needs of the country and the betterment of the people?' In the final analysis 'the support of the geologist depends on public appreciation of the value of his services'.

'Do you wish to be a patriot? – then tune yourself in love with your country and the people.' – Swamy Rama Tirtha.

B. P. Radhakrishna is in the Geological Society of India, P.B. 1922, Bangalore 560 019, India.

Academy initiative in university education

The Indian Academy of Sciences, as a part of its initiative in university education, has limited funds available to support:

- Short visits (4–8 weeks) by college/university students and teachers to Academy Fellows for joint work on specific projects.
- Short intensive lecture series by Fellows in colleges and universities.

Proposals are invited by the Education Panel of the Academy (R Narasimha, Chairman) for the above from college and university teachers and students. They should include a brief resume, a one page description of the proposed activity including its duration and tentative dates, and a letter of consent from the concerned Fellow, and should be mailed to: *Executive Secretary, Indian Academy of Sciences, PO Box 8005, C V Raman Avenue, Bangalore 560 080.*