Earth science scenario in India: A perspective*

During the past few years there were discussions in various national fora on the excellence and accountability of scientific research in our country. The members of the Programme Advisory Committee on Earth Sciences (PAC/ES) also have been discussing these issues among themselves and with their colleagues outside PAC. These discussions naturally focused on the research activities in the field of earth sciences. This write-up by and large summarizes these discussions along with a few comments on the quality and content of the earth-science research proposals received at the Department of Science and Technology (DST) and the general geoscientific environment in the country.

The views presented in this report are not exhaustive as the discussions were limited to PAC members and some of their colleagues; the views of earth science community in many national/state organizations and universities may not have been fully presented here. Nevertheless, we are of the opinion that this write-up should serve as a good document to initiate changes in our thinking and approach to earth science teaching and research in our country. The general feeling was that *a large fraction of our earth-science programmes lack modern interdisciplinary trends and still rely on classical approaches to study and research.* Many factors have contributed to the current state of earth science scenario and this report attempts to address them in some detail. The natural question after reading the report would be 'how do we implement the suggested (or other) remedial measures?' This is not an easy task, but a beginning must be made soon by the various funding agencies (State and Central Government Education Departments, DST, UGC, CSIR, Department of Environment, etc.) by sitting together and evolving a 'wholesome' implementation plan.

The earth science scenario can be viewed under the following headings:

(a) The quality and pattern of input in the universities and other organizations.
(b) The working environment of the earth scientists in professional and other organizations.
(c) The real output in terms of academic, economic and environmental results and discoveries.
(d) Suggestions for better growth of earth science, in turn, contributing to an increase in the academic and material wealth of the nation.

The most important entity controlling the quality of research is the researcher. The quality of researchers, in turn, is determined by the aptitude of students in the graduate/post-graduate levels and the teaching they receive. *Students naturally choose for their higher education disciplines which hold better promise for their future. Because of this it is often difficult to get good students for the earth-science stream, as this area offers less opportunity compared to engineering, medical and other professional courses.* Even average students can be made into good ones if the universities can sustain their interest through good courses, laboratory experiments and field work. *The teaching should be designed to broaden the outlook of students and to be inquisitive about nature and natural processes.* The main objective of education should be to foster spirit of enquiry and cultivate abilities of analysis, synthesis and correlation. Many universities today, unfortunately, are not able to cope with this basic requirement, as a result of which *we have a number of post-graduates with text-book information but lacking in research aptitude and scientific temperament. Many such inadequately trained post-graduates constitute a large percentage of present teachers and researchers striving to generate intellectual urge and capacity for new science through teaching and research activities in the earth science departments*, and in State and Central Government earth science organizations. As many of these teachers and researchers are not up-to-date on modern trends in earth sciences and recent developments in the topic of their own study, particularly at an international level, *they tend to teach from the books they learned without bringing the current excitement in the field.* As a result, the students and research workers who later become scientists end up as narrowly educated as their supervisors or teachers. This has put the earth science programmes in a vicious circle. *Despite this, pockets of excellence in research are growing in many national institutes, select IITs and university departments, partly because of the driving force of the individuals and partly because of competitions among fellow workers. This has resulted in a quantum change for better laboratory and instrumental facilities with the liberal attitude of funding agencies, particularly the DST.* At the same time we see a diversification in non-traditional fields of geoscientific enquiry, and scientists have become more conscious of the fact that their research is under scrutiny.

The inadequate training imparted to the students during their education and early research is also reflected in their subsequent research career. From the projects submitted for funding, it is often noticed that many of them lack the skill of defining their research problems. They have often given too general objectives of their research projects including routine field work and a variety of laboratory investigation (relying on outdated techniques) which could hardly be completed within the time schedule and projected manpower. Those better trained young scientists who come from select earth science departments of universities, the IITs and a few research laboratories have a good back-up of subjects/branches related to their research work, which is due to compulsory course work and seminar systems conducted by these institutions. But even such scientists tend to submit *project proposals which are of routine type, both in approach and data handling, to work in a new geographic area, to confirm some known results or to repeat some studies carried out elsewhere in the world.* Such exercise is good at the beginning of a research career but the *need to have new or innovative science component in their research proposals must be stressed. The scientists must strive to bring out*

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broader implications of their results, i e 'think global'.

Research environment

Earth science management and administrative machinery in India has made significant strides, and a formalized system is gradually emerging in which the UGC, CSIR and DST are playing significant roles. *The introduction of qualifying examinations by UGC-CSIR has ensured some degree of standardization in the selection of suitable candidates for research and teaching appointments DST has been instrumental in providing organizational and financial support to major projects and national colloquia, in chartering new areas of thrust and in monitoring the pulse rate of ongoing geoscientific research.* Furthermore, the environment of research in earth sciences has been activated by incentives for research, recognition and awards, promotion avenues and grant-in-aids.

Despite this, because of several factors we have not progressed as much as we should have One cause for this, as discussed earlier, *is the inadequate coaching in the formative years, lack of regular scientific discussions among colleagues* and among research groups engaged in similar studies. Better science can result if there is healthy competition among scientists and groups, both at national and international levels. Another cause is that *the importance of having high-quality research on topics of current interest is not brought out fully in many universities*, often they are indifferent to such needs. This is a difficult proposition, as good quality research needs good facilities in terms of equipment, library, appropriate man-power, etc. DST and other agencies are trying to cope with these requirements, but are unable to satisfy the needs at a national level. *These problems are compounded by the general monopolistic attitude amongst the research workers in regard to the use and maintenance of equipment Two problems are noticed, many scientists own the equipment, they do not share it with others The other is the lack of accountability Often the equipment under a research project is non-operational due to lack of infrastructural facilities, non-availability of trained technicians, absence of proper workshop and lack of know how by the users. Scientists must be made accountable for the proper running of the equipment they procure.* We need to evolve a national policy on the procurement, maintenance and use of sophisticated equipment.

Another major hurdle in increasing our awareness is the *inadequate library facilities and complicated method of procuring scientific journals* from one laboratory to another in our country. As a result, *scientists lose much time in getting access to relevant scientific literature and gradually lose track of modern research in their working fields of specialization It is this inaccessibility of scientific literature that adversely affects both research and teaching in our educational institutions.*

We need to recognize our priorities of research (thrust areas), outstanding group of researchers, and to specify areas of possible national and international collaborations. *Recent major geoscientific research programmes are multi-disciplinary, and, often collaborative research among scientists with complementary expertise.* But it was observed that many of the submitted projects to DST lacked such approach, even though the investigators were aware that similar research was being carried out in other organizations. We also strongly feel that *better understanding of the problems and processes needs inputs from several allied disciplines and therefore as and when needed multidisciplinary approach should be encouraged.*

Output

The scientists must be made fully accountable for the support they receive from the funding agencies. The project should yield good quality results within the stipulated time Many funding agencies attempt to monitor the progress of research projects by getting yearly progress reports and by oral presentation of the research progress. In many cases it was found that the programmes were running behind schedule because of difficulties in procurement and installation of equipment and man-power recruitment. In a few cases, the *investigators were involved in many projects (sometimes in projects of closely allied themes funded by different agencies) making it difficult for them to devote sufficient time for completing the project in stipulated time.* Regarding some of the high-budget earth-science projects there was concern that their results were not commensurate with the expenditure, time and effort.[1] Possible causes can be the acceptance of high-cost foreign technology and/or data from foreign laboratories in collaborative programmes, without critically assessing their adaptability to our needs. What was therefore planned as a catalytic input often failed to energize our programmes.

We have to recognize some output indicators to assess the efficacies of the research programmes in our country vis-a-vis similar works from advanced countries. *The funding agencies must urge the scientists to publish their final results in well reputed and widely circulated journals. The science citation index for earth sciences is below the average SCI of western countries. This may have many reasons, but suggests the need to improve the publication record of Indian earth scientists in high impact journals* It was also observed that in some cases results of the research work done during the project period remained as a final report to the funding agency and are yet to be published.

Man-power in earth sciences is mainly generated from two IITs, the Indian School of Mines, Dhanbad, 40 universities and a score of post-graduate colleges offering courses in geology/geophysics/applied geology. UGC is playing a constructive role to strengthen research in the university system by way of its Special Assistance Programme and COSIST Programme in the universities and institutions of higher learning on a highly selective basis with a view to achieving high-quality performance in research and post-graduate teaching. Eight departments in earth sciences have so far been identified and supported under the COSIST programme.

The total pool of scientists engaged in earth science faculties of the universities, central and state research institutes, GSI, ONGC (exploration) and organizations with its R&D section, is certainly above 5,000. If we assume that at least 1% of the manpower is brilliant and engaged in productive and original research, we should get 50 major research projects maturing every three years in earth science. Our earth science scenario in this aspect is rather not so promising as we should expect in this era of technological development.

The earth scientists must have their accountability of research and professional efficiency so that we can develop multidisciplinary centres, a team of

research workers at different levels of scientific work and a well-knit industrial relationship

We give below some suggestions and recommendations for a better scientific scenario in our country.

Suggestions and recommendations

In order to keep pace with trends in S&T research and development to have a better scope for Indian scientists to compete with their contemporaries elsewhere in the advancing world, we need a wholesome change in our attitude, approach and implementation of earth science research.

(i) Earth science is continuously evolving into a quantitative multidisciplinary science. It is not an isolated compartment, but is strongly interlinked with physical sciences and mathematics especially statistical methods and mathematical modelling. Hence *the foremost need is to incorporate mathematical and quantitative methods of interpretation in the earth science curriculum* at the appropriate level.

(ii) The challenging and fascinating facets of earth sciences are not known to most of students when they come out of the schools at the +2 stage. *It is possibly the only subject that is not taught in any detail at school level. Therefore, to attract bright students into the earth sciences stream, this aberration needs to be rectified immediately by introducing a well-framed curriculum on earth sciences, at least at the +2 stage of the school.*

(iii) *The syllabus at the undergraduate and post-graduate levels of studies needs to be drastically pruned and re-oriented, keeping in mind that earth science is a multidisciplinary subject where substantial input from physical and biological sciences and mathematics is essential.* Unfortunately these subjects are neglected in the earth science curriculum or taught as subsidiary subjects at the under-graduate level. It is strongly felt that the course contents of these so-called subsidiary subjects be pruned and restructured, keeping in view their needs in earth sciences and all these subjects after necessary re-orientation, should be introduced (preferably at an advanced level) as part of the honours course. It will be a signal service towards the uplifting of standards for teaching and research in earth sciences in India.

(iv) *Acceptance of M Sc students into research should be after a rigorous scrutiny of their research aptitude, despite their qualifying the UGC/CSIR examinations* As far as possible, student intake at post-graduate level should be restricted and only those with research aptitude and scientific temperament should be encouraged for post-graduate studies.

(v) *Curriculum offered at the post-graduate level* also needs to be re-oriented accordingly The courses could be general or specialized keeping in mind the country's needs and priorities. *During the period of M Sc. research the students must be trained for field work, instrumentation, interpretation of data, presentation of seminars, and discussion of published papers that have a bearing on their research problem.* They should also be encouraged to take up summer projects in well-equipped scientific institutions so that they *become familiar with modern techniques in earth sciences.* Post-graduation should indeed be a stepping stone for a research career.

(vi) *Field work forms an essential component of earth sciences* and unfortunately this is the most neglected aspect in India. Many colleges/universities in .India offer degrees in earth sciences without conducting rigorous field work at the under-graduate/post-graduate level. This shortcoming must be rectified immediately and *the field-work component in the earth science curriculum must be rigorously enforced.* Colleges/universities, which offer degree in earth science with or without minimal field work, should be asked to take corrective measures.

(vii) Whilst the present-day research involves *use of computers, we must train our students of earth science in its applications Universities must seriously consider having a compulsory course on computer applications at the under-graduate level.* The ability to make use of computers in research of earth sciences should be an additional qualification for a well-trained student and it would help him in his research work later in his life. Software on data processing in earth science investigations should be stored at NIC, which could be made available to other researchers, in most places of the country. *Advanced training may be arranged for research students and senior earth scientists to get acquainted with modern technologies, particularly on computer-aided data processing in geological science.*

(viii) Another important aspect is to *encourage students and researchers to keep abreast of major scientific and technological advances in allied fields* Results of research in other branches of sciences and techniques applied in those fields often lead to methods and techniques which can be applied in earth sciences. Such trans-application of results and techniques of research from one branch of science to another leads to advancement by quantum jumps.

(ix) We have discussed the qualifications of students, their course and field work. Another critical factor influencing the *research aptitude* of students is the quality of teaching and laboratory work at all levels, particularly in the graduate/post-graduate levels. While the government has been laying emphasis on funding to improve the quality of research through agencies like DST, UGC, CSIR, etc. *an equal emphasis coupled with matching financial support has not been given to teaching.* While there is an admission test prescribed by UGC and CSIR for research students having M Sc. degree in earth sciences, *there is no such formal test applied to the teachers of the subject of the universities* It is acknowledged that implementation of any such tests could be a formidable task and will be resisted by most of the universities and colleges, it is felt that it is not impossible to identify good teachers in different subjects/topics in earth sciences in some of the universities/institutes in the country. (It would be a good idea to have their lectures videotaped and distributed amongst various departments) We must realize now than later that teachers in our higher-level institutions may have to work in a pattern similar to that existing now in developed countries, where the teaching personnel have to be actively involved in research and keep abreast of developments in the field. They should be urged to develop laboratory facilities from mainly research funding.

(x) Another major hurdle in our earth sciences research is the inadequacy of modern instrumentation facilities in the country. Today in earth sciences, like in any other fields of science, technology is the key to do competitive research at international level. Many of these technologies and instruments are expensive and need to be imported and hence are available only with few research centres and universities. *A policy for the use of sophisticated/costly equipment should be evolved to enhance their routine use. There should be proper maintenance and upkeep of laboratory/field equipment and they should be frequently shared with other scientists to maximize their utility.* Training of students and/or technicians is essential in high technology analytical techniques. It would be desirable to run on regular basis programmes of training in the use of sophisticated equipment – particularly related to geochemistry and geochronology – by the institutions which have requisite expertise and facilities.

The investigators should ensure that the equipment procured under the project are fully operational and that they are in routine use. They should also encourage maximum utilization of the various equipment.

DST and/or other national agencies may consider publishing an information booklet on the facilities available for earth sciences research in various institutes/universities and research centres in the country. This information should be disseminated widely and a system worked out so that this can be updated periodically.

(xi) *Access to current literature is* essential for keeping abreast on the progress in the field. The prohibitive cost of books and journals make it difficult for universities/institutions to procure them. Therefore there must be a *national network to library facilities It is suggested that the earth scientists should individually avail of the 'Current Awareness Service' and 'Retrospective Search Scheme' (for references of topics of interest) of the National Centre for Science Information, Indian Institute of Science, Bangalore 560 012, and the departmental libraries should subscribe to the COPSAT Service Scheme of the Bangalore NCSI or the INFLIBNET Programme of the UGC, near Gujarat University Guest House, Post Box No 4116, Navrangpura, Ahmedabad 380 009 for abstracts of papers published in journals of repute (at least 25 journals)*

(xii) It is desirable to develop our own standards for geochemical analyses, and sets of reference material. The Wadia Institute of Himalayan Geology, the Physical Research Laboratory and the National Geophysical Research Institute can take up this onerous task.

(xiii) For a better scientific environment it is necessary that our earth scientists are self-critical and accountable. If all of us have a critical self-assessment, cultivate openness and accept our strengths and weaknesses, it would go a long way in establishing better scientific environment and temperament and help in scientific growth in the country. *The scientists must be fully accountable to the projects they have been funded and they should strive to complete them in the stipulated time-frame.* It is also the responsibility of the scientists to *ensure publication of their final results in refereed national/international journals.*

(xiv) We are convinced that paucity of reasonable funds from the *funding agencies* like DST, CSIR, UGC, etc., is not likely to be a major constraint in the progress of earth sciences research in our country. However, they *must be very selective in funding proposals.* The proposals must be reviewed by experts in the field, if necessary from outside the country. Projects which have well-defined goals and appropriate techniques to carry out the work in stipulated time should be encouraged. They should also *look for proposals from groups of scientists with complimentary expertise as such projects are likely to make more impact and advancement in earth sciences.* Research projects which are generally applications of known techniques on new sets of data or new location is unlikely to make much impact in the international circle of earth science research.

The funding agencies should *encourage open discussions among earth scientists on issues relating to the priorities of research,* a co-ordinated programme for their implementation and a better dissemination of the results. But it is the initiative of the individual scientist which would seek scientific collaborations with government organisations, research laboratories and universities. Without a close interaction and exchange of views and research material as well as discussion on field and laboratory data and theoretical aspects, we cannot do modern science. We feel that a rationale between sharing of facilities and establishment of interdisciplinary centres would allow good science to develop in our country. It may be pointed out that the basic infrastructure facilities are now available in the country for carrying out research in frontline areas, particularly those which are unique to the geological history of the Indian landmass; it is for us to take full advantage of this.

It must be emphasized that no society without competent scientists can cope with the ecological, engineering, medical or social challenges that a burgeoning human population and warming climate are going to throw at it. Indian earth scientists have reached a situation where mineral finds on the surface have become scarce and not a single major economic mineral discovery in the eighties has come about. Earth scientists will have to probe deeper into the earth's crust, integrating geophysical, geochemical and petrological tools to meet the mineral and energy demands. This would require a rigorous understanding of plate tectonics *vis-á-vis* mineralization and heat-flow regimes. Posterity demands that we leave behind good traditions of scientific workings to be continued as a better earth science scenario in our country.