# CORRESPONDENCE

## RADICAL RESTRUCTURING OF EARTH-SCIENCE EDUCATION

*Introduction*

Enough has been said of the ills and inadequacies of earth-science education and research in India. Lamenting over what has already happend would be an exercise in futility. Time has come for making a departure from the beaten paths and for adopting non-nonconformist approach by making radical changes. The principal objective of education today is to prepare students for meeting growing ambitions and expectations of the fast upward-moving society – preparing them not for life-time careers but for avocation that our nation on the threshold of material advancement constrains and calls for at the present juncture of history. Since the interests, needs and ambitions of a nation on the march "change every five to ten years, there is no alternative to the continuing education in earth-science education" (Hsu, 1997)

*Achieving Social Relevence*

Achieving greater relevance to the new interests and needs of the society must be the primary aim of the continuing earth-science education. It has to be responsive to the needs of the people (Radhakrishna, 1995, 1996). In other words, the earth-science students must be equipped with the knowledge of and trained in the techniques/practices of tackling problems our society faces and wants to be solved. This calls for "moving our emphasis away from the traditional topics to the ones which have application" (Ernst, 1997) – to the application measures for "improving community life and thus making a geologist a caring and community-serving person" (Cooray, 1998). The researchers, likewise, should endeavour for answering questions which the people are asking and not expending energy "in trying to answer questions which nobody is asking (Radhakrishna, 1996). "There is nothing great in imitating the West, in indulging in aimless and costly research having no relevance to the concern of the Indian society"(Radhakrishna, 1997). Unless the earth-science is socialized – rendered a science with a strong component of social welfare – it will lose all its worth and become redundant.

*Questions the Society is Posing to Earth Scientists*

Among the myriads of questions people are posing, the folowing are directed at earth scientists:

1. Is there any option anywhere in the country for making use of the land in accordance with its capability – in consonance with the carrying capacity of its ecosystem? What is the nature of the soil that supports vegetation and permits construction of civil and other structures? Is the ground stable enough to withstand the stress of intended uses? What factors are operating that cause deterioration of and damage to land? What can be done to control degradation and erosion of land?

2. Where are underground reserves of water located and what is the quality (and quantity) of the entrapped water? What could be the most efficient and inexpensive ways of tapping this underground asset? How to replenish the groundwater reservoirs in the plains and recharge springs in the mountains? How are surface and ground waters getting polluted? Have the geologists any strategy aimed at combating water pollution?

3. Which areas or belts are unsafe from quickened earth processes manifesting as natural hazards? What would be the nature/character and intensity of the disaster when it occurs? What

human activities can promote and/or trigger hazardous phenomena? What can be done to prevent the recurrence of natural hazards and minimize the severity of disasters?

4. Where should one look for mineral deposits? What are the reliable, quick, and cost-effective methods of exploring mineral deposits? What new techniques can be applied to find the extension of known deposits of minerals, oil, gas and water? What innovative approaches could be resorted to for mining natural assets but with minium damage to the environment and loss of the reserves? What engineering and biotechnological measurers are available to ensure miners' safety and for the conservation of reserves?

5. What geological-geophysical conditions favour harnessing of flowing water without impairing the environment? Is the place chosen for a power plant, a building, a dam, a bridge, an airfield or a seaport safe from natural hazards? Is the road alignment cutting through the zones of weakened rocks, spring lines and active tectonism? Is the foundation-ground of the proposed structure strong enough to bear the load and endure stress changes?

6. Where can solid and liquid wastes that our explosively growing population generates be dumped or disposed of without causing adverse impact on the hydrological regime and atmospheric circulation?

7. How has climate changed through geological time, and where would the prevailing trends lead to? What measures can the earth scientists suggest to overcome the problem of global climate warming and the advance of arid frontier?

***Integration of Geology, Geophysics and Geography***

The questions raised above can be best answered and addressed satisfactorily if the practitioners of the sciences of geology, geophysics, geodesy, physical geography and mining geology combine their efforts and integrate their techniques and practices. The need of the time is a fusion of all disciplines of earth science. This calls for having just only one subject -- the *Earth Science* without pieces or divisions and compartmentalization -- and to be pursued by *Earth Scientists*. In other words, I am making a plea for the merger of existing departments of geology, geophysics, physical geography or geomorphology, and oceanography and the formation of an integrated *Department of Earth Science*. This earth science would accommodate changing and expanding body of knowledge, and form the firm foundation of environmental science. It is imperative that the study courses comprise of two parts: (1): modelling powerful tools for the appraisal of natural resources and the understanding of nature's processes through quantitative analysis combined with assessment with reference to observation; and (2): learning methodologies/techniques that are not only efficient and cost-effective but also environment-friendly (Valdiya, 1987).

Since Indians have never learnt from their own past history, they are unlikely to learn from what happened millions and billions of years ago. They may perhaps be encouraged to develop interest in what happened – or rather what went wrong during the last 10,000 years of the Holocene. In other words, the emphasis of study of geological history should shift to and be focused on the Quaternary period.

While geology, geophysics, physical geography or geomorpholoy, oceanography, geodesy, mining, engineering geology be amalgamated and integrated as one subject -- the *Earth Sciences* at the post-graduate level, the *curriculum to be pursued at the B.Sc. level* should encompass the following:

(i) Structure of the earth and nature and characteristics of its interior and crust (elementary geophysics).

(ii) Landform development, drainage pattern and landscape reshaping, bathymetry and submarine features (geomorphology).

(iii) Soil and rocks and their constituents and fundamentals of major and trace-element geochemistry (mineralogy, crystallography and petrology).
(iv) Earth resources, their mode of occurrence, origin and evaluation (economic geology).
(v) Evolution of plains, plateaus and mountains (structural geology and tectonics).
(vi) History of life in seas and on lands (palaeontology, palaeobotany, stratigraphy).
(vii) Ecosystem structure and ecology and their study through air photos and satellite imageries.

There is need to be flexible at the post-graduate level. The *M.Sc level curriculum* would include three parts, A, B and C.

(A) 1. Foundation courses on (a) mathematical-statistical geology (b) computer programming, including Geographical/Geological Information System (GIS) and (c) photogeology and remote sensing.
2. Physics of the earth, embracing-physical fields, plate tectonics, seismology in the context of earth's structure and composition, geophysical surveying techniques, crustal movements and position-fixing techniques (GPS).
3. Land classification, terrain assessment and landuse planning
4. Hydrological cycle, prospecting for groundwater, recharge of groundwater, conservation and management of surface water and groundwater.
5. Natural hazards, hazard-zonation and measures for coping with disasters.
6. Exploration and prospecting of earth resources, inland and offshore mining methods, sampling techniques and ore-reserve calculation, well-logging, mineral beneficiation, mineral economics, laws of terrestrial and submarine mining.
7. Geotechnics and engineering geoscience including project site selection.
8. Waste disposal, pollution abatement and alternative sources of energy.
9. Palaeobiology, palaeoecology, palaeoclimate and palaeogeography

(B) *Ground-Truth Data Acquisition* entailing comprehensive training and independent endeavour in mapping in the field (at least one month in a year). It will be desirable to ensure compulsory draft of students for training camps run by the Geological Survey of India, Oil and Natural Gas Corporation and other mining concerns. These organizations should be in a position to offer free training and provide month-long stipend to the trainees.

(C) *Project Assignment* to be allotted towards the end of the first year on the topic of the choice of the student. One learns more as an apprentice or trainee – as one who fumbles, gropes and struggles – than by sitting passively in lecture halls or prepares for examinations. The students can be persuaded and be provided with opportunities of interacting with scientists of national laboratories of the DST, CSIR, NRSA, DOEn, etc. In other words there must be summer schools in these institutions for earth-science students, as very successfully conducted by my institution, Jawaharlal Nehru Centre.

### *Role of Earth Scientist in Society*

The earth scientist plays a crucially important role in understanding, preserving, ameliorating and restoring natural environment and nature's wealth stored in rocks. He has the comprehension of the dynamics and mechanism of the various earth processes that not only give rise to mineral deposits, form diverse soil types, permit movement of surface- and underground waters, but also shape terrain morphology and fashion landscapes. The knowledge of the character and capabilities of the terrain (including the conditions of soils and their stability) permits scientifically sound and ecologically appropriate use of land for maximum benefit with minimum damage.

As a student of hydrogeology he explores the ground to provide the society with the life-supporting water of requisite quality in adequate quantity. Knowing the problems related to the underground water-distribution and flow, and the sickness of water-logged soil, the hydrogeologist suggests remedial measures and techniques for augmenting supply of water on the surface as well as underground. In the management of mineral resources the earth scientist in the garb of economic geologist helps the society by ensuring a predictable and plentiful supply of minerals, which constitute the foundation of all industry. Not only does he identify locations of deposits and suggests methodologies of extraction without harm to the environment, but also suggests ways and means of conserving non-renewable, fast depleting resources.

As a practitioner of engineering geoscience and geotechnics, the earth scientist provides insight into ground conditions, their stability and capability to bear loads and stresses, and identifies sites suitable for buildings, roads, bridges, dams and utility structures. He is thus an active but critical participant in all programmes of development without destruction. He has also to determine the factors that influence the safety and stability of structures constructed by man. The knowledge of the dynamics of earth processes equips the earth scientist well to evaluate the hazard potential of an area, and plan strategies for mitigating risks to life and property.

The disposal of wastes and pollutants is another area in which the geologist is competent to provide guidance in selecting sites which could not create problems of poisoning the soils and polluting the waters. He is required to know and explain causes of climate changes in the past and their future implication. Earth science is thus an integrated application of science for the benefit of man and his living and inanimate world.

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