A PARADIGM FOR GEOSCIENCE INSTRUCTION IN THE DEVELOPING COUNTRIES IN THE TWENTY-FIRST CENTURY

Introduction *:* The realm of geoscience is exceedingly vast—it encompasses studies as diverse as the 100 km high, blue-tinted, sulphurous plume that has been emitted on June 28, '96 by Ra Patera volcano on Jupiter's mo *lo*, to locating and digging a water well in an arid, hard-rock area in Rayalaseema in Andhra Pradesh, India. It does not follow, however, that the study of *lo* volcanism is inherently superior intellectually to the study of groundwater, or that they are mutually exclusive. Under the circumstances, a country or an institution has to identify as to which part of the geoscience knowledge spectrum serves their interests best and is *affordable,* and hence needs to be focussed upon, and which part could constitute the background. There are Geology Departments in USA which are almost wholly devoted to planetary studies; it is jokingly said that they do not keep a hammer as they do not have to break a rock! At the other end of the spectrum, there are community colleges where one can acquire a specific skill (*e.g.* groundwater exploration) as a "cook-book" recipe. There is much merit in the flexibility that this a *la carte* model implies. 73 Large, Developing countries like India and China which have a few hundred universities, can determine which 73 institution should concentrate on which part of the geoscience knowledge spectrum. In the case of small, low-income Developing countries (like those of Sub-Saharan Africa) which have just one or two universities, the focus has necessarily to be on water, soil and mineral (specially, non-metallic minerals) resources (plus marine resources, in the case of littoral countries). Since individual countries cannot afford the whole range of modern facilities, regional institutions, like SADC and ASEAN, should operate regional laboratory and training facilities to make good the deficiencies.

Any paradigm for geoscience instruction in the twenty-first century has to be based on three crucial considerations: (i) Development is going to be increasingly information-driven, with knowledge as the cutting edge, (ii) Geoscience instruction has to be addressed to ecologically-sustainable, economically-viable and people-participatory management of natural resources (waters, soils, sediments, rocks, biota, *etc.*), and (iii) The global trend of liberalisation of economies would mean that employment opportunities in the State sector will be minimal, with private enterprise and self-employment becoming the principal avenues of employment. This has a corollary–the training of a geologist will have to include sociological skills for interacting with individuals and communities, and economic skills for making cost-benefit analysis. Each of these considerations has its own logic, in terms of what kind of geoscience needs to be taught, with which cognate subjects should it be linked, what tools would be needed to implement this approach, and how to assess the performance of students, *etc.* The biggest challenge facing geoscience community is how to integrate these approaches into a *coherent* and *affordable* plan of action, by using technology innovatively. In sum, we will have to identify the destination and provide a road map for how to get there.

Earth System Science : In the Earth System Science, we make an integrated study of how, under the influence of the solar energy, the interactions between the sub-systems of the Earth, namely, the atmosphere, solid earth, hydrosphere and biosphere, produce the world we see around us (there is going to be an international conference on the subject, in Hawaii, USA, July 28 - August 1, 1997). While the use of the Earth System Approach in teaching earth science is relevant globally, it is desperately important to do so in the case of the Developing countries. The undergraduate curricula in geology in universities in most Developing countries are patterned after the *then-existing* systems of education of the colonial powers. The route for upward mobility in the formal sector came to be identified with the passing of examinations based on this style of academic education, which happens to be irrelevant to the urgent needs of the people, namely, food, water, energy and habitation. If earth science has to discharge its social and intellectual responsibilities to the community, it must necessarily address these life-and-death issues. This cannot be accomplished if the earth science is taught, as is done now, as pieces of compartmentalised pure science represented by the traditional branches, such as petrology, mineralogy, stratigraphy, 73 *etc*. The extremely limited resources available to the earth 73 science departments in the Third World countries do not allow them the luxury of curiosity-driven quest for pure knowledge. Instead, they should opt for instruction through more mundane, practical approaches, for which geological science is admirably suited.

An end-use oriented scheme of geological education with the following attributes, is proposed: (i) geology needs to be taught as an earth-system science, by strengthening the mathematics, physics and chemistry, *etc*. prerequisites, by making geology, geophysics and geochemistry co-terminous, and by linking it with cognate subjects like Agriculture, Land-use, Meteorology and Oceanography, (ii) Through the instrumentality of the management of soil, water and mineral resources, geological knowledge and skills are put to use to grow more food with better nutrient content, provide water for drinking, irrigation and other purposes, provide energy for domestic use and improve the habitation of the people - and all these in ways which will bring about ecologically and economically viable, sustainable development. A candidate learns a subject and develops a skill by doing.

Philosophical basis of the proposed system of instruction

The National Research Council-National Science Foundation of USA has recently brought out a 262-page document entitled "National Science Education Standards" (*Eos*, American Geophysical Union, Sept. 17, 1996, summarises and comments on the document.). The document recommends that instruction in any kind of science should include "unifying concepts", which constitute the fundamental content of science, and on which all other concepts are built: "system, order and organization; evidence, models and explanation; constancy, change and measurement; evolution and equilibrium; and form and function." Students need to be helped to acquire *knowledge, with understanding*. Rote memorization should be replaced by interactive learning, involving self-directed enquiry and problem-solving. Multiple choice and fill-in the blank questions which are the staples of the examination exercise, should be replaced by student-directed inquiry, analytical report and essays. Geoscience education should be transformed from the absorption of mass of data, to training how to gather information from the field, and make sense of the data. In sum, geoscience education should be a "hands-on" and "minds-on" activity.

Role of PC as a training tool

The PC (Personal Computer) is going to be the centre-piece in the proposed process of interactive learning. A computer can store, analyse, display and retrieve a vast mass of data and analog information. It is continuously upgradable. It can provide us instant access to the 73 global knowledge pool. Most importantly, it is affordable, and 73 the computer prices keep going down. It will be with the help of the PC that the Developing countries would be able to take the "quantum jump" in the case of geological instruction. In the old days, skill in mathematics used to be considered synonymous with ability to handle big numbers. The pocket calculator changed that. Now, with the help of a calculator, even a child can handle big numbers. The emphasis in mathematics is now on mathematical logic. Whether it is a good thing to happen or not, is no longer germane to the issue. It has happened, and it is irreversible. In the same manner, it will be unnecessary in future for a geology student to memorize (and be tested for his knowledge of) the stratigraphic sequences, geological vocabulary, mineral formulae, descriptions of petrography, crystal and fossil morphology, etc. All this information can easily be preloaded into the computer hard disk. Most text books are less than 2 MB in extent, and PC's with 1000 MB hard disk are now-a-days routine. An enormous variety of software* is available for almost any kind of mineralogical-geological application, such as calculation of norms, geological cross-sections, subsurface profiles, X-ray identification of minerals, three-dimensional displays of structural elements, contouring, data plotting, *etc*. These no longer constitute skills which need to be learned laboriously and memorised. These jobs are done not only fast, but also accurately and inexpensively. The text, including maps, diagrams and sketches, can be printed in colour.

One may think that a system as sophisticated as this, is bound to be expensive, *but it is not.* A desktop computer with 1.2 GB (1200 MB) hard disk, costs as little as $1300. A network station, including CD (Compact Disk) drive, bubble-jet colour printer, etc. is available for less than US $ 2000. An institution needs to buy the proprietary software only once, and then it can be copied onto other PC's.

It is said that humans and chimpanzees have about 98.4% of the same genes. In other words, the profound difference between chimpanzees and ourselves is based on just 1.6% of genes. We know that no two brothers are alike in all respects - it is possible that difference between siblings may be attributable to just 0.1% of genes. For the first time in the history of the teaching process, the computer has made it possible to mimic nature, and customise instruction and examination individually. It is perfectly possible to prepare individual (say, twenty) exercises (with the same broad format, but with different numbers and analog information) and question papers. Copying is just not possible under the set-up, because no two question papers are alike!

PC as a monitoring tool

The applications of information technology through the instrumentality of a PC could be illustrated with an example.

The demand for good quality irrigation water is far in excess of the supply. It has hence become desperately important to use water optimally. Any system of efficient use of water in irrigation has to take into account the complexity of the variables in regard to soil, water, climate, crop and people, and it has to be compatible with other inputs such as seed varieties, fertilizers, tillage, pest control *etc*. Advances in information technology have made it possible to optimize the various system variables. Efficiency of water delivery needs to be optimised in terms of conveyance of water with minimal losses (say, in closed conduits), capability to provide measured amounts of water calibrated to meet the needs of crops in time and space, while preventing wastage, salinity and rise in water-table. Efficiency of water utilization is to be optimized to low-volume, low-pressure, high-frequency, partial-area irrigation to achieve high crop yields. Computers ensure the delivery of the precise requirements of irrigation and nutrients to crop plants, as sensed by satellites in a pixel area (of about 25 m^2) in the context of a particular weather setting. Thanks to the availability of inexpensive PC's, groups of small farmers in Developing countries should be able to avail of this approach, where the irrigation source is decentralized and compact, and is directly under their control.

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* Analy Series is a Macintosh computer program which has graphical and interactive tools that can perform a variety of time-series analyses, such as stratigraphic correlation of sedimentary rocks, age-model development, *etc*. This software can be obtained *free of charge* from Didier Paillard at the following e-mail address : <paillar@asterix.saclay.cea.fr>

PC as a database tool

It should not be forgotten that a mine, a watershed, or a farm keep on getting modified depending upon the way they are utilized. Just as a hospital maintains clinical records of a patient to determine further treatment, a geologist has to keep track of the parameters relating to the concerned entities. This is best done with the help of the PC.

Curriculum development

The curriculum will reflect the kind of employment opportunities that are going to arise, and the knowledge and skills that would be needed to get employed. The programme will be strongly focussed on *water, soil and mineral resources* (plus marine resources, where relevant). It will emphasize field learning, and interaction with the local communities. It will make use simple field equipment (geological-Brunton compass, hammer, hand lens, toposheet, geological map, airphoto or space image, soil augers, etc; portable geochemical kits for the *in situ* analysis of waters and soils; portable geophysical equipment for measuring the depth of the soil, and water-table, *etc.*)

Acquisition of knowledge and skills are the core components of any instructional process. As already stated, the PC will be the centre-piece of interactive learning. A candidate will make use of the PC not only 73 for the analysis of the field and laboratory data acquired by him, 73 but also for the analysis of simulated data. Most departments cannot afford modern analytical equipment, such as ICP-MS (inductively Coupled Plasma-Mass Spectrometer), but a candidate can do the next best thing - he can learn to process simulated results arising from such an instrument (hands-on skills on specific instruments could be acquired later, where needed or possible).

A possible structure of the course (a four-year, B.Tech. programme, with entry based on an IIT-type entrance examination ?) is given below:

Yr. I: Two semesters: Prerequisite custom-made courses in Mathematics, Physics, Chemistry, Biology, Sociology, Economics, Engineering, *etc.* (Field training for six weeks).

Yr. II: Semester 1 : Linkage courses in Geomorphology, Agriculture, Meteorology, Land-use, *etc.* custom-made in the context of the local biophysical situation; *Semester 2*: Environmental Monitoring, Environmental Impact Assessment, Environmental Economics, Environmental Law, Sustainable development (field training for six weeks).

Yr. III: Two Semesters : Natural Resources Management–waters, soils, sediments, rocks, biota, *etc.*, their dynamics and linkages, and optimising their productivity use. This will constitute the core of the instruction. *Semester 1:* Waters and soils; *Semester 2:* Rocks, sediments, biota, *etc.* (training for six weeks attached to appropriate institution).

Yr. IV: Semester 1 : will be devoted to specialised supplementary courses/skills needed for pursuing the dissertation topic (which has been identified in Yr. III); *Semester 2* : Dissertation.

The structure of the programme is only *indicative*. It can be adjusted, time-wise and course-wise, to suit a given academic situation. The programme can be so structured that if an institution so wishes, they could provide for the majoring of a candidate in one of the four themes; Geoenvironment, Bioenvironment, Environmental Technology, and Environment and Development.

Prognosis

"Progress is a nice word. But change is its motivator, and change has its enemies"

- Robert Kennedy.

The author dose not underestimate the horrendous difficulties involved in realising the vision presented in the paper. Concerned institutions, such as UGC, DST, GSI, *etc* should come together to identify the destination, and come up with a road map of how to get there. 73 As a practical measure, a beginning could be made by initiating 73 one or two new entities with this kind of approach (say, Nagpur University in cooperation with NEERI/Indian School of Mines, Dhanbad/Indian Institute of Science, Bangalore), test the practicability of various approaches, and then replicate the process. A decade of hard work will be needed to formulate the course content, develop new teaching methods, write new textbooks, prepare instructional materials, train the teachers in the new methodology, develop new examination systems, *etc.* The question is not whether we can afford not to do this. "Business-as-usual" approach will have catastrophic consequences; the graduates will not be able to find employment as their learning has no relevance to the needs of the situation, and, India will be left behind in the knowledge race.

In his own humble way, the author has attempted to contribute to this campaign by writing a book to cover a possible course, "Geochemistry in Soil Resources Management" (complete with exercise), on the basis of the philosophy spelt out above. The book is expected to appear in print shortly.

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WORKSHOP ON "INTEGRATED MINERAL EXPLORATION PROGRAMME IN GOA – A VISION", 6TH DECEMBER, 1996, PANAJI, GOA, INDIA

The revised geological map of Goa on the scale 1:125,000 published by the Geological Survey of India was released by Dr.S.K.Acharya, Director-General, Geological Survey of India at a function held at Panaji, on the 6th December, 1996. The map incorporates the updated data collected during the special thematic mapping (STM) carried out by GSI between 1987 to 1994. The STM has clearly brought out the basement-cover relationship between the older Peninsular Gneissic Complex and the overlying supracrustals, *viz.*, Dharwar Supergroup marked by orthoquartzite. The mapping has also brought out a number of younger ultramafic bodies as at Usgaon, Londa and Aven.

As an adjunct to the release of the geological map, a one day Workshop, co-sponsored by Geological Survey of India, the Government of Goa, Goa Mineral Ore Exporters Association and the Goa Mining Association, was also held on the theme "Integrated Mineral Exploration programme in Goa - A vision". Seven papers were presented at the Workshop covering various aspects of mineral exploration in Goa, past, present and the new emerging horizons, environmental impacts of mining and sustained mineral Exploration.

The geological map of Goa is available for sale at Rs.150/- per copy.

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