relative immunity to post-crystallization disturbances (sulphide inclusions in olivines are shielded by the host mineral) make this method suitable[14]. Studies, using this isotope system, on xenoliths from a number of cratons (Kaapvaal, Siberia, Wyoming, Slave and Tanzania) have shown how the crust and mantle parts of stable continental lithospheric roots have remained coupled since formation in Archaean, despite continental drift[15,16]. In the Cordilleran Mountain Belt also, Re–Os studies have confirmed that the age of the xenoliths was same as the crust above. In this context, it may be mentioned that during the break-up of Gondwanaland and separation of India from Australia–Antarctica, cratonic roots of India may have been disrupted during drift. This is inferred from osmium isotopic studies of xenoliths of Proterozoic age, from Kerguelen Island (southern India Ocean)[17]. These xenoliths distinctly belong to the continental lithosphere, caught up in the newly forming oceanic lithosphere.

The stability of some of the continental crusts, undoubtedly, appears to be controlled by density, the depleted mantle intrinsically less dense than the fertile mantle, due to loss of iron extracted during melting. If cooling by conduction leads to the lithospheric mantle thickening further, its deepest parts will be forced to sink into the mantle because of their low buoyancy[18]. The degree of depletion, which regulates the thickness, thus creates a thermal boundary layer between the deep convecting mantle and the crust, thereby reducing or eliminating convection-related tectonic instability at the surface. Only those Archaean crusts that developed a strong, thick, high viscosity, thermal and less-dense boundary layer achieved ability to resist tectonic forces[10]. Stabilization of nuclear Archaean cratons in the interval 2.8–2.0 Ga period possibly marked the earliest phase of formation of thick lithospheric root zones conferring long-term stability. The observed geological stability of some of the Archaean cratonic areas in India may, therefore, be attributed to their 200–300 km deep[5,6] lithospheric roots. It is possible that these areas may be lying over depleted lithospheric mantle, though there is presently no Re–Os isotopic data on mantle xenoliths of Archaean–Proterozoic age from these areas to substantiate this inference.

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COMMENTARY

On the state of physics in India – Personal viewpoint

S. Dattagupta

Today we are in the 55th year of independence, and if we look back, in 1947, we hardly had any semblance of what may be called organized physics. The geniuses of our country, such as J. C. Bose, M. N. Saha, C. V. Raman, S. N. Bose, K. S. Krishnan and others, achieved great heights, essentially through individual efforts. But, today's world is different. In order to make progress, one needs collective, cooperative approaches backed by effective infrastructural support.

If we analyse all that has happened in organized physics in India in the last 54 years, we realize that we have come a long way. We have different ministries such as the Ministry of Atomic Energy and Space, the Ministry of Science and Technology, the Ministry of Human Resource Development, the Ministry of Planning, etc. looking over physics. Under these ministries, we have different organizations such as the Bhabha Atomic Research Centre, the Indian Space Research Organization, the Tata Institute of Fundamental Research and a plethora of other institutions, busy in carrying out research and development activities. In the city of Kolkata itself, we have several research institutes, supported by one ministry or another, such as the Saha Institute of Nuclear Physics and the Variable Energy Cyclotron Centre of the Department of Atomic Energy, the S.N. Bose National Centre, the Jagadish Bose Institute and the Indian Association for the Cultivation of Science of the Department of Science and Technology, the Institute of Chemical Biology, the Central Glass and Ceramic Research Institute of the Council of Scientific and Industrial Research, etc. All these institutes have excellent facilities, comparable to the best in the world. So, why is it that we are unable to produce Sahas, Ramans or Boses today? I will try to give my reasons for it.

If we consider the success stories in physics, especially in the Western world, we would quickly realize that most of the breakthroughs have come from university settings, in which the professors have had a very interactive and engaging relationship with a vigorous bunch of students. Research has been carried out in conjunction with teaching, as these two aspects of creative endeavour are intimately intertwined. In our country, however, we have kept teaching divorced from research, by building research institutes *outside* the university system. Thus the institutes have been kept deprived of young, inquisitive minds, joining the curriculum year after year, whereas the universities have been devoid of talents in its teaching faculty and been allowed to languish due to political interferences.

The second reason that we have not seen world-class contributions emanating from our physics community is that physics is essentially an experimental science. It is all about understanding and explaining natural phenomena. Although we have got excellent facilities in our laboratories, what we need is matching infrastructure, in terms of uninterrupted power and water supplies, sample preparation facilities, dust-free, clean environments, etc.

A third related point, and one that may not be universally acceptable, is what I consider the technology spin-offs for basic research. If we look at the American scene in particular, there is this continual synergy between technology on the one hand, and basic physics on the other – technology leads to spurt in basic physics, while research in basic physics yields technology. Examples are superconductivity, lasers, nanomaterials, etc. We have not had that kind of symbiosis in our country.

My final point, and it is one that I have made earlier, is that physics is no longer an individual exercise – it flourishes only through collective, cooperative, teamwork. I think, temperamentally we Indians lack this team spirit.

Against this background, I want to mention now what we are doing in a limited, local manner to improve the situation. In order to bring together research institutes, universities and colleges together, we have created a society called SRISTY (Society for Research and Instruction in Science and Technology) involving among others the S.N. Bose National Centre, the Saha Institute, the Bose Institute, the Indian Association for the Cultivation of Science. One of the tangible, concrete examples of this synergy has been the launching of a new post B Sc – Integrated Ph D programme – from 16 August this year. In this programme, we have admitted students who have a B Sc degree and put them through a completely residential teaching programme in a research ambience. Students, in addition to doing course work, will have concomitant opportunities of accessing facilities extant in our national laboratories. Teachers, in this course, are also brought from a consortium of colleges, universities and institutes, in order to optimally use our resources. Under SRISTY we are now thinking of creating a Science Centre to train higher secondary and undergraduate students.

I now turn my attention to another issue – there is a discernible despondency amongst our youth about career opportunity in basic science in general, and physics, in particular. Coming as it does amidst ‘globalization’ which has opened up tremendous job opportunities elsewhere, especially in the computer-related areas, this has caused a severe decline of interest in students opting for physics. While economic reasons are certainly a causative factor, I think the dwindling standard of university teaching, as I have alluded to before, is equally responsible for creating this situation.

Physics has to be a creative enterprise, to be pursued with passion and once that is realized by our youth, it is bound to be an enjoyable profession indeed. What is significant is that our profession becomes almost like our hobby. And I feel that there is no dearth of career opportunities in physics, even in our country. It is being increasingly realized worldwide that physics-trained students are readily geared to solving important problems for technology and industry, be it in the realm of finite element analysis in mechanical engineering or computational electromagnetics in radar technology and oil industry or even DNA engineering in biotechnology. I refer to the April 2001 issue of *Physics Today*, which discusses the upbeat scene of physics-related career opportunities in USA.

In conclusion, I want to express my personal views on the danger of moving away from basic science and gravitating towards what is variously called Information Technology. I return once again to what I mentioned at the outset, and that is about the situation prevailing at the time we became an independent nation. We were a colonized nation and as a result, denied opportunities to strengthen our traditional base of mathematics and astronomy. Now, think about it for a moment. We have assiduously built up our organizational infrastructure of science, but now we are faced with another colonized state of affairs. Because, after all, if we disregard the base of science and try to leapfrog into software industry, we will only be feeding the industrial complexes of the West. Those of us who have seen the recent movie *Lagaan* would do well to remember the true meaning of independence – we must beat ‘them’ in their own game, be it cricket or science. Only when we create our own niche areas in which we are strong in our own right, will we be able to earn respect as an independent country in the comity of nations.

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