## COMMENTARY

# Fire of the dragon, roar of the tiger? Opportunities for Indian palaeontology

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Indian scientists have recently expressed concerns about the future of academic geology in India. The long-term decline in facilities and field training has been widely noted, and some have dismissed geology as an outdated science. The President of the Geological Society of India has ably defended the value of geology both as an applied and a natural science, pointing out the varied ways in which the discipline contributes directly to human welfare. Here I suggest ways in which a renaissance in Indian paleontology, a sub-discipline within geology, might be achieved modelled on the current international success of Chinese palaeontology. I argue that China provides an appropriate subject for comparison with Indian palaeontology, just as for economics. My qualifications are those of a professional geologist who has worked on Himalayan stratigraphy and palaeontology in India, China and Bhutan for the last fifteen years. My motivation is the expectation that highly significant discoveries can be made within India that will bring credit to the country at relatively low cost. I suggest that prudent management of Indian palaeontology will likely bring India greater return than investment in many other areas of science.

Geology departments in many institutions in China are thriving. Within the last five years the salaries for productive academic geologists have seen major increases, and government research funding for palaeontology, surely the most 'traditional' area of geology is currently 40 million yuan ($5 million) per year. This reflects the variety of truly outstanding fossil localities in China that have recently been identified and exploited, yielding an astonishing array of fossils ranging from Precambrian embryos to feathered dinosaurs. Hardly a month goes by without more spectacular Chinese fossils appearing in the pages of the world's two most prestigious scientific publications – *Nature* and *Science*. China is the frequent host of major international conferences in geology, and its scientists are often funded to travel to international meetings or spend periods abroad working in research labs. A professional position in geology is an attractive prospect, encouraging the brightest young people to give the profession serious consideration. The result of this is that China is now recognized throughout the globe as a leading nation in palaeontology. For a country keen to attain international front rank in science, investing seriously in palaeontology makes good sense: it builds on the unique strengths of the natural resources of the country and is extremely cost effective. Without the high technology equipment required by almost every other science, a relatively modest investment in palaeontology can go a long way.

How has China, a country that until about twenty five years ago had temporarily ceased almost all scholarly activity, achieved this miraculous turnaround? The key ingredient has been the recent discovery of localities bearing truly exceptional fossils. China's initial geological surveys were completed only in the 1990's and so its riches have only recently been exposed. Furthermore, much of the exposed rock in China is Phanerozoic in age, and such rocks commonly bear abundant fossils. China is also an amalgam of many different continental fragments, each with a potentially different set of rocks and fossils. All these factors combine to make China unusually fortunate in its fossils.

The situation in India is different. Most of India is a large mass of ancient cratonic rock with fossil-bearing sedimentary rocks draped over it in odd corners, buried in deep basins, or squeezed into the Himalaya. Hence, the area of exposed fossil-bearing rock in India is significantly smaller than in China. Also, the subcontinent was largely mapped geologically by the start of the last century and so many of its important fossil resources have been known for a long time. These differences notwithstanding, they cannot fully explain the huge disparity in palaeontological research within the two countries. Like most large countries, India has many important fossil resources. And just because the Siwalik mammal fauna, the *Pentoxylon* flora, the Madhya Pradesh microvertebrates, the Spiti ammonoids, the Kutch Jurassic, and the Vindhyan sequence were discovered many years ago does not mean that their potential has been fully exploited. The Burgess Shale of British Columbia has been known to yield Cambrian fossils with soft parts preserved in exquisite detail for a hundred years but the full significance of these fossils was not realized until recently. New collections have provided profound new perspectives on the evolution of biological diversity that have served as a direct stimulus for the Cambrian soft-bodied research in China. These have ultimately yielded the Chinese Chengjiang fossils of even greater importance. Furthermore, despite the excellence of many of the early geologists of India, their perspectives and objectives were different from those of modern times. The radical revision of the stratigraphy of the Lesser Himalaya realized by Indian geologists in the last twenty years provides a clear example of this, by taking a sequence once considered Mesozoic and showing that it contains the Proterozoic – Cambrian boundary interval. The bottom line is numerous important fossils localities already known from India require additional study, and many more await discovery.

Quality and novelty of fossils per se have been essential prerequisites for the Chinese revolution in palaeontology, but these have not been the only factors. Of key potential interest is the way in which China has managed the exploitation of these resources. In my view the following have been critical to this success:

1. China has invested prudently in a wide range of basic sciences where it can make significant impact.
2. The great majority of the most significant finds have been reported by research teams consisting of both Chinese and foreign scientists, and have been published in journals with wide international distribution and prestige.
3. Chinese scientists are expected to become internationally recognized authorities on special topics, and receive the financial and logistic support necessary to do so.

4. Concentration of specialists in a relatively small number of key institutions with adequate library and technical facilities along with sufficient on-going funding.
5. A competitive promotion system that rewards research success.
6. The support of several different groups of scientists working independently on similar problems, fostering active competition and scientific debate.
7. Strong emphasis of field-based and specimen-based science.
8. A willingness to explore beyond the 'classic' fossil localities in order to discover new sites, and the confidence to question the interpretations of previous scientists.
9. Extensive use of internet to facilitate fast international collaborations and exchanges.

Indian palaeontology offers some hopeful signs with respect to this list. Financial resources for palaeontological research are available in India, although I am told that the application procedures are daunting to some researchers. Palaeontology has traditionally been strong in some Indian university departments and India has established research institutes with departments specifically dedicated to stratigraphic geology. These could be rejuvenated. The print quality of Indian publications has improved markedly in recent years making evaluation of reports much easier. The internet also offers the possibility of wider ease of access to international literature and specialists, one of the major hamstrings for geologists working in India. Also, in related areas such as sedimentology, papers are commonly written with international collaborators. With these encouraging signs, what additional steps would be required for India to realize the potential of its fossils and achieve comparable success?

Other than the quality of the fossils themselves, the single greatest factor that has propelled Chinese palaeontology to international prominence has not only been the publication of research reports in leading international journals including the 'weeklies' such as *Nature* and *Science*, but also in high profile specialist journals such as *Palaeontology* and the *Journal of Paleontology*. The two principal advantages of this are international publicity and credibility. Achieving this has required collaborating with foreign specialists that provide expertise both in palaeontology and in the mechanics of publishing in such journals. As experience grows some Chinese palaeontologists have begun to publish such papers independently of foreign collaborators, and increasingly Chinese authors are publishing on material from outside their country. The acceptance of Chinese papers in the world's best science publications serves as primarily the standard by which the Chinese government assesses the success of its scientists. Expectations are high, and performance is rewarded. At the same time, more foreign authors are contributing to such Chinese journals as the *Acta Palaeontologica Sinica*, which has improved in print quality, shortened the time that papers are in press, and relies increasingly on an international slate of reviewers.

China has also recognized that sufficient investment is necessary for its scientists to become leading international authorities. It allows its best palaeontologists to become specialists in specific topic areas, rather than requiring them to change disciplines when they are promoted. Talented Chinese palaeontologists have the resources to travel to institutions abroad to consult and, critically, to acquire scientific literature that can be brought home. A good library is essential to all palaeontological work, but building one is a fraction of the cost required for any significant analytical machine, and a library does not breakdown. If India were to choose a few areas of palaeontology for investment, send younger scientists abroad for significant periods of training, and provide resources and incentives on their return, this might go a long way toward fostering comparable success.

A further important aspect of China's success has been the recognition that science progresses best when there is active, constructive debate among its practitioners. At least three major research programmes in institutions within China are studying the Chengjiang fauna. These groups, each with independent sets of foreign collaborators, frequently clash in their interpretations. Despite occasional rough spots, this competition is healthy, fueling further research and keeping interest vital.

What if a similar situation pertained in India? There is every reason to expect that the results would be similarly beneficial, and perhaps have an even wider range of impact. For example, the Himalaya is surely the pride of Indian geology, attracting scores of geologists from all over the world. Papers on the subject commonly occur in the world's leading weekly and specialist science journals. But a glance over lists of references quoted in these papers reveals a striking discordance. It is almost as if there are two geological literatures: an Indian one and a foreign one, with authors of papers in one literature seldom quoting the papers of the other. Most of the highest profile work on Himalayan geology involves approaches that require expensive analytical equipment used to analyze samples collected in the field. It is commonly difficult for Indian scientists to be competitive in this work, largely concentrated in the areas of geochemistry and geophysics, unless they have access to expensive laboratory facilities often through foreign collaborations. But it is becoming clear that geochemical and geophysical methods will not resolve Himalayan geology alone. Models derived from geochemistry or geophysics must be tested with reference to stratigraphic data, and such approaches can yield radically different results. Here Indian stratigraphic geologists have a great advantage. Few foreign scientists have the time available for the extended field visits needed to become fully familiar with the basic geology of the region (although there are notable exceptions). With prudent investment there is the potential for India to use its advantages of innate talent, proximity to unique geological resources, and cost-effectiveness of supporting a significant number of stratigraphic geologists in the field and lab, to define the next generation of factual and theoretical approaches to the geology of its greatest treasure. Hence, opportunities exist for Indian geologists to use stratigraphic geology as an independent test of geochemically-based models, but also to collaborate with those using such approaches to provide integrated solutions to the challenges of Himalayan geology. The key to realizing this potential will be to do as China has done: open up its palaeontology, provide opportunities for its brightest young scientists, and then demand the best of them.

In his majestic poem 'Pritibi', Rabindranath wrote 'You abandon your creations without regret; strew them layer upon layer, forgotten'. Perhaps the time has now come for us to rediscover them.

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