A tale of two eras: Notes on Himalayan geology

Rasoul B. Sorkhabi

The past two decades have witnessed an unprecedented interest among international geological community in the Himalayas. This is partly due to the emergence of the plate tectonic theory that has recognized the Himalaya as a type example of continent-to-continent collisional orogen, and partly because foreign geologists are now allowed to visit many sectors of the once Forbidden Lands of the Himalaya, the Karakoram, and Tibet.

India opened Ladakh to the outsiders in 1974. This ushered in many studies of the Indus–Tsangpo Suture Zone, which represents the initial plate boundary between India and Asia. The Chinese opened Tibet in 1979, and the Academia Sinica organized the Symposium on Qinhai–Xizang (Tibet) Plateau in Beijing in 1980. Since then, collaborative projects have been carried out by Chinese, French, British and American scientists, and their results have been published in several issues of *Nature*. In 1980, the International Karakoram Project was organized by the Royal Geographical Society in the Hunza Valley of Pakistan. Since the Karakoram Highway was opened to tourists in 1986, many geologists have conducted research in the Pakistan Himalaya and the Karakoram. Since 1985, a series of international Himalaya–Karakoram–Tibet workshops have been held in Europe[1].

Despite these modern ventures, Himalayan geology is not a new field of study. It dates back to the first half of the 19th century, when the British began to explore the Indian subcontinent. The Trigonometric Survey of India commenced in 1800, and the East India Company employed geologists for mapping and expeditions. There were also individual naturalists who explored the mountains of south-central Asia. Himalayan geology is not a foreign monopoly, either. Over the past four decades, much work has been done by native geologists in the Himalayan countries. Unfortunately, in the present boom of internationalized Himalayan geology, adequate attention is not given to the classical works or native contributions.

In this article I communicate some of my impressions and notes during a trip to north India in October–November 1995 to attend two Himalayan geology meetings and field excursions, and to visit New Delhi, Roorkee, Dehra Dun and Calcutta, which are among the important centres of geological research in the country. Through these meetings, conferences and tours, I briefly analyse several significant issues in Himalayan geology, both as a science and as a scientific activity.

A passage to Calcutta

A trip to Calcutta is also a trip through the history of modern geoscience in Asia. Calcutta, which was the capital of British India from 1833 to 1912, mirrors the development of the British Empire and her Utilitarian Sciences in the 19th century, of which geology held a top position[2].

Moorhouse[3] has observed that 'almost everything popularly associated with Calcutta is highly unpleasant and sometimes very nasty indeed'. Dominique Lapierre's *The City of Joy* (1985) is typical of this one-sided image about Calcutta: overpopulation, refugees, slums, poverty, disease and pollution. However, Calcutta is a major intellectual centre in Asia and houses many historical monuments, most of which are of interest to geologists; e.g. the Asiatic Society of Bengal, founded in 1784 by Sir William Jones as a research centre for Indology; the Indian Museum (1814), displaying one of the largest collection in Asia; the Presidency College (1817), the first European college in India, where also geology was first taught; the Geological Survey of India (1851), one of the World's oldest national geological surveys; and the University of Calcutta (1857), India's first university.

The Geological Survey of India (GSI) was initially set up for two main purposes: Firstly, mapping and survey work. During the 19th century, Russia, China and Britain were trying to gain control over the strategic lands of the High Asia, and the major tools of this Great Game (so-called by Rudyard Kipling) were exploration and expansion of geopolitical frontiers.

Secondly, finding mineral resources, especially coal that was needed for the development of the great Indian railway system. Indeed, the very idea for the establishment of the GSI came from the Coal Committee of Bengal in 1841, when the Committee approached Charles Lyell and Roderick Murchison, leading geologists of Britain, to persuade the East India Company set up a permanent professional survey to develop India's coal resources[2].

Geoscience in India, however, proved to be more than simply utilitarian. Studies in the Indian peninsula and the Himalaya contributed some of the most fundamental concepts in physical and historical geology. For example, although Henry Medlicott's study of what he called 'Gondwana System' in Satpura in 1872 was meant to explore the coal seams, his observations led to the discovery of the former supercontinent Gondwanaland when similar sedimentary formations and fossil flora were found in Africa, Madagascar and Australia. Another textbook example is the theory of isostacy (although the term 'isostacy' was coined by Charles Dutton in 1893), which was formulated in two different (but complementary) ways by George Airy, Astronomer Royal of England, and John Pratt, Archdeacon of Calcutta, in 1855 based on the results of the Great Trigonometric Survey of India led by George Everest.

Thomas Oldham, once a professor of geology in Dublin, was the first Superintendent of the GSI. From Oldham to the last British Director of the GSI, W. D. West[4] (who died in 1994), there is a time span of one century. During this time, the GSI served as a hub for geological exploration in south-central Asia and produced some of the finest geological research published in its *Memoirs* and *Records*. Unfortunately it seems that these classical publications, which constitute the foundation of our geological knowledge of a vast region of the planet, are not preserved by modern technologies (e.g. microfiches and computer storage systems). Old copies are fragile and decay over time. They need to be reprinted, which can also make these valuable publications readily available to thousands of Himalayan geologists both in the Himalayan countries and around the world.

Geological events that have produced the Himalaya are not confined to the mountains. More than 500 million people (10 per cent of world population) living in Pakistan through north India to Bangladesh depend on the fertile soil and fresh water resources supplied by the Himalaya. As I was traveling from Calcutta to New Delhi, I thought of how the Himalaya have risen higher partly because the depositional basins of Indus–Ganga–Brahmaputra have become deeper (due to flexural isostacy). An integrated Himalayan geology should consider both these provinces as a unified dynamic system not only geophysically but also socio-environmentally, and try to offer solutions to some of the environmental problems (from hydropower dams to deforestation and soil erosion) arising from the interactions between highland and lowland communities. The Himalayan region constitutes a natural laboratory not only for continental tectonics but also for environmental geology[5].

Restless abode of Gods

From New Delhi to Roorkee is only a four-hour drive. It is, however, a great jump in geological time from the Proterozoic rocks of the Indian shield to late Cenozoic sediments shed from the rising Himalaya.

Roorkee is little known to foreign visitors. My travel guidebook, *Fodor's India* (1993), does not even mention it. The town has, however, significance for geologists. The University of Roorkee, which houses one of the most prestigious geology departments in the country, was established as Thomson College in 1847. (It was given a university status in 1949). Henry Medlicott taught geology at Roorkee in 1854. An interesting site in Roorkee is the Ganga Canal, engineered by Captain Proby Cautley in the 1830s in order to get water out of Ganga into a vast area in the present Uttar Pradesh, which often suffered from famine. It was during the construction of the Ganga Canal in the Hardwar hills that vertebrate fossils in the Siwalik sandstones were first discovered. (They were called the Siwalik Group after the hills dedicated to Lord Shiva.) These fossils were studied by the palaeontologist Hugh Falconer, who ascribed a Miocene age for them. This was the first and still a most reliable evidence for the uplift age of the Himalaya.

The Group Meeting on Seismotectonics and Geodynamics of the Himalaya was held at the Department of Earth Sciences in Roorkee from 12 to 14 October 1995. It was organized by Dr A. K. Jain and sponsored by the Department of Science and Technology, New Delhi. It was perhaps the largest geological conference ever held at Roorkee. Over 80 oral presentations were given, out of which selected, refereed papers will be published as a *Memoir of the Geological Society of India*. The inaugural lecture was given by V. C. Thakur, Director of the Wadia Institute of Himalayan Geology, Dehra Dun. He presented an interesting report of his geological observations during the Silk Route Expedition to central Asia in 1994. Almost all aspects of Himalayan geoscience were covered at the Roorkee Meeting: Seismotectonics of Garhwal–Kumaun Himalaya; Metamorphism; Gravity and Himalayan tectonics; Seismotectonics of the Himalaya and adjoining regions; Magmatism; Deformation; Main Central Thrust; Tectonics of foreland basins; Neotectonics; Intraplate seismicity and palaeoseismicity; and Archean–Proterozoic evolution.

The main focus of the meeting was on seismotectonics. The 1991 Uttarkashi earthquake and the 1993 Latur earthquake have aptly intensified seismotectonic studies in the country. ('Response to crisis policy' is not, however, confined to India.) Especially motivating is the idea that a seismic gap of 650 years exists in the central sectors of the Himalaya[6,7]. The Central Gap is a very populous region for nearly 800 km long, and if hit by an earthquake of $M\,8$ or greater it would be very disastrous for the nation. A very important result of the Roorkee meeting, in my view, was that geologists and geophysicists came forward not as historical rivals but as concerned scientists to present their data and exchange ideas. This is a healthy approach, and needs to be encouraged in future conferences.

The meeting was followed by a five-day field excursion to the Bhagirathi Valley (upper Ganga) in the Garhwal Himalaya. A bus full of geoscientists travelled from Roorkee through Uttarkashi in the Lesser Himalaya as far north as Gangotri, lying in the midst of lofty granite summits in the High Himalaya. On the way, we visited Tehri, where the Indian government is constructing a large hydropower dam, despite concerns from some scientists. Tehri lies within the Central Gap. The 1991 Uttarkashi earthquake ($M\,7$) killed 1000, injured seven times more, and caused much destruction. Surprisingly, however, it left the nearby Tehri dam site undamaged, thus boosting technological optimism. The problem of large dams is not unique to the Himalaya. However, with frequent earthquakes having shallow focii (< 25 km) and resulting from all kinds of active faults, the issue has been magnified in the Himalaya[8] and rightly so. One solution that has been suggested is the construction of several small dams instead of a few large ones. But in the end, the issue seems to be more political than scientific.

The Garhwal Himalaya was one of the earliest sectors of the Himalaya to be explored by geologists in the 19th century. Captain Richard Stachey's work in 1851 laid foundation for other explorations. Garhwal is also where the Main Central Thrust (MCT) was first mapped by the Swiss geologist Augusto Gansser in 1936. The MCT is a large intracontinental rupture bringing the metamorphic core of the High Himalaya over the Proterozoic sediments and low-grade metasediments of the Lesser Himalaya. This thrust has played a major role in shaping the Himalaya. However, its tectonic nature along the strike of the Himalaya has been controversial. These and many other issues were discussed in the field trip, thanks partly to the inquiring mind of R. S. Sharma of Banaras Hindu University. Geological mapping over the past two decades has shown that the MCT in Garhwal is a duplex structure with two[9] or three[10] thrust planes, probably joining at depth to a main décollement of the Indian crust. The upper (roof) thrust, the Vaikrita Thrust, has a steeply dipping surficial plane and is actually a crush zone frequently visited by landslides. The lowest thrust, the Munsiari Thrust some 15 km to the south, juxtaposes rocks of low-grade metamorphism and slight internal deformation, and corresponds to the MCT originally mapped by Gansser.

Extensional tectonics in compressional orogens has drawn much attention over the past 15 years. In the Himalaya, the contact between the High Himalayan crystalline rocks and its sedimentary cover (the Tethys Himalaya) has been mapped as a detachment fault and interpreted as a gravitational collapse structure coeval with the intense activity of the MCT during Early Miocene[11,12]. A. K. Jain argues that this scenario masks the complexities observed in the Himalaya as extensional structures are not confined to a single basement-cover detachment but are distributed throughout the orogen. In Garhwal, we did observe S–C fabrics with top-to-south sense of shear in several zones of high strain in the Higher Himalayan metamorphic rocks. We also observed brittle normal faults even in the MCT zone. These extensional structures have resulted from rapid compressional uplift of the orogen. Jain also criticizes the gravitational collapse models, which estimate some 20 km of displacement along the detachment. He argues that such large displacements would have produced half-grabens parallel to the detachment and filled with post-collapse deposits (as has happened in the Basin-and-Range in Arizona).

Jain and his colleagues[13] model views extensional structures as integral components of compressional deformation and also offers a new approach toward solving the long-standing puzzle of the inverted metamorphism in the Himalaya. He and his colleagues argue that ductile shear displacements along ubiquitous, closely spaced S–C shear planes have caused inversion of metamorphic isograds across a 20-km-thick, south-vergent, Higher Himalayan crystalline belt. A main problem with this model is that the S–C shear fabrics are not distributed everywhere across the metamorphic pile, but seem to be limited to zones of higher strain. However, if it can be demonstrated by detailed mapping that the exposed boundaries of metamorphic zones are loci of such higher strain, we will be close toward solving the Himalayan puzzle, first pointed out by Richard Oldham in Kumaun in 1883.

Tethys in focus

Dehra Dun was the last station in the Great Trigonometric Survey of India. After the Survey work in Dehra Dun was completed in 1841, George Everest could retire with satisfaction. If Tsukuba is the Science City of Japan, Dehra Dun may be called India's Science City (although Bangalore also comes to my mind in this regard) as it houses several important research institutions, such as the Wadia Institute of Himalayan Geology (WIHG), established by D. N. Wadia in 1968. Since 1970, WIHG has held conferences on the geology of the Himalaya, and their proceedings have been published in *Himalayan Geology* volumes.

The Symposium on the Tethys of the Himalaya and Adjoining Regions, held at Dehra Dun from 15 to 17 November 1995, was the eighteenth conference in the series. It was organized by A. K. Sinha and N. K. Mathur, and inaugurated by S. P. Nautiyal, former President of WIHG. The symposium was well-organized and informative, with 49 oral and 29 poster presentations in six sessions: Regional tectonics and deformation; Palaeontology and stratigraphy; Sedimentology and basin evolution; Geomorphology and environment; Geophysical aspects; and Magmatism and metamorphism. The symposium proceedings will be published in a future volume of *Himalayan Geology*.

Papers covering the theme of Tethys in the symposium used it in three contexts. It is important to define them precisely.

(i) 'Tethys Ocean' as a Mesozoic oceanic basin between Gondwanaland and Angaraland, was originally proposed by the Austrian geologist Eduard Suess in 1893. This concept stemmed from correlations of Mesozoic marine strata and fauna studied independently in the Himalaya and in Europe[14]. In the Himalaya, field mapping and fossil collections made by Richard Strachey and Ferdinand Stoliczka were valuable contributions that led to the concept of Tethys. In the past, some geologists (mostly those who were 'fixists' and opposed to the continental drift hypothesis) viewed Tethys as only a shallow, narrow epicontinental sea or geosyncline. I am afraid such outdated views are still held by some Himalayan geologists.

(ii) Tethys Himalaya is a term coined by John Auden[15] in 1937. It was formerly known as the Tibetan Himalaya. This zone encompasses largely fossiliferous sediments from Cambrian through Middle Eocene deposited on the passive continental margin of India, and is now exposed between the Indus–Tsangpo Suture Zone to the north and the High Himalayan crystalline complex to the south. I think Auden's definition should be honoured, and as far as possible, the basal metamorphic rocks should be included in the Higher Himalayan Crystalline Zone, not in the Tethys Himalaya.

(iii) Tethyan tectonics is concerned with the evolution of the orogens spanning from the Alps through Turkey and Iran to the Himalaya and Tibet. They have resulted from the closure of Tethys, drift of the continental fragments of Gondwanaland and their final collision with Eurasia. The Swiss geologist Emile Argand first formulated Tethyan tectonics in 1922, reconciling Suess' ideas of Tethys and Gondwanaland with Alfred Wegener's hypothesis of continental drift[14]. As I discussed at the Symposium, over the past 25 years, many of Argand's views have been incorporated into the plate tectonic theory with or without acknowledgement. Interestingly, the Symposium on Tethys held in 1995 coincided with the 55th anniversary of Argand's death. A major post-Argand development has been the discovery of at least two Tethyan basins (Paleo-Tethys and Neo-Tethys) and buildup of Asia by the accretion of Gondwanaland fragments to Siberia over the past 500 million years.

A tale of two eras

Himalayan geology began in India, and geology in India is a tale of two eras: British Raj and Independent India. Himalayan geology has now become truly international. Native voices are abundant. Although only two foreigners attended each of the conferences (R. S. Yeats and myself in Roorkee, and M. Gaetani and myself in Dehra Dun), more than 100 Indian geologists attended each meeting.

As discussed above, geological studies in India and the Himalaya have contributed some fundamental concepts to geology, such as isostacy, Tethys and Gondwanaland. These potentials are still there. If students of Asian geology try to develop concepts derived from their own observations and data (rather than merely applying the geological interpretations originated in other continents), greater contributions will be made.

Community organization, professional cooperation and flow of information are some of the major factors in the progress Himalayan geology (or any other scientific discipline, for that matter), both at national level and global level. India has one of the largest geologist communities in the world. Expectations are therefore high. Collaboration between universities and research institutions, such as WIHG, can solve some of the instrumentation and information (journals) problems facing universities as well as strengthen human resources at research institutions. On a global scale, perhaps the time is ripe to establish an International Society of Himalayan Geoscientists (or whatever name it may be given) because the British heritage and native developments in Himalayan geology are now parts of a new era in our science – one that is global.

1. Sorkhabi, R. B., *Curr. Sci.*, 1995, **69**, 489–490.
2. Stafford, R. A., *J. Imperial Commonwealth Hist.*, 1984, **12**, 5–32.
3. Moorhouse, G., *Calcutta*, Harcourt Brace Jovanovich, New York, 1971.
4. Radhakrishna, B. P., *Curr. Sci.*, 1995, **68**, 98–100.
5. Sorkhabi, R. B., *Prof. Geologist*, 1994, **31**, 4–7.
6. Khattri, K. N. and Tyagi, A. K., *Tectonophysics*, 1983, **96**, 281–297.
7. Bilham, R., *Curr. Sci.*, 1995, **69**, 101–128.
8. Valdiya, K. S., *Curr. Sci.*, 1992, **63**, 289–296.
9. Valdiya, K. S., *Tectonophysics*, 1980, **66**, 323–348.
10. Bahuguna, V. K. and Saklani, P. S., *J. Geol. Soc. India*, 1988, **31**, 197–209.
11. Burg, J.-P. *et al.*, *J. Struct. Geol.*, 1984, **6**, 535–542.
12. Burchfiel, B. C. *et al.*, *The South-Tibetan Detachment System, Himalayan Orogen*, Geol. Soc. Am. Sp. Paper 269, Boulder, Colorado, 1992.
13. Jain, A. K. and Manickavasagam, R. M., *Geology*, 1993, **21**, 407–410.
14. Sorkhabi, R. B., *Curr. Sci.*, 1995, **68**, 853–858.
15. Auden, J. B., *Rec. Geol. Surv. India*, 1937, **71**, 407–433.

ACKNOWLEDGEMENTS. My sincere thanks to numerous friends, colleagues and teachers for their efforts in organizing the meetings discussed here and for their kind hospitality, especially, A. K. Jain, R. M. Manickavasagam, Sandeep Singh, H. Sinvhal, V. C. Thakur, A. K. Sinha, N. S. Mathur, Talat Ahmad, Rotash Kumar, S. K. Ghosh, Nand Lal, Neptune Srimal, D. M. Banarjee, S. K. Tandoon, P. K. Verma and C. S. Dubey.

Rasoul B. Sorkhabi is in the Department of Geology, Arizona State University, Tempe, AZ 85287-1404, USA.

The role and responsibility of a scientist in the Indian context*

Rajaram Nityananda

One can try and define the role and responsibility of a scientist in many ways. The approach here is to try and describe the kind of scientific community we would like to build up in the Indian context. The views that I will be expressing are based on my own first-hand experience and observations as well as discussions over the years with friends and colleagues. It goes without saying that a different person would express different views. My own overall perspective is based on the idea that it is a privilege to be involved in scientific research. The feeling that we are being supported by others in our efforts to answer questions about the universe has been expressed in the following words with which a world-famous textbook on gravitation (*Gravitation* by Misner, C. W., Thorne, K. S. and Wheeler, J. A., Freeman, 1973) begins:

'We dedicate this book
To our fellow citizens
Who, for love of truth
Take from their own wants
By taxes and gifts
And now and then send forth
One of themselves'

Indeed, every Indian scientist has been sent forth on his research career by contributions from people whose own basic needs have not been met. This is very much like a poor family saving to educate one of their members. It is therefore natural to ask ourselves what society gets in return. Frankly I do not think that the direct results of research provide the complete answer. At its best, a community of scientists can also act as the custodian of information, knowledge, understanding and skills all of which have to be preserved, improved and passed on to posterity. This was dramatically illustrated in China some time ago when the entire system of learning and research was dismantled in the name of the cultural revolution. It then had to be painfully built up again. One consequence of this role is that scientists as a body have to be deeply concerned with what happens in schools, colleges and universities and must try to help, even though there are well-known constraints and difficulties.

Another significant potential role is to act as an example of the spirit of healthy skepticism, systematic inquiry, and logical debate. Perhaps this is what some people have called the scientific temper. More importantly, in my opinion, scientific achievements on our soil contribute to a sense of motivation, self-confidence and self-reliance that is as important to a nation as it is to an individual. We have all witnessed this in the world of sport. Whenever Kapil Dev or Gavaskar is in his heyday every little boy in the street with a ball or a bat walks a little taller. As a negative example we have our Institutes of Technology where I have personally witnessed bright young students being brought up in an atmosphere of cynicism and self-depreciation concerning science or for that matter anything else in our country. Little wonder that these institutes essentially function as tutorial colleges feeding American universities.†

*This is the text of a talk given over All India Radio on a subject suggested by them in 1991. It was not a response to any single event or issue but simply to the challenge of collecting thoughts on a subject which, though important, one had not considered before in a systematic way.

†This first hand experience is 25 years old.