Earth science, earthquakes and aftershocks

The earthquake that rocked Gujarat on 26 January 2001, was a sharp and apocalyptic reminder of the immense destructive power of natural disasters. Even as seismologists differed on the precise magnitude of the earthquake and rescue teams worked through the rubble to locate survivors and bodies, public discussion brought to the fore the inadequacy of our preparedness to face sudden emergencies and the ineffectiveness of our hazard-mitigation strategies. But, as public consciousness of the disaster slowly fades in the rest of India and the world, for those who experienced it in Gujarat the earthquake will remain one of the most frightening and awesome experiences of their lifetimes. The stability of the earth beneath us is something we take for granted. For the overwhelming majority of the residents on Earth, the planet’s surface remains unchangingly placid, reassuringly stable and solid. Indeed, most of us will echo a view of the Earth: ‘no vestige of a beginning, – no prospect of an end’. Only those scientists interested in probing the origins of the universe, the stars and planets, would have the courage and imagination to consider the birth of the Earth itself. Only the faithful would precisely mark the date on which the Earth was created; James Usher, a 17th century Irish prelate, did indeed estimate the date of the Genesis as 4004 BC, clearly in line with the Old Testament.

Modern earth science, or geology as it was originally christened, has its origins about a century after Usher, when James Hutton thought up the interesting idea of the ‘Earth as a giant machine that had run and would continue to run’. Hutton realized that the erosion of continents, uplift of compacted sedimentary layers in the ocean and igneous activity constituted a geological cycle that was based on dynamic renewal. Jules Verne’s 19th century novel, *Journey to the Centre of the Earth* was one of the rare attempts in fiction to imagine the core of the planet. The 20th century has been the setting for two major revolutions in the earth sciences, which have led to ‘moblistic views of solid earth’. Alfred Wegener, a German meteorologist and an outsider to the geological establishment, proposed in a lecture in Frankfurt in 1912, ‘that continents had actually moved thousands of miles apart during geological time’. Wegener’s idea of ‘continental drift’ was ‘based on palaeontological and geological correspondence’ between the continents separated by the Atlantic Ocean. Wegener’s idea was a firm and more scientific restatement of Roger Bacon’s 17th century view, that the similarity in shape of the Atlantic coasts of Africa and South America constitute ‘conformable instances which are not to be neglected’. Wegener’s concept of a supercontinent, Pangea, as the precursor of our present day continental distribution was to change the face of the earth sciences forever. His ideas summarized in a book in 1915 were to remain largely unaccepted in his lifetime. Wegener disappeared on 1 November 1930, on his fiftieth birthday, while on an expedition to Greenland. In a 1928 conference, a group of eminent geologists were split down the middle, with half of those present opposing the idea of continental drift. Support for drifting continents was to come only two decades after Wegener’s death, when the science of palaeomagnetism was born [Dictionary of Scientific Biography (ed. Gillispie, C. G.), Charles Scribner’s Sons, New York, 1976, vol. XIV, pp. 214-217]. The second revolution emerged in the 1960s, when the concepts of plate tectonics took root; a modestly titled paper, ‘A new class of faults and their bearing on continental drifts’ (Wilson, J. T., *Nature*, 1965, 207, 343), was to signal a paradigm shift. The boundaries between ‘plates’ are relatively narrow and demarcate the areas of greatest seismic risk, the Rann of Kachchh amongst them. But, unlike other natural disasters like cyclones or even volcanoes, even approximate prediction of earthquakes appears to be a formidable or nearly impossible task (*Current Science*, Special Section on Seismology, 10 November 2000). Diverse warning signs have been probed as potential indicators of an earthquake. Seismic precursors, velocity of seismic waves in fault vicinities, tilt and strain precursors, electromagnetic disturbances, hydrologic phenomena like sudden changes in water tables, chemical monitors like radon emissions and even animal behaviour, in the hope that they respond to ‘inaudible acoustic signals’ have been, hopefully, investigated. But, the view of the professionals would be that plate tectonics only provides a ‘broad view for assessing seismic hazard’. This conclusion necessarily suggests, that at best, we can hope for a ‘probabilistic approach to hazard man knowledge of the statistical risks ‘can provide a rational basis for building codes, zoning regulations and the provision of back up systems’ for coping with the aftermath of an earthquake (Turcotte, D. L., *Annu. Rev. Earth Planet. Sci.*, 1991, 19, 263).

The Gujarat disaster is the latest reminder that India is poorly equipped to implement any scientifically sound
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strategy for hazard assessment and disaster management. The Bhopal gas tragedy, the Surat ‘plague' and the periodic cyclones that ravage the eastern seaboard have passed into history. At its very best civic administration in our midst is indifferent. At its worst local administration can be a barrier to well-meaning efforts at relief. The concept of ‘building codes and zoning regulations' is completely alien; there is little doubt that civil engineering of 'earthquake-resistant' buildings will remain wishful thinking in reports generated by newly constituted committees for hazard management. It is also doubtful if mitigation strategies favoured in the richer countries are applicable in a populous and poorly developed country. Inevitably, like the annual cycle of droughts and floods, earthquakes too recede from the public eye, with the passage of time.

Tragic as they are, earthquakes provide earth scientists with a wealth of data, which will, hopefully, enhance our understanding of the underlying phenomena, that culminate in those few, terrible and catastrophic, moments. As in many other fields, understanding the cause may hardly provide any clues towards prevention; Nature’s forces do not easily brook control. However, many curious features that intrigue geophysicists can emerge in the aftermath of earthquakes. The 1994 earthquake in California provided the unusual observation of ‘excessive damage' in Santa Monica, located 21 km from the epicentre; raising the possibility that anomalous damage may result from geologic focussing of seismic waves (Davis, P. M. et al., Science, 2000, 289, 1746). How well positioned are earth scientists in India? Geology has been a traditionally classical discipline in the universities; its teaching like many other sciences, descriptive and dull. The CSIR manages a major institution in the area, the National Geophysical Research Institute at Hyderabad. Ocean research is geographically separated, the National Institute of Oceanography being located in Goa. The Geological Society of India and the Geological Survey of India are organizations with a substantial history. But, modern earth science is a melting pot of disciplines; our own institutions are notably insular. At the level of basic research the earth sciences maintain a low profile. In the hierarchy of desirable professions, science itself ranks low; the earth sciences (and this may be a prejudiced view) appear to be even less sought after than sister disciplines. A somewhat forlorn weekly newspaper column, entitled ‘Career Quest', highlights career options in various fields. Coincidentally, attention was focussed on ‘studying the forces that shape the earth' (Geophysics) in the 30 January edition of The Hindu. In the almost obligatory nod towards the computer sciences, the article suggested that ‘geologists are refocussing their skills and drawing heavily from satellite and computer technology'. Major institutions like the Indian Institute of Science and the Tata Institute of Fundamental Research do not have focussed groups in the area of earth sciences; in an ironic twist the former has a Centre for Atmospheric and Oceanic Sciences, which appears, at least in a titular sense, to exclude the land mass.

Japan is a country which has spent much effort in coping with earthquakes. In browsing through the library, I came across the reflections of Japanese earth scientist, tempered undoubtedly by personal experience (Wadati, K., Annu. Rev. Earth Planet. Sci., 1989, 17, 1): ‘The environment surrounding us is of both natural and artificial origin, and these are intertwined in a complicated way. Recently the artificial side has become predominant, particularly in densely populated districts. It is not an exaggeration that the Earth is changing its original state and nature will be destroyed if things go as they are going now. Actually, it may be impossible to stop this present trend of gradual worsening of environmental conditions. But we must at least endeavour to create a new ideal Earth, searching for the best way to human happiness, today and in the future. In the quest for this goal, research in geophysics will naturally play a part, and its advance is strongly anticipated. Lastly, I think we should always be modest while carrying out this serious task, as our knowledge about the Earth is not yet enough.' Earthquakes that come upon us without warning emphasize the limits of our ignorance.

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