Table 1. Isolation of *Mycobacterium tuberculosis* from cetylpyridinium chloride stored sputum during various seasons

	Within two weeks (N = 564)				Beyond two weeks (N = 252)			
Season	Cul +ve number (%)	Cul –ve number (%)	Conta number (%)	NTM number (%)	Cul +ve number (%)	Cul –ve number (%)	Conta number (%)	NTM number (%)
Winter	109 (94.0)	5 (4.3)	2 (1.7)	0 (0)	41 (77.4)	10 (18.9)	2 (3.7)	0 (0)
Summer	172 (90.5)	15 (7.9)	3 (1.6)	0	49 (77.8)	13 (20.6)	1 (1.6)	0 (0)
Other	219 (84.9)	28 (10.9)	8 (3.1)	3 (1.1)	101 (74.3)	26 (19.1)	5 (3.7)	4 (2.9)
Total	500 (88.7)	48 (8.5)	13 (2.3)	3 (0.5)	191 (75.8)	49 (19.4)	8 (3.2)	4 (1.6)

Winter months, December–February; Summer months, April and May; Other months March and June–November.
Cul +ve, Culture positive; Cul –ve, Culture negative; Conta, Contamination; NTM, Nontuberculous mycobacteria.

to the recovery of *M. tuberculosis*. Specimen collection from inaccessible areas is certainly a problem and transport delays are common leading to exposure of samples to environmental temperatures. Laboratory-based control studies on the effect of low temperature on CPC-containing sputum specimens may be made, to know the exact temperature up to which it can be used. However, the present observations may be helpful for laboratories interested in using CPC as a transport medium in areas with similar low temperature variations. The study was not planned to find the impact of temperature on CPC-stored sputum specimens, and the monthly temperatures based on which the results are interpreted are only indicative of maximum and minimum temperatures during a month.

1. Smithwick, R. W., Stratigos, C. B. and David, H. L., *J. Clin. Microbiol*., 1975, **1**, 411-413.
2. Pardini, M. *et al*., *J. Clin. Microbiol*., 2005, **43**, 442–444.
3. Selvakumar, N., Kumar, V., Narayana, A. S. L., Suryanarayana, D. and Umapathy, K., *Indian J. Tuberc*., 1993, **40**, 95–97.
4. Pal, N., Sharma, B., Malhotra, B. and Rishi, S., *Indian J. Pathol. Microbiol*., 2009, **52**, 59–61.
5. Das, D., Dwibedi, B. and Kar, S. K., *Int. J. Mycobacteriol*., 2014, **3**, 76–78.
6. Das, D., Dwibedi, B. and Kar, S. K., *J. Infect. Dev. Ctries*., 2014, **8**, 1059–1062.
7. Ribón, W., In *Biochemical Testing* (ed. Jimenez-Lopez, J. C.), InTech, Croatia, 2012, pp. 21–25.

ACKNOWLEDGEMENTS. We thank the State Tuberculosis Officer, Odisha for permission to collect sputum samples for the study. We also thank the laboratory technicians of Rayagada designated microscopy centres for specimen collection and technicians of Regional Medical Research Centre, Bhubaneswar laboratory for culture processing. This work was supported by the Indian Council of Medical Research, New Delhi under extramural research grant.

Received 1 February 2016; revised accepted 6 August 2016

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Perspectives for geoscience in India

Geoscience deals with the earth system, specifically the geosphere, on which humans and other biota live and depend for water, food and energy requirements. The understanding of dynamic processes within the earth's crust, mantle and core, and their linkages with geophysical observations and processes at the land surface is complex but significant. These processes vary greatly in space from local, regional to global scale and from a few seconds to millions of years in time. Our knowledge about the composition of the earth, and its dynamic state has advanced manyfold in the last few decades, however, there are several scientific challenges to meet. This knowledge is critical in the context of water, mineral and energy resources, natural hazards and environment.

The evolution of the Indian subcontinent is linked to the fragmentation and dispersal of the Gondwanaland Super-Continent[1]. The Gondwanaland started fragmenting about 133 million years ago. The study of fragmentation processes is one of the most challenging areas. India has recently set up a permanent station at the Larsmann Hills on the east coast of Antarctica. One of the key reasons for choosing this site is to provide opportunities to study the fragmentation process on Antarctica and the east coast of India. We need to probe geology below the ice, through remote sensing, geophysical methods and scientific drilling.

The journey of India from the Southern to the northern hemisphere began about 83 million years ago. About 65 million years ago, Reunion hotspot activity led to widespread volcanism over the Indian land mass and created the present day Deccan Traps. Recent deep drilling (up to 1.5 km) in the Koyna–Warna area, penetrating the Deccan basalt all the way into the underlying granitic basement, has revealed the thickness of the Deccan Traps as ~1200 m in the Koyna region. It has also provided evidence for the peneplaned nature of the basement. Both these features were not known previously[2,3]. It is interesting to note that no infra-trappean sediments were found at Koyna drilling sites. Drill cores from bore holes, about 10 km in length have been recovered, and petrological and geochemical studies are in progress to understand endogenic processes that gave rise to the Deccan Traps. The study is expected to provide hitherto unknown facts about the Deccan Traps and basement granitic rock formations.

India separated from Antarctica during the early Cretaceous[4] and moved at a speed of 18–20 mm/yr, while today the plates are moving around 8 mm/yr. How do we explain such fast movement? We need to answer this question. The Indian plate collided with the Eurasian plate and the Himalaya mountain gradually rose. Erosion of Himalaya resulted in the largest sediment accumulation in present-day seas, the Indus Fan in the Arabian Sea and the Bengal Fan in the Bay of Bengal. We know that these oceanic sediments and rocks have recorded the history of climatic variations and rate of erosion of the Himalaya. In view of this, India under the International Ocean Drilling Programme has recently carried out deep drilling (up to 1.1 km depth) in the Laxmi basin in the Arabian Sea[5]. This was a joint initiative between India and USA, and boreholes were drilled using the US ship *JOIDES Resolution*. These boreholes have penetrated the entire sedimentary sequence and reached the basement. The study of sediment cores will allow us to reconstruct patterns and rates of erosion, how and when continental environmental conditions changed, etc. We know that there is strong coupling between climate change and surface uplift of mountain ranges. High-resolution continuous records on millennial scale generated by this drilling are expected to provide insights into climatic transitions. The experiment is likely to provide answers to how the Himalayas evolved and what role its evolution has played in the origin of monsoon in India, as well as the nature of the crust of the Laxmi basin and its evolution (www.ncaor.gov.in).

The next question is how much sediments are transported from land to oceans. The surface of the earth is a critical interface on which geological processes transport material either in dissolved or suspended forms. About 20 billion tonnes each of particulate matter and solutes are transported every year, which is equivalent to a loss of about 135 tonnes/yr/km^2 from the earth's surface[6,7]. Such large sediment transport influences biogeochemistry, nutrient loading and hence biological productivity of the oceans. Such annual delivery of sediments to coastal regions is in turn controlled by topography, lithology and climate of the river basins. We need to study loading of nitrogen and phosphorus along with sediments to streams, rivers and coasts and ultimately to the oceans. A major programme to monitor and study biogeochemistry of the Arabian Sea and Bay of Bengal, and a project on 'Geotraces' to study the distribution of trace elements and their deposition are in progress. These experiments will provide answers to variability and changes in productivity patterns and their relationship to climate change.

The changing water cycle due to climate change is another major issue. In India, we have observed that heavy and very heavy rainfall events are increasing, and low and moderate events are decreasing[8]. The future projections also suggest that light rainfall events are likely to decrease and heavy rainfall events will increase. How do these changes affect groundwater, especially the shallow groundwater table? We know that shallow groundwater supports terrestrial ecosystems by sustaining base flow in rivers and root zones in the absence of rainfall[9]. Groundwater modelling forced by changing climate, terrain and sea level has been initiated in the Narmada and Sutlej basins to provide insight into the processes and regional patterns of depth to the water table.

Our current knowledge of earthquake processes is not sufficient to make reliable prediction of magnitude, time and location of earthquakes. We need to carry out assessment of long-term strain rates to facilitate probabilistic forecasting. In the Himalaya, continued northward movement of the Indian plate and its under-thrusting beneath the Eurasian plate resulted in accumulation of strain energy. GPS measurements have provided evidence of strain accumulation in the region[10,11]. This energy is periodically released during large and great earthquakes. It has been observed that during the past 200 years, less than 50% of the Himalayan arc has ruptured during great earthquakes[10]. Large earthquakes in the unbroken segments (Uttarakhand, Himachal Pradesh) along the Himalayan belt cannot be ruled out. However, when the accumulated strain energy will be released through great or major earthquakes is not known.

Triggered earthquakes are drawing a lot of attention world over. Such earthquakes are continuing at Koyna since the last 50 years or so. The existing models do not explain the genesis of such earthquakes, essentially due to lack of direct observational data. In view of this, scientific deep drilling and setting up of a fault zone observatory at a depth of 5–7 km have been planned[5]. It is envisaged to make direct observations on how physical and chemical properties change before, during and after earthquakes. An exploratory phase has been recently completed by drilling 9 preliminary boreholes of about 1.5 km depth[2,3]. Seismometers deployed in the granitic basement provided accurate hypocentral locations and disposition of fault zones. A pilot borehole reaching about 3.5 km has been planned and drilling will commence shortly. A Borehole Geophysics Research Laboratory is being set up in Karad, Maharashtra, and would likely be ready by early 2017. Based on the information collected from pilot borehole, the main borehole will be drilled and it is expected to provide answers to many questions about the genesis of triggered earthquakes.

The Indian Ocean geoid low has been of great interest due to its shear amplitude and spread. This geoid low centred at 2°N and 80°E covers the Indian shield and most of the adjoining Indian Ocean. The causative sources of the geoid low are primarily located in the mantle. However, there is no clear understanding about causative factors of this anomaly. It has been suggested that this anomaly indicates remnant of a subduction zone[12], or is related to the core–mantle boundary[13]. The Earth System Science Organisation, New Delhi is launching a major project to understand this phenomenon.

There is also a need to initiate new programmes which have global importance as well as regional relevance. One of the critical requirements is to develop a model to understand what lies underneath the Indian plate. One can approach this challenge in the following way.

Recent developments in seismic tomography have shown great potential for high-resolution imaging of the structure of the interior of the earth[14]. We need to build tomographic models, starting with the Himalayan region. A network of seismic stations and Ocean Bottom Seismometers, about 300 each on land and in surrounding ocean to image deep interior continuously, need to be planned and installed. This can be supported by seismic surveys by ships and temporary stations on land. Earth System Science Organisation has already initiated plans to set up about 100 stations next year in the Indian subcontinent, including Myanmar, Nepal and Bhutan. All these stations would be networked and real-time seismic data would be available for analysis.

A dense network of GPS stations to measure the rate of change and building up of strain along the plate boundaries has been set up and is being augmented in the Andaman and Nicobar islands and the Himalaya. This needs to be supported by a satellite-borne interferometric synthetic aperture radar to measure the strain. Such data from Sentinel-1 satellite are expected to be available in the near future and will provide long-term strain measurements. NISAR, a joint venture between NASA and ISRO, to be launched in the near future, will also provide interferometry capability and facilitate measurement of strain everywhere.

The study of the earth's magnetic field provides information about the interior of the earth. The MAGSAT in eighties and CHAMP during the last decade have provided new knowledge about the interior of the earth. Recently, SWARM, a trio of three satellites, has been providing immense data on the magnetic field to unravel the mysteries of the solid earth[15]. The measurements carried out during the first six months confirmed that the magnetic field is weakening with dramatic decline in the western hemisphere and strengthening in the southern Indian Ocean[16]. The magnetic contributions from the mantle, crust and oceans need to be studied to probe the interior of the Indian subcontinent using SWARM satellite data.

Satellite altimetry has emerged as a powerful tool for gravity survey and geoid studies over offshore regions[17]. As such missions are continuing, a very high resolution database needs to be developed for such studies. Data from GOCE (Gravity field and steady state Ocean Circulation Explorer) have been used to produce global anomaly maps of gravitational gradients and infer structure of the interior of the earth[18]. Use of available data from SWARM, along with GOCE and GRACE (Gravity Recovery And Climate Experiment), and altimeters should be initiated for probing the interior of the earth. This needs to be supported by about 5–6 deep boreholes, may be about 3–4 km deep in the Indo-Gangetic plains, north and south of the Narmada–Son lineament, and north and south of Palghat gap to measure the build-up of stress as well as to understand the dynamics of faulting, fault nucleation and propagation processes in rocks. Deep drilling in the Andaman subduction zone is another critical requirement.

A National Geochronological Facility to support dating of various events is being set up in the Inter-University Accelerator Centre at Delhi; it is vital in all the programmes of geoscience. It will house HR-SIMS and ion accelerator along with other support facilities. Earth is dynamic in nature, and observing and attributing changes that occurred in the past, as well as their global and regional patterns are critical to define our response to the current environmental change.

1. Powell, C. M., Roots, S. R. and Veerers, J. J., *Tectonophysics*, 1988, **155**, 261–283.
2. Gupta, H. *et al*., *Int. J. Earth Sci.*, 2015, **104**, 1511–1522; doi:101007/s00531-014-1128-0.
3. Rao, P. N. *et al*., CSIR-NGRI Technical Report No. NGRI-2016-SEISM-907, CSIR-National Geophysical Research Institute, Hyderabad, 2016, p. 156.
4. Acharya, S. K. *J. Geodyn*., 1998, **26**(1), 149–170.
5. Nayak, S., In *Challenges and Opportunities in Science and Technology (Approach to an Action Plan)*, Science Advisory Council to the Prime Minister, Department of Science and Technology, New Delhi, 2012, pp. 47–52.
6. Millman, J. D. and Meade, R. H., *J. Geol*., 1983, **91**, 1–21.
7. Allen, P. A., *Nature*, 2008, **451**, 274–276.
8. Goswami, B. N., Venugopal, V., Sengupta, D. Madhusoodan, S. and Xarier, P. K., *Science*, 2006, **314**, 1442–1445.
9. Fan, Y., Li, H. and Miguez-Macho, G., *Science*, 2013, **339**, 940–943.
10. Bilham, R., *Ann. Geophys*., 2014, **47**(2/3), 839–858.
11. Bilham, R., Gaur, V. K. and Molenar, P., *Science*, 2001, **293**, 1442–1444.
12. Vam der Voo, R., Spakman, W. and Bijwaard, H., *Earth Planet. Sci. Lett.*, 1999, **171**, 7–20.
13. Hager, B. H. and Clyton, R. W., In *Mantle Correction, Plate Tectonics and Global Dynamics* (ed. Peltier, W. R.), Gardon and Breach, 1989, pp. 657–763.
14. Prieto, G. A., *Science*, 2012, **338**, 1037–1038.
15. Helmholtz Centre – GFZ German Research Centre for Geosciences. Satellite Trio to Explore the Earth's Magnetic Field.
16. ESA. SWARM reveals earth's changing magnetism, 2014; www.esa.int
17. Majumdar, T. J., Bhattacharya, R. and Chatterjee, S., *Curr. Sci.*, 2006, **91**, 683–686.
18. Panet, I., Pajot-Metirier, G., Greff-Lefftz, M., Metirier, Z., Diament, M. and Mandea, M., *Nature Geosci. Lett.*, 2014, **7**, 131–135; doi:10.1038/NGEO2063.

ACKNOWLEDGEMENTS. I thank Dr M. Rajeevan (Ministry of Earth Sciences, GoI) and Dr M. Ravichandran (Director, ESSO-NCAOR) for their support.

Received 23 August 2016; accepted 10 November 2016

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Unique geological and geomorphic features of River Ken with a bedrock channel

River Ken (also known as Karnavati) – a major north-flowing tributary of River Yamuna – has attracted much attention during the past two decades for the controversial Ken–Betwa Link project, touted to be the first of India's ambitious river interlinking programme. River Ken hosts along its course the Panna National Park and Tiger Reserve, a Gharial Sanctuary and several historical sites, all of which lie within 15 km from Khajuraho, a World Heritage Site in Madhya Pradesh (MP), India. River Ken is probably the only Indian river with near-pristine water quality and which has so far escaped from the impacts of a large dam on its main stem, except for two weirs at Bariyarpur (constructed in 1903) and Gangau (in 1915) in its middle reach. The 427 km long River Ken with a total basin area of more than 28,000 sq. km qualifies to be a medium river system. However, only a few preliminary studies on water quality, biodiversity and hydrology have been made[1–4]. The River Ken is also distinguished by its geological and geomorphic features, as it forms a