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Earth Sciences

This issue of *Current Science* puts together a special section on earth sciences to highlight the work being done in the country.

The formation of continents, cratons and supercontinents constitute a focal theme of wide interest for not only evaluating the geological and tectonic history of the Earth, but also in understanding how our planet became habitable through drastic changes in the surface environment. Santosh (**page 871**) presents a synopsis of some of the recent concepts on the mechanism of evolution of continents, cratons and supercontinents and its implications on the surface environmental changes and the dawn of modern life. Starting from the magma ocean stage at around 4.6 Ga, and evolving through a water-covered oceanic realm in the early Archean with island arcs floating on a double-layered convecting mantle, the dynamic planet Earth commenced the building of continents and cratons. These were then episodically assembled into large supercontinents and broken apart. Drastic environmental changes influenced by both galactic and terrestrial processes in the late Neoproterozoic, finally set the stage of making Earth a habitable planet for modern life. Building a habitable environment on our planet involved cleaning up toxic oceans, building granitic crust, bringing down sea level to enable weathering and nutrient supply, and starting oxygen pump, among other factors, finally leading to the bloom of modern life in the dawn of Phanerozoic.

The two great tsunamigenic earthquakes of the last decade have generated vast volume of data that further our understanding of subduction zone processes. The 2004 Sumatra–Andaman earthquake, unprecedented in its size and transoceanic tsunami reach, also questioned the traditional views on the age and subduction-rate-dependence of great earthquake. The 2011 Tohoku-Oki earthquake occurred on a segment of the Japan Trench where an *M* 9 type earthquake was not expected and its tsunami reach was under-predicted. While Japan has a longer documented record of great earthquakes, the history of the Sumatra–Andaman subduction zone has to be reconstructed mostly from geologic records. The science of tsunami geology uses archives of palaeo-deformation along the subduction front as well as tsunami deposits preserved in the sedimentary records. These studies have helped estimate the time and rupture extent of past tsunamigenic earthquakes, using evidence for coseismic subsidence, tsunami sand sheets and offshore turbidites. Kusala Rajendran (**page 880**) reviews the current understanding of the subduction zone earthquakes from the perspective of earthquake recurrence, using the examples of Chile, Cascadia and Sumatra–Andaman subduction zones.

In the Earth's interior thermo-mechanical instabilities take place at the core–mantle boundary (a seismically distinct zone, called D″ layer), resulting in upwelling of hot and buoyant materials in the form of thermal plumes. These plumes drive a large-scale thermal advection process of million-year timescale, as reflected from hotspots and large igneous provinces across the globe. A mantle plume typically shows a large head trailing to a cylindrical tail rooted into the D″ layer. It has been demonstrated from analogue and numerical models that the head can evolve with either a balloon-shape or a curled-shape depending upon the viscosity ratio between the plume and the ambient mantle materials. Using volume of fluid models, Dutta *et al*. (**page 893**) show the conditions for ballooning versus curling mode of plume ascent, taking into account the effects of influx rates, in addition to density and viscosity contrasts. Their models suggest that there will be a ballooning-to-curling transition with increasing influx rates or decreasing density contrast, while viscosity contrast remaining constant. With the help of phase and thermal boundary maps they address why curl-shaped plumes have been rarely detected from seismic tomography even though these are quite common in numerical and analogue model simulations.

Palaeoceanography is an important component of Earth Sciences that provides useful information on evolution of ocean circulation driven by changes in climate, continental configuration and opening and closing of the Seaways. The eastern Indian Ocean is a very sensitive region, away from the influence of the Indian monsoon, where deep waters of the Indian, Pacific and the Southern Oceans affect the deep water mass character and fauna. Thus changes in deep-sea faunal composition and species diversity in the region provide important clues to the understanding of evolution of the water mass through time slices. Changes in diversity parameters of benthic foraminifera from the eastern Indian Ocean DSDP and IODP sites show close linkages to changes in the water mass stratification, productivity and high latitude glaciations during the past ~25 Ma. Results suggest major Antarctic glaciations and intensification of the Indian Ocean oxygen minimum zone to have impacted deep-sea benthic foraminiferal diversity during the middle Miocene–early Pliocene. The water mass stratification in the eastern Indian Ocean appears to have intensified at ~17 Ma and peaked at ~12 Ma. Extensive results based on species diversity and abundances supported by oxygen and carbon isotope values of deep-sea benthic foraminifera are presented by Gupta *et al*. (**page 904**).

The first continuous records of high resolution palaeoclimatic changes for the last ~5,000 years from a modern lake core in the Garhwal Himalaya are presented by Kotlia and Joshi (**page 911**). The chronology of the core is based on five AMS ^{14}C dates. By using a number of geochemical parameters, e.g. major oxides (CaO/MgO, CaO/TiO_2, MgO/TiO_2, Na_2O/TiO_2, TiO_2/Al_2O_3, Na_2O/K_2O and Fe_2O_3/TiO_2), major elements, chemical index of weathering, chemical index of alteration and loss on ignition, the core profile has captured four major global events, such as 4.2 ka arid event, Medieval Warm Period, Little Ice Age and modern warming, alternated with minor climatic oscillations. The data gathered by using various proxies specify six climatic phases: (1) a cold/dry period from 5.1 to 3.5 ka BP including 4.2 ka event, (2) a wetter/moister phase from 3.5 to 1.8 ka BP, (3) an arid period from 1.8 ka BP to 920 years BP, (4) a wetter pulse from 920 to 440 years BP, (5) a cooler LIA from ca 440 to 160 years BP and (6) a warming trend during the post-Little Ice Age.

Tectonic geodesy has greatly enhanced our understanding about the plate motion and earthquake occurrence processes. Nowadays, the tectonic geodesy discipline mainly involves Global Positioning System (GPS) measurements of motion and deformation of the region to study earthquakes, their occurrence processes and associated seismic hazard. Kundu and Gahalaut (**page 920**) apply this technique to address many issues related to the tectonics of the Indo-Burmese Arc. In this region, where the Indian plate interacts with the Burma plate, estimate of plate motion, earthquake occurrence processes are largely unknown. There is a debate whether it is subduction zone or a transform plate boundary. Also, it is not known whether this region has a potential to generate a great earthquake. Nevertheless, seismic hazard in the region has been projected to be high and has been considered similar to that in the Himalayan arc. Application of the tectonic geodesy, in which eight years of GPS measurements of crustal deformation in the region, suggests that about 18 mm/year of the relative plate motion is accommodated in the Indo-Burmese wedge through dextral strike–slip motion and this motion occurs predominantly through aseismic slip. The aseismic behaviour of this plate boundary fault significantly lowers down the seismic hazard due to major and great interplate earthquakes along this plate boundary.

Barren Island is the only active volcano of India. It is located in the Andaman Sea at distance of 140 km from Port Blair. The volcano towers ~300 m above the sea level. The volcano became active in 1991 after 159 years dormancy and has remained active since then with almost continuous ash and intermittent lava eruptions. The ash record preserved in the ocean sediments near the volcano had revealed that it had erupted sporadically many times over the last 70,000 years. However, it was not known when it formed and breached the sea surface. Ray *et al*. (**page 934**) report an effort to provide time estimates for above events through ^{40}Ar–^{39}Ar dating of plagioclase minerals collected from two of the oldest ash layers present in the above marine sediment record. The ages of plagioclases from the ash layers at 310 and 375 cm are determined to be 1.8 ± 0.4 (2σ) and 1.5 ± 1.8 (2σ) million years ago respectively, of which the former is deemed to be an acceptable age of crystallization. The age of the minerals is older than the age of deposition (and hence the age of eruption) of the ash layer, which indicates that the minerals were derived from older rocks present in the plumbing system of the volcano. This essentially means that the Barren Island volcano is older than 1.8 million years.