

models with higher reliability shows an increase of 0.75 mm/day in rainfall and around 3.0°C in summer temperature over India for a high CO<sub>2</sub> emission scenario by the end of this century. The third session of the conference ended with 25 2-min poster presentations followed by formal poster-viewing.

During the last session of the conference, Thamban Meloth (National Centre for Antarctic and Ocean Research) discussed a high-resolution study of dust fluxes, stable isotope and glacio-chemical composition in ice cores corresponding to the last 100 years from the coastal East Antarctica. He showed that the estimated surface air temperatures using the δ<sup>18</sup>O profiles of two ice cores revealed a significant warming of 0.6–1°C per century, with enhanced warming during the recent decades (~0.4°C per decade). Using observations of TMI SST for the years 1998–2010, R. R. Rao (IITM) showed that the near-surface layers in the Arabian Sea progressively

warm from February to early May, resulting in the formation of the Arabian Sea Warm Pool (ASWP), with core warming exceeding 30.5°C. He suggested that the mechanisms that govern the observed interannual variability of the ASWP are Sea Surface Temperature/heat content during October–January, near-surface vertical salinity stratification during November–February, surface net heat flux forcing during February–May and El Niño/La Niña. Krishna Achuta Rao (IIT Delhi) highlighted the various sources of uncertainty in climate projections: scenario uncertainty, internal variability and model uncertainty. He used the model projections of precipitation over NE India to illustrate that while the model uncertainty increases with time, uncertainty related to internal variability decreases. He also showed that weighting models based on various performance metrics result in little improvement. In this session, poster presentations were made by 22 students

and research scholars from the Indian Institute of Science (IISc), Bengaluru.

The last talk of the conference on climate policy was delivered by T. Jayaraman (Tata Institute of Social Sciences). Based on the recently identified proportionality between cumulative carbon emissions and global mean warming, he argued that climate negotiations should use ‘emission units’ on the basis of entitlements to countries. He suggested that India should claim access to its legitimate ‘carbon space’ in global negotiations. The conference ended with closing remarks by G. Bala (IISc) and J. Srinivasan (IISc) and presentation of best poster awards.

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## MEETING REPORT

### Palaeogene of the Indian subcontinent\*

The Palaeogene period, spanning about 42 million years (from approx. 65 to 23 million years BP), commenced with one of the most destructive volcanic eruptions on Earth (Deccan Traps volcanism) which led to the mass extinction of organisms, including dinosaurs, at the so-called Cretaceous–Palaeogene or the K–Pg boundary. Later, the early Palaeogene interval, between 56 and 50 Ma, witnessed several global warming (hyperthermal) events that include the Palaeocene–Eocene Thermal Maximum (PETM) at ~55.5 Ma and the Second Eocene Thermal Maximum (ETM2) at 53.7 Ma. Also during this interval, one of the most profound tectonic events on Earth, the continent-to-continent collision between India and Asia took place, resulting in the closure of the Sea of

Tethys and the rise of the mighty Himalaya. The collision is believed to have caused climatic changes on a global scale, and the Indian monsoon system was established during the Palaeogene period. The development of seasonality during Palaeogene allowed deciduous flora (particularly grasses) to dominate the Earth’s surface. Fossil records also suggest the sudden appearance of a number of modern mammal orders, particularly Artiodactyls, Perissodactyls and Primates (APP taxa) at the Paleocene–Eocene transition that is popularly known as the Mammalian Origination Event (MOE). India’s present-day demand of fossil fuels (natural gas, oil and lignite) is also met from the Palaeogene sedimentary sequences which were deposited along its western and north-eastern margins.

To highlight the geological importance of the Palaeogene period, especially its Indian context, a two-day national conference was held recently. The diverse themes of the conference included issues related to stratigraphic correlation of the

Palaeogene sequences of the Indian subcontinent, fossil records (both flora and fauna) in an evolutionary, palaeobiogeographic and the paleoclimatic context, rise of the Himalaya and related events, and also the exploration of energy resources from the Palaeogene sedimentary basins of the India.

K. S. Valdiya (Chief guest), Harbans Singh (Geological Survey of India (GSI)), Sunil Bajpai (Birbal Sahn Institute of Palaeobotany (BSIP), Lucknow), Siddharth Swaroop (GSI, Lucknow), D. M. Banerjee (INSA-IUGS) and S. C. Tripathi (CRDHG, GSI-Northern Region, Lucknow) were present at the inaugural session.

Scientists, academicians and research scholars from 7 national institutes, 14 universities (including Tribhuvan University, Nepal) and 5 Central Government Organizations participated. Forty-four oral presentations were made and 24 posters were displayed.

In his keynote lecture, O. P. Pandey (CSIR-National Geophysical Research Institute (CSIR-NGRI), Hyderabad) stressed

\*A report on the two-day national conference on ‘Palaeogene of the Indian Subcontinent’ held on 23 and 24 April 2015. The conference was jointly organized by the Birbal Sahn Institute of Palaeobotany, Lucknow and the Geological Survey of India, Lucknow.

on the geophysical evidence in the context of K–T boundary asteroidal impact, crust–mantle structure and geodynamics of the western continental margin of India. In the purview of energy and mineral resources of the Indian Palaeogene, Sudhir Shukla (Oil Natural Gas Corporation, Dehradun) emphasized the importance of foraminiferal studies used in hydrocarbon exploration. Sedimentation pattern and transgression–regression events during the Palaeogene were discussed by B. P. Singh (Banaras Hindu University (BHU), Varanasi). On the basis of high-resolution seismic data from the Bay of Bengal and eastern half of Arabian Sea, K. S. Mishra (University of Petroleum and Energy Studies, Dehradun) discussed the tectonics of the Palaeogene basins. Jyotiranjan S. Ray (Physical Research Laboratory (PRL), Ahmedabad) discussed the provenance of Palaeogene sediments in Andaman forearc and its implications based on geochemical studies. Overall Cretaceous–Palaeogene biogeography of the Indian subcontinent was highlighted in a talk by Ashok Sahni (Lucknow). O. N. Bhargava's keynote lecture on the controversies surrounding the stratigraphy of the Palaeogene sequences of Lesser Himalaya, brought to focus the need for new researches.

Jyotsana Rai (BSIP) reported the discovery of nannofossils from the Deccan intertrappean deposits of central India with the nannofossil assemblage (NP1–NP6) indicating a Danian to early Thanetian age. This nannofossil record also supports the idea of a marine invasion along the Narmada–Tapti lineament during the K–Pg transition. In another talk, Jyotsana Rai presented a comprehensive account of nannofossils from the Indian subcontinent and highlighted the importance of these tiny marine microfossils in the Palaeogene fossil record. Dipankar Saikia (CSIR-NGRI) presented a talk on the lateral variation in the Moho characters beneath the eastern Himalaya on the basis of geophysical evidence.

Pradeep Pandey discussed the favourable factors for hosting of uranium mineralization in the Palaeogene sediments of NW Himalayan region (at the contact of Lower Dharamshala (=Dagshai) and Upper Dharamshala (=Kasauli) formations) based on exploration work spanning a decade. Detailed work on facies analysis and depositional environment of the early Palaeogene Naredi Formation, Kutch, Gujarat was the highlight of the presentation by V. K. Srivastava and B. P. Singh (BHU). Milan Kumar Sharma presented field observations (geological structures, deformation patterns and others) of the Palaeogene succession in Simla Hills. Jyoti Srivastava and Vandana Prasad (BSIP) focused their talk on the effect of global warming, on the diversity pattern in mangrove palm *Nypa* from South Shillong plateau, Meghalaya, and postulated that a decline in the diversity of *Nypa* occurred during the post-warming phase (late Ypresian). Neeraj Awasthi (PRL) presented geochemical and isotopic data from the sedimentary rocks of the Andaman Forearc Basin and supported the idea of prevalence of monsoon system possibly in late Eocene. Vivesh V. Kapur and Sunil Bajpai (BSIP) emphasized the importance of basal Eocene (~54–55 Ma) land mammals, especially perissodactyls (horses and related mammals), from the Cambay Formation exposed in the open-pit lignite mines of Surat district, Gujarat, western India. They also reported the discovery of a tapiromorph (second perissodactyl group from the Vastan lignite mine) from the Indian subcontinent and discussed its significance in a phylogenetic and biogeographic context. Prabha Kalia (University of Delhi, Delhi) emphasized the biostratigraphic significance of Eocene–Oligocene foraminifera from the Arabian Sea and western tropical Indian Ocean. Kapesa Lokho (Wadia Institute of Himalayan Geology, Dehradun) highlighted the present state of knowledge of foraminifera fossil record from

the Eocene sedimentary succession of the Naga–Manipur Hills, Indo-Myanmar range, North East India. Rahul Garg discussed the biochronology of the lignite-associated sedimentary succession (Kharsalia Formation) from Bhavnagar, Gujarat, based on dinoflagellate cyst record and suggested Thanetian–Ypresian age, possibly extending into Lutetian, but not younger than middle Lutetian for the studied succession. His group has also inferred that the sedimentary succession accumulated in a fluctuating coastal swamp and marginal marine environment. S. R. Mishra (Geological Survey of India, Lucknow) presented a study on the sedimentological and fossil data from the Palaeogene Subathu Formation, Mussoorie and Garhwal region for delineating palaeodepositional environment and microfacies analysis.

A special session was also organized on the first day of the conference related to the 36th International Geological Congress 2020 to be held in New Delhi. This mega event will be organized jointly by the Ministry of Mines and the Ministry of Earth Science, with the assistance of the Indian National Science Academy. During this special session, Marvin D'Souza (36th IGC Working Office-cum-Secretariat (WOCS), New Delhi) gave a detailed presentation and highlighted the preparedness of the Indian geoscience community for this event, followed by discussions with the delegates.

The scientific deliberations in the national conference are expected to lead to further studies on the Palaeogene of India.

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