Precambrian geodynamics*

Understanding the geodynamic processes that underpin the formation of continents is fundamental to decoding the complex evolutionary history of the Earth and the terrestrial planets. In the Phanerozoic Eon, the paradigm of plate tectonics and Wilson-cycle processes not only constitutes a robust and unifying mechanism to explain the orogenic processes of crust formation, recycling and preservation, but also the complex interactions among the solid earth, biosphere, hydrosphere and atmosphere relevant to evolution of life and climate. However, there is yet no consensus on a global geodynamic framework for the Hadean and Archean Eons. Many fundamental and long-standing questions, such as what processes led Earth to adopt plate tectonics and since when did plate tectonics became operative on Earth remain challenging and unresolved. While some authors propose that plate tectonics, in some form, operated during the Hadean Eon (>4 Ga), others favour a much later beginning of plate tectonics in the Earth's history. Away from the plate boundaries on modern Earth, 'mantle plumes' and 'hot spots' contribute to intense volcanism leading to the development of oceanic plateaus and large igneous provinces. There is no dispute that the Earth has been on a cooling trajectory since its very early history and that during the Archean, the mantle was hotter by ~250°C and the radiogenic heat production was 3–5 times higher than at present. This has a direct bearing on the thickness, composition and rheology of early crust and forms the basis for rationalizing the observed secular changes in the global geological record and the geodynamic regime, especially in the context of the onset of plate tectonics. There is presently an increasing consensus that the change from a non-plate tectonic Earth to a plate tectonic-dominated Earth was not abrupt and may have taken place over an extended period of hundreds of millions of years through the Archean around 3.0 Ga. Several changes in the behaviour and character of the lithosphere around 3.0 Ga are interpreted in terms of a geodynamic transition from a non-plate tectonic mode to the birth of plates, followed by sustained plate tectonics through the Neoarchaean and Proterozoic Eras. The dynamics of such a transition is believed to be distinctly nonlinear.

Table 1. Scientific questions and themes

Question 1	What is the evidence of transition from 'pre-subduction', plume-driven vertical tectonics to the 'modern style of subduction' regime of horizontal plate motions in the geological record of the Dharwar Craton?
Theme 1A	How can the mantle geochemical and isotopic signatures be used to constrain the evolution of the lithosphere from the pre-plate tectonic to the plate-tectonic regime?
Theme 1B	What are the geodynamic setting, thermal history, timescales and rate processes of Archaean orogenesis in the WDC–Coorg granulite massif? How can it be linked with the global record of transition, to horizontal plate tectonics at this time period?
Theme 1C	Can the secular cooling of the Archaean mantle, which is primarily linked with the plate tectonic transition, be documented from the Dharwarian rock record?
Theme 1D	Can the changes in petro-tectonic assemblages in the stratigraphic sequence of the Dharwar Craton (e.g. tonalite–trondhjemite to potassic granites; mafic, komatiitic greenstone belts to less mafic, MORB-type crusts; siliciclastic–dolomitic sedimentary associations to their modern analogues) which are regarded as evidence for the changing styles of tectonics be recognized in the Dharwar Craton? What is the time span of transition?
Theme 1E	What was the spatio-temporal link of metallogeny with sedimentation, magmatism, deformation, metamorphism and fluid-flow pathways?
Theme 1F	Can the pre-plate tectonics, transition phase and plate tectonics recorded in the Dharwar Craton be numerically simulated through thermo-mechanical models?
Question 2	What is the nature of Archarean surface environment, redox state of ocean, atmosphere and emergence and evolution of biosphere in the Dharwar Craton?
Question 3	What is the nature and geometry of the Archaean/Proterozoic terrane boundaries and sutures in the Dharwar Craton/Southern Granulite Terrane, and how can they be linked with the reconstructions of supercontinents?
	Some suggested regional traverses:
	EDC–WDC transect
	PCSZ transect
	Coorg granulite massif–WDC transect
	EDC–Cuddapah transect continuing into the EGMB
	Bastar–EDC transect
	Singhbhum craton–Chhotanagpur Gneissic Complex
Theme 3A	Geophysical image of the architecture of terrane boundaries to decipher the variations in crustal composition, stratification and thickness using multidisciplinary geophysical, structural, petrological, geochemical and isotopic fingerprinting techniques.
Theme 3B	Are there detached lithospheric fragments down to the Mantle Transition zone?
Theme.3C	What is the nature of the upper mantle anisotropy?
Theme 3D	Palaeo-pole reconstructions

*A report on the Brain Storming Seminar on the Archaean Terrane Assembly with special reference to the Dharwar Craton and Southern Granulite Terrain held during 21–22 October 2019 at the CSIR-National Geophysical Research Institute, Hyderabad.

The Archean Eon is also unique in terms of evolving redox conditions during the Earth's history. Reducing conditions were more prevalent during the Eo- to Mesoarchean Eras. The rock record of this time interval is indicative of pervasive reducing conditions with scanty and feeble evidences of life. The supracrustal rock record of the Eo- to Mesoarchaean is dominated by greenstone belt volcano-sedimentary successions. Preservation of stromatolites in the rocks as old as 3.3 Ga suggests presence of some form of life. The key question regarding the Archean redox evolution is when did oxygenic photosynthesis begin? The Archean Biosphere Drilling Programme led to the finding of interesting evidences from South African and Australian cratons which indicated that whiffs of oxygen developed and there was oxygen oasis in the Neoarchean ca. 2.65 Ga. This is approximately 200–300 Ma prior to the onset of the Great Oxidation Event (GOE) at 2.4–2.32 Ga, which led to irreversible enrichment of free molecular oxygen in the atmosphere–hydrosphere system. The whiffs of oxygen of Neoarchean Era could not have been possible without the initiation of oxygenic photosynthesis. The Archean oceans were dominated by biogeochemical cycles of Fe and S, and the atmosphere largely with methane and CO_2. Understanding the evolution of ocean–atmosphere redox conditions and life during the Archean Eon is a fundamental problem while decoding the Earth's history.

To address the outstanding problems in Precambrian geodynamics summarized in the foregoing, Dharwar Craton forms an excellent natural laboratory. Recent data on the geology, age relationships (mainly zircon U–Pb ages and Hf-isotopic compositions) indicate that the Archean crust in the Dharwar Craton, exposed along a 10–23 km oblique section of middle to lower crust, archives geologic history spanning over a billion years from the Paleoarchean to Neoarchean Eras (3.5–2.5 Ga). Two major episodes of juvenile crust accretion are evident in the craton; one between ~3.45 and 3.15 Ga and the second between 2.6 and 2.5 Ga. A minor event around 2.7 Ga has also been postulated. The craton records protracted phase of crustal reworking between 3.1 and 2.7 Ga. A dominantly vertical tectonic regime is evidenced in the Palaeo-Mesoarchean, when sagduction processes produced a dome-and-keel structural pattern. This seems to have been succeeded by plate tectonic regime unambiguously evident around 2.75 Ga. The latter orogeny is associated with accretion and collision processes culminating with the development of the craton with wide homogeneous strain pattern and high-temperature – low-pressure regional metamorphism. The 3.5–2.5 Ga Archaean sequence of the Dharwar Craton has preserved a variety of chemogenic sediments, including carbonate rocks, BIFs, barites, sulphides, etc. Models of redox evolution during the Palaeo- to Neoarchean were largely developed based on studies from ancient cratons and little is known from one of the important cratons of India. Preservation of diverse and temporally varying (from ~3.3 to 2.6 Ga) chemogenic sediments in the Dharwar Craton provides an opportunity to contribute to this important and fundamental problem in Earth science.

Keeping the foregoing information in view, a seminar was held in October 2019, which was attended by 52 geoscientists from 18 leading universities and academic institutions from all over India. During the seminar, the different datasets and geodynamic perspectives were thoroughly reviewed by the participants. Two days of intense brain storming on different datasets led to a follow-up meeting in 11 November 2019 with the identification of scientific questions and themes (Table 1).

Two major transects/corridors were identified (Figure 1) along which several geophysical (deep seismic, controlled source seismic, magnetotelluric, gravity, magnetic) studies were proposed. It was also proposed to undertake focused geological, structural, petrological, palaeo-

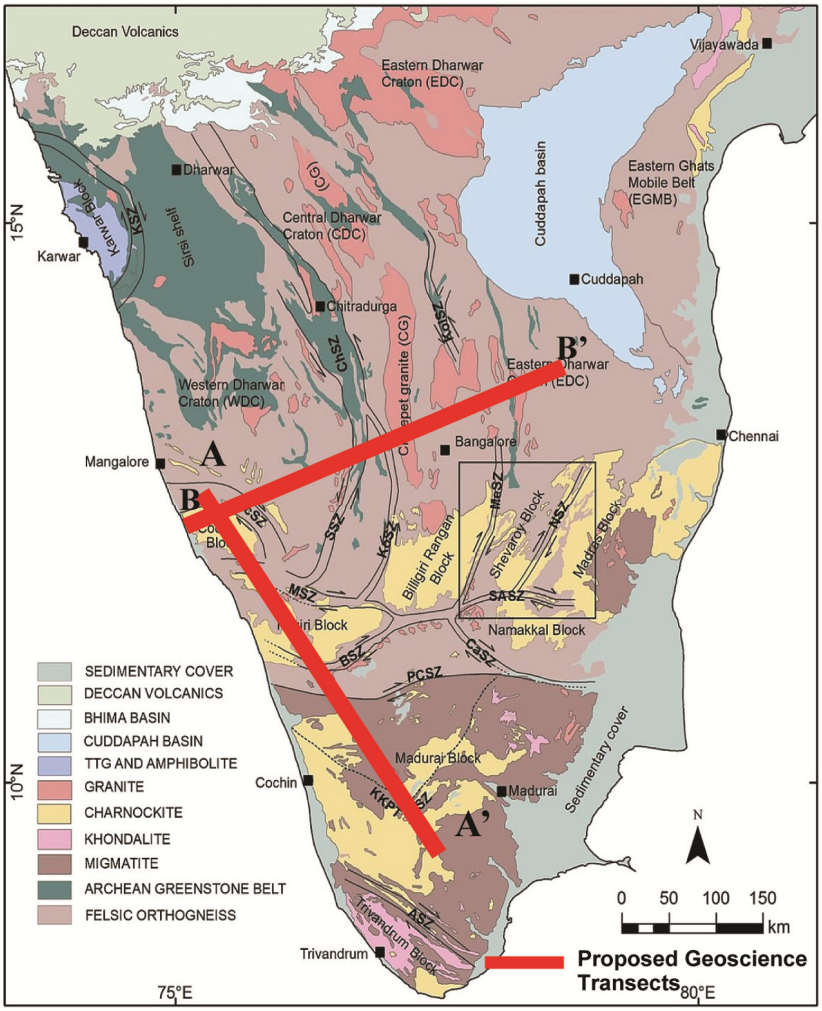

Figure 1. Geological map of Dharwar Craton and Southern Granulite Terrain showing the proposed geophysical traverses/corridors (in red).

biological, geochemical, geochronological and isotopic studies along these corridors, specifically targeting Archaean geodynamics and terrain assembly of the Dharwar Craton and Southern Granulite Terrain. Interested geoscientists can send their focused proposals aiming to solve the scientific questions on any of the above-mentioned themes to PAMC-Geosciences, Ministry of Earth Sciences (MoES), Government of India (GoI) preferably by 25 January 2020. It is further proposed to prepare a consolidated project proposal with several verticals for possible funding by the MoES, GoI.

E. V. S. S. K. Babu* and **V. M. Tiwari,** CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad 500 007, India; **Somnath Dasgupta,** Indian Institute of Science Education and Research, Kolkata, Mohanpur, Nadia 741 246, India.
*e-mail: evsskbabu@ngri.res.in

MEETING REPORT

Current challenges in the management of forest insect pests and diseases*

Insect pests and diseases can cause serious damage to natural/man-made forests. Many records on such losses have already been reported worldwide. Therefore, the solution should focus on keeping the pest/pathogen population at low levels, which will not interfere with the management objectives. A seminar on current challenges in the management of forest insect pests and diseases was held recently. Fifty-seven delegates, including eminent scientists, researchers, academicians from colleges and universities, farmers and personnel of the State Forest Departments (SFDs) participated in the event. The seminar aimed to share knowledge and ideas on the available techniques and technologies for the management of forest insect pests and diseases.

The welcome address focused on the need of biological control of insect pests and diseases in the forestry sector, as pesticides have a devastating impact on the non-target and beneficial insect fauna (parasitoids, predators and pollinators) and beneficial microbes. Over 90% of these pesticides enter into the aquatic environment, grazing areas and human settlements, causing environmental pollution and human health hazards. Other serious problems associated with pesticide use include development of pesticide resistance and resurgence of pest populations. Biological control of insect pests and diseases is an effective, environmentally safe and economically viable management system.

The Forest Research Institute (FRI), Dehradun has developed a method for biological control of teak and poplar defoliators and Eucalyptus gall wasp, which has been successfully utilized in the management of these key insect pests. For instance, approximately 134,100 parasitoids of *Megastigmus* sp. were released in the gall-infested Eucalyptus nurseries, plantations and vegetative multiplication gardens (VMGs) in Punjab during 2013–2017, and by 2017 gall infestation in most of the districts of the state was found nil.

While highlighting the contribution of FRI in the management of important diseases and insect pests of forestry species, collaborative research was suggested on shisham, sal and kikar mortality, Cylindrocladium leaf blight of *Eucalyptus*, rust of poplar and gall-forming insects. Further, work on the biological control of invasive species needs to be taken up. Importantly, scientists should develop suitable methods for the management of key insect pests and diseases of important forestry species.

Ten presentations were made during the first technical session. In the keynote address, the relevance of survey of forest diseases and insect pests for their management was discussed. Forest diseases along with insect pests constitute the major deterrents of forest productivity, and instances of losses due to insect pests and diseases are affecting the developmental plans in many countries. In some countries like the Lao PDR, forest diseases and insect pests are not reported so far, but many likely exist and need to be explored. Therefore, continuous surveillance of all forested land for diseases and insect pests is necessary, because pathogens and insect pests do not recognize national boundaries. Disease and insect pest surveillance, an information-based activity involving the collection, analysis, and interpretation of large volumes of data originating from a variety of sources, is required to be used in several ways to evaluate the effectiveness of control and preventative health measures. Further, the climate change scenario is posing new challenges for scientists as it will probably alter the geographical and temporal distribution of insect pests and pathogens. As a result, new epidemics may occur in certain regions and others may cease to be economically important, especially if the host plant migrates into the new areas. Plant pathogens and insect pests are ubiquitous in natural and managed systems, being among the first to demonstrate the effects of climate change due to large population, ease of reproduction and dispersal, and the short time between generations. Forest disease and insect pest surveys are therefore strongly required with the following main objectives: (1) continuous census of forestry diseases and insect pests generally; (2) detect and even predict new outbreaks; (3) timely assessment of the actual and potential threat due to them; (4) appraise damage both qualitatively as well as on a quantitative basis; (5) diagnose the diseases and insect pests in order to evolve control measures and (6) identify economically important insect pest and disease problems that would help in assigning priorities for taking up intense research on them.

The next presentation was on the 'Development of lure and kill trapping system for the management of forest insect pests: a safe and effective technology'.

*A report on the seminar on 'Current Challenges in the Management of Forest Insect Pests and Diseases', held at the Forest Research Institute, Dehradun on 27 June 2019.