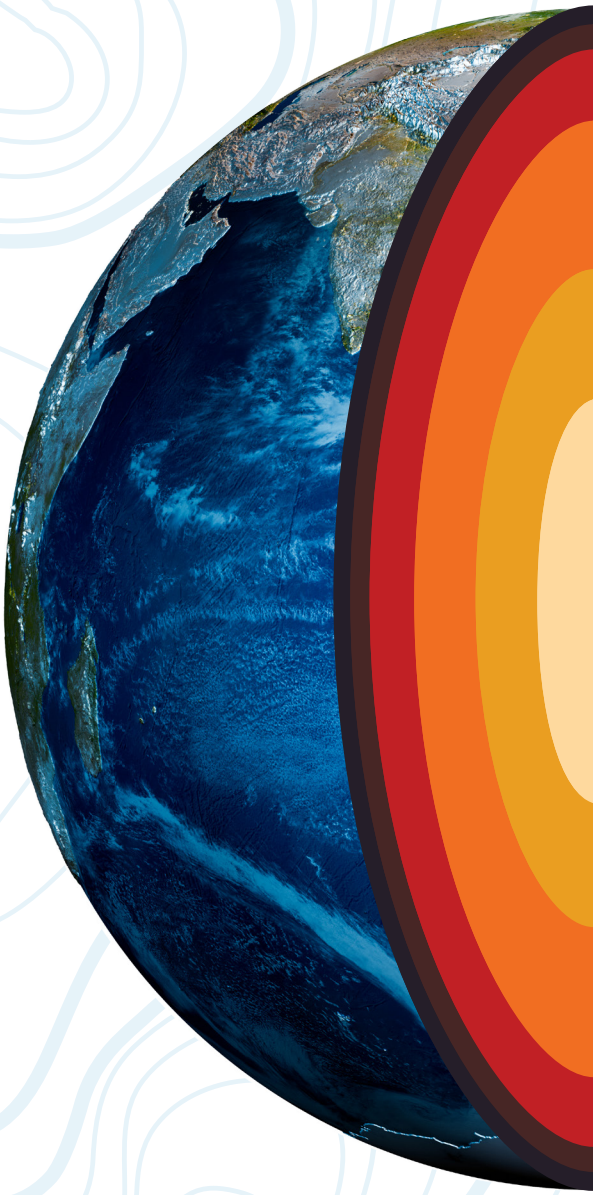
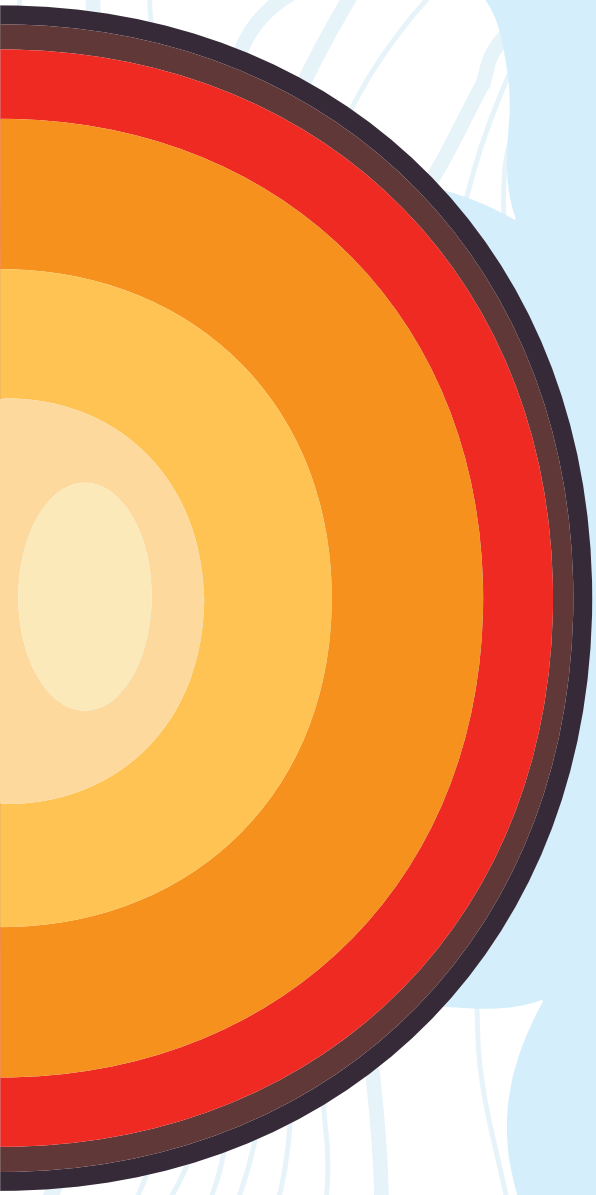
VISION 2047

To Excel in Solid Earth Research & its Applications

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES

Ministry of Earth Sciences, Govt. of India





Vision

To excel in solid earth research and its applications for unravelling the mysteries surrounding the evolution of the Indian lithosphere, sustainable development of its natural resources, conservation of environment and management of natural hazards.

Mission

- To foster multidisciplinary research in emerging areas of solid earth science and develop as a centre of excellence in earth science research in India.
- To provide services to society by utilising the knowledge for earth science applications and generate leadership capabilities for the country.

From Director's Desk

National Centre for Earth Science Studies (NCESS), founded in the year 1978 as Centre for Earth Science Studies (CESS) and amalgamated with the Ministry of Earth Sciences (MoES) in 2014, is one of the leading institutes of Solid Earth research and its applications in the country. Over the years, some of the flagship programmes of the NCESS such as the crustal evolution of the southern Indian shield, landslide and earthquake-related research, submarine groundwater discharge, critical zone observatory network, river basin studies, coastal zone management and risk assessment, lightning, etc., are well acknowledged by the geoscientific community. This Vision Document 2047 envisages the roadmap of NCESS, keeping in mind not only the mandate of the institute and that of the MoES but also focusing on the scientific needs of the country in the coming two decades. As NCESS is gearing up to celebrate its Golden Jubilee in 2028, we are venturing into newer domains of research activities involving non-traditional isotopes, *in-situ* petrochronology, critical minerals, coastal hydrogeology, microplastic pollution and cloud microphysics to address the most pertinent scientific questions in earth system science.

Prof. N.V. Chalapathi Rao
FNA, FASc, FNASc
Director, NCESS

Earth Science Research and NCESS Vision-2047

Introduction

Our habitable environment and landscapes that shape the planet, are the results of a complex interplay of processes happening in the deep interior that drive the constant movement and deformation at the surface. Investigating the evidence of these deep processes that happened in the past will help to understand the present active physical processes and also predict models to protect our future Earth. Besides, the formation and evolution of the Earth and its components influence the life on its surface in many ways. The different components of the solid earth react and influence forces of the oceans and atmosphere. The manifestations of these combined forces are the causes of most of the natural hazards that affect mankind. Therefore, the dynamics of solid earth and its influence on ocean and atmosphere, the so-called earth system, are to be understood through multidisciplinary research of a wide range of interdependent components. Such studies are helpful in understanding the evolution of solid earth and in developing applications to mitigate natural hazards. In recent years, there has been a change in perspective of the role of earth sciences, calling for an understanding of not just how the earth works or mineral resources can be exploited, but also how the life and activities of mankind are affected.

Earth Science Research In India
The Role of NCESS

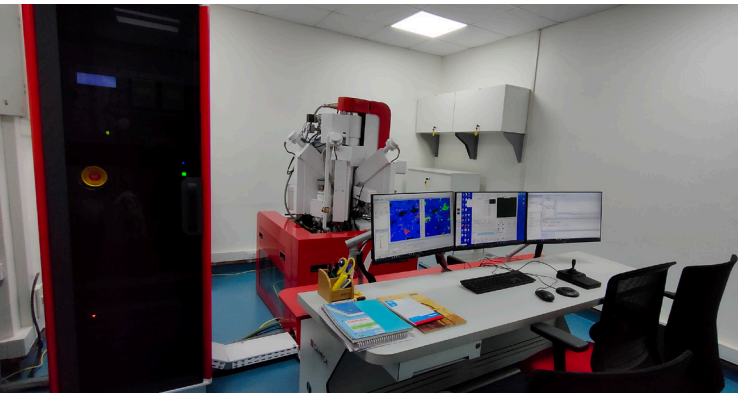
The Centre for Earth Science Studies (CESS) at Thiruvananthapuram, established in 1978 by the Government of Kerala, was one of the earliest organisations to embrace the earth system science concept and initiate multidisciplinary research. As an institute dealing with specific aspects of solid earth research, the centre was taken over by the Ministry of Earth Sciences (MoES) and thus, CESS became one of the constituent members of the Earth System Science Organisation (ESSO) in January 2014 with a new name National Centre for Earth Science Studies (NCESS). The takeover of CESS was to fill the solid earth research component of Earth System Science Research carried out by the MoES and fulfil its commitment to create a framework for understanding the complex interaction among the key elements of the Earth system, namely ocean, atmosphere and solid earth, through its national programmes. NCESS is therefore mandated to take up multidisciplinary research on solid earth and aims to expand its research capabilities and consolidate its position as a centre of excellence in Earth Science research in the country. This will be achieved by:

- ***Identifying, developing and leading new themes in Solid Earth research and its applications across frontiers in Earth System Science.***
- ***Establishing new facilities with the state-of-the-art techniques, analytical capabilities and associated expertise.***

Accordingly, high-impact interdisciplinary themes built on basic research advances in different sub-disciplines in earth science will be implemented by various research groups of NCESS. The core competence of NCESS in terms of human resources, analytical capabilities and infrastructure will be added to realise the long-term objectives under the stated vision of NCESS.

Milestone Scientific Achievements of NCESS in Recent Years

- Established state-of-the-art analytical facilities for geochemistry, geochronology, radiogenic and stable isotope geochemistry such as XRF, EPMA, LA-ICPMS, MC-ICPMS, IRMS and a centralised facility for soil, sediment and water analysis for assessing quality and contaminant chemistry.
- Established broadband seismological observatories in western India to decipher crustal, mantle structure and geodynamic history of the Western Ghats and established a permanent seismological observatory in Larsemann Hills, Antarctica to study the India-Antarctica correlation.
- Developed the start-of-the-art methodologies to unravel the mid- to lower- mantle structure in the continent and oceanic regions using global seismological data and provided the model to explain the causes responsible for the world's largest geoid anomaly, i.e., the Indian Ocean Geoid Low.
- Established new geophysical facilities with seismological instruments, GPR, electrical resistivity, gravity and magnetic instruments and developed advanced methodologies along with the AI/ML/DL to unravel the concealed internal structure and tectonics of the Indian region.
- Set up Critical Zone Observatories in Kerala and Tamil Nadu (Munnar, Attappadi and Aduthurai) to study the impact of climate change and anthropogenic interventions on the aquifer-soil-atmosphere interface.
- Decoded the Late Quaternary evolution of the coastal wetlands along the southernmost part of the Western Ghats.
- Established hydrological monitoring stations in selected rivers of the southern Western Ghats to trace the impact of climate change on the base flow contributions in the rivers.



- Video Beach Monitoring System (VBMS) was developed to monitor coastal changes, studying the complex beach-surf zone processes along the coasts of peninsular India.
- Established a national facility for Geofluids Research and Raman Analysis for pioneering the latest technology for comprehensive geofluids research.
- Brought out causative factors for the landslide incidences and land subsidence in different parts of the Western Ghats region and prepared district-level hazard maps for risk assessment and management.
- The Submarine Groundwater Discharge project achieved a milestone, establishing baseline data for coastal aquifers on the east and west coasts. It identified 82 potential Submarine Groundwater Discharge zones, covering about 1200 km of India's coastal length.
- The Central Chemical Laboratory of NCESS was equipped with cutting-edge facilities to advance the research and our understanding of hydro-biogeochemical processes.
- High Altitude Cloud Physics Observatory (HACPO) at Munnar was established to study cloud microphysics during monsoons.
- Establishment of lightning location network over the southwest coast of India (Collaboration with IITM Pune) for improving the accuracy of the nowcasting of lightning.
- Established the National Geosciences Data Portal, a comprehensive data repository capable of storing and sharing all kinds of geospatial data, viz., satellite, aerial, thermal images, geophysical and field monitoring data.
- As part of the Digital India eGovernance initiatives, NCESS is the first Institute under the MoES to implement eOffice and online payment services since 2016. These services have been instrumental in streamlining administrative processes and reducing paperwork, leading to greater efficiency and transparency in government operations.

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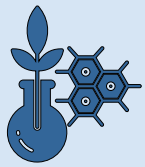
FUTURE DIRECTIONS

The vision of NCESS is "to excel in solid earth research and its applications for unravelling the mysteries surrounding the evolution of the Indian lithosphere, sustainable development of its natural resources, conservation of environment and management of natural hazards".

To set out the journey to excellence, Viksit Bharat and the Amritkaal of 2047, NCESS identified potential directions to fulfil the envisaged commitment to understanding the complex interaction among key elements of the Earth system.

Direction	Major Considerations	Core Research Area
 **Solid Earth**	Indian lithosphere, particularly the southern Indian shield, has a rich geological heritage spanning from the Archaean to the Holocene. The geological framework includes the Precambrian high-grade granulites surrounding the cratonic regions, Purana sedimentary basins, deep faults and shear zones, several igneous units, sedimentary cover sequences, and one of the largest escarpments (Western Ghats) developed along the passive continental margin following the final breakup of India from the Gondwana. Therefore, it provides an excellent opportunity for detailed studies of various geological processes pertaining to the solid Earth. The research programs envisaged will integrate sub-disciplines in Earth Science to address some outstanding issues concerning the evolution of the Indian lithosphere from the Haedean to the Holocene.	Petrology, Geochemistry, Isotope Geochemistry, Geochronology, Palaeomagnetism, Sequence Stratigraphy, Geophysics, Numerical Modelling, GIS, Remote Sensing and Critical Minerals
 **Marine Science**	The coastal zone, consisting of the narrow area from the outer edge of the continental shelf to the estuaries where salt and fresh water meet, is one of the most modified sectors of the ocean and is affected by natural and industrial disasters. Most past studies on coastal processes have looked at it and the driving forces on a macro scale. With better instrumentation and numerical modelling capabilities, it is possible to study nearshore dynamics, beach-surf zone morphology, coastal hydrogeology, mudbank dynamics and estuarine dynamics on a micro-scale to decipher the complex processes at work. Multidisciplinary programmes are proposed, encompassing studies of the coastal land, the estuaries, the surf zone, the nearshore and the inner shelf.	Marine Geology / Marine Geophysics, Sedimentology, Micropalaeontology, Physical Oceanography and Numerical Modelling

Direction	Major Considerations	Core Research Area
 **Hydrology and Biogeochemistry**	Hydrology plays a crucial role in understanding the Earth's intricate water system and addressing water-related problems against the backdrop of ongoing climate change. Access to a reliable and abundant water supply is a crucial part of the United Nations Sustainable Development Goals (SDGs), and most of the 17 SDGs are directly or indirectly impacted by water-related issues, such as escalating water resource scarcity. The quality and quantity of surface and subsurface water are a function of natural influences and human activities. Therefore, conservation and/or better management of water can be achieved only by improving the quality of the environment. Considering the future need for clean and safe water, sustainable environment habitat and utilisation of natural resources for a growing India, the programs are proposed.	Hydrology, Hydrometeorology, Aquatic Biogeochemistry, Environmental Sciences and Isotope Hydrology
 **Atmospheric Science**	Understanding the variations in cloud cover, precipitation and microphysical parameters along the Western Ghats are challenging. Key areas of investigation include cloud and precipitation systems, the interaction of environments from the scale of individual clouds embedded in the monsoon systems and thunderstorms through mesoscale convective systems and cyclonic storms to the scale of the impact of these systems on regional and global climate and in view of natural hazards.	Cloud Microphysics, Thunderstorms, Lightning and Convective Storms

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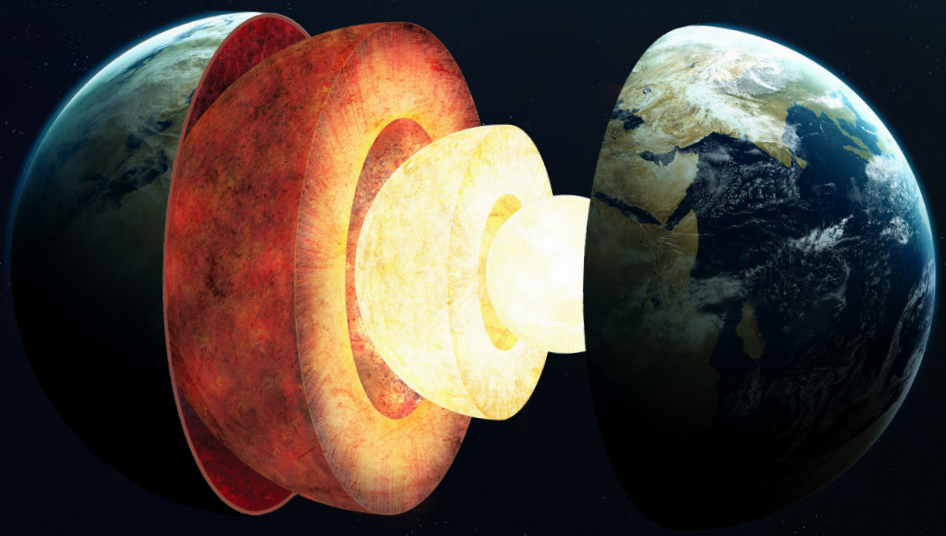
PREFACE

NCESS, over the years, has generated a significant quantum of data and enhanced scientific knowledge on the natural processes involved in continental magmatism, deep continental processes in the Precambrian terranes, the evolution of the passive continental margins and rift tectonics giving rise to the evolution of the north-western Indian Ocean. For 2047, NCESS envisions furthering the knowledge on the origin and development of the Indian lithosphere with detailed investigations on the deep crustal and surface processes. To have a full view of the geosystems, landscapes and changing patterns of geoenvironment, studies on the mantle and crustal evolution, weathering, geochemical processes and mineralisation are included in the multidisciplinary programs. This approach also will help to resolve the complex processes associated with mineral resources, natural hazards, and environmental management.

The key scientific questions proposed are

- How did the Indian shield become an ensemble of differentially evolved Archaean-Early Proterozoic cratons overlain by Early to Late Proterozoic platform basins?
- How did the tectonic and temporal evolution of cratons, mobile belts and cover sequences influence the genesis of economically rich mineral deposits?
- What are the geophysical and geochemical constraints on the lower and upper crustal rheology of the Indian shield?
- What are the neotectonic and surface processes that influence the Peninsular Indian landscape evolution?
- How do the coastal, estuarine and inner shelf sedimentation processes influence the coastal geomorphology of India and can predictive models be generated in view of global climate change?
- How to understand, predict and manage the various geo-environmental factors that affect the Earth's critical zone which is key to the sustenance of human life?
- What are the new strategies for optimum use and sustainable management of natural resources to be laid out for the country to meet the rising demand in the future?
- What are the drivers/processes that lead to natural hazards such as earthquakes, landslides/subsidence, coastal erosion, sea level rise, lightning, etc., and how to assess the vulnerability and suggest mitigation?



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MAJOR THEMES

The major scientific themes envisioned by NCESS to foster multidisciplinary research in emerging areas of solid earth science and to transform itself into a centre of excellence in earth science research in India are:

1. SOLID EARTH STUDIES

1.1. Lithospheric evolution and geodynamics of the Indian Shield: An integrated approach

1.1.A Study of deep earth processes

1.1.A. (a) Magmatism, metamorphism and metallogeny

1.1.A. (b) Granulites and lower crustal processes

1.1.A. (c) Alkaline rocks and mineralisation

1.1.A. (d) Petrochronological evolution of the youngest UHP orogen: Insights into the operation of modern-style plate tectonics

1.1.A. (e) Solid earth geophysics

1.1.B. Study of sedimentary cover sequences

1.1.C. Study of near-surface processes

1.1.C. (a) Natural hazards

1.1.C. (b) Weathering processes

1.1.C. (c) Landscape evolution and uplift history of Western Ghats escarpment

1.2 Deep mantle structure and geodynamics

2. MARINE SCIENCE STUDIES

2.1. Integrated studies on estuaries, beach and inner-shelf dynamics

2.2. Submarine groundwater discharge across the Indian sub-continent

3. HYDROLOGICAL AND BIOGEOCHEMICAL STUDIES

3.1. Critical zone research across environment gradients

3.2. River basin hydrology

3.3. Hydrometeorology

3.4. Biogeochemistry studies

3.5. Geothermal spring research

4. ATMOSPHERIC SCIENCE STUDIES

4.1. Cloud microphysics and thermodynamics studies over the high-altitude regions

4.2. Mesoscale atmospheric processes: Thunderstorm research

4.3. Polar weather and climate studies: Investigating the lower atmospheric dynamics over Antarctica

4.4. Past climate modelling of the Indian monsoon: Unravelling past patterns and future projections

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ENVISIONED RESEARCH

1. SOLID EARTH STUDIES

1.1 Lithospheric evolution and geodynamics of the Indian Shield: An integrated approach

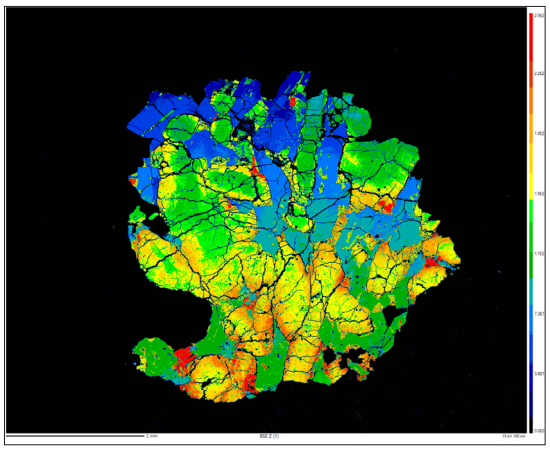
1.1.A. Study of deep earth processes

1.1.A. (a) Magmatism, metamorphism and metallogeny

- To bring out a more reliable correlation among the dyke swarms across the Indian shield and identify the discrete phases of magmatism, locate the magma sources and characterise the Proterozoic continental magmatism / LIPs.
- To bring out significant differences of these Proterozoic magmatic rocks in comparison to the Phanerozoic large igneous provinces or the flood basalt volcanism and interpret in terms of plume or non-plume evolution.
- Integrated studies of magmatic suites for improved understanding of lithosphere-asthenospheric interactions under the Indian shield, establish palaeopole data for Indian shield to improve Apparent Polar Wander path (APWP) of India, geotectonic evolution of supercontinental assembly/dispersal and terrane boundaries through geological time.
- Study the Ni-Cu-PGE mineralisation potential of the large-scale igneous suites.
- Geochemical studies on peridotites/ pyroxenites that occur as xenoliths, orogenic peridotites or ophiolites to characterise the composition of the mantle and constrain melt-rock reaction processes at subduction zones.

1.1.A. (b) Granulites and lower crustal processes

- Obtain important insights into the composition, evolution, and position of the crustal units of South India, Eastern Ghats and Antarctica.
- Knowledge of the fluid-rock interaction processes in the deep crust and crust-mantle interface.
- Precisely determine the time of peak metamorphism from HT-UHT mineral assemblages from in-situ analysis of texturally controlled accessory phases (petrochronology) from granulite terranes in Indian shield.



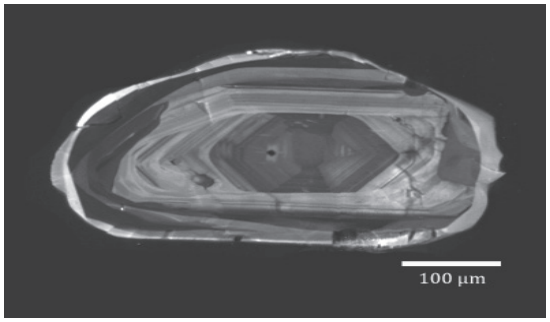
- Forging an international collaboration for "Gondwana Studies" with NCESS as the centre point, where bilateral exchange programs and international field studies are taken up.

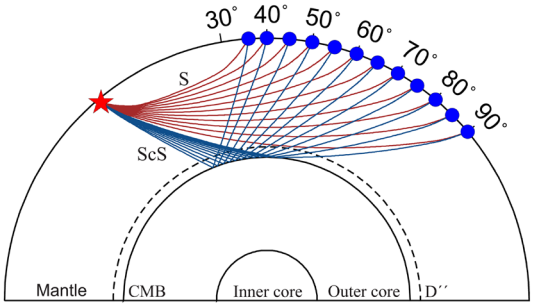
1.1.A. (c) Alkaline rocks and mineralisation

- Trace the alkaline and acid magmatic history spanning from the Late Archaean to the Phanerozoic in various parts of India, characterise the magma tectonics and correlate with supercontinent cycles.
- To understand the nature and origin of economic mineralisation associated with them.
- Study the origin and precise age of emplacement of alkaline complexes within south India and their relation to rift tectonics.

1.1.A. (d) Petrochronological evolution of the youngest UHP orogen: Insights into the operation of modern-style plate tectonics

- Characterise the timing and duration of UHP metamorphism in the Himalayas using in-situ accessory mineral geochronology.
- Delineate the cooling/exhumation rate of UHP rocks using solid-state diffusion chronometry.
- To simulate tectonic processes, examining the mechanisms leading to the formation and exhumation of ultra-high pressure (UHP) rocks in the Himalayas using numerical modelling.





1.1.A. (e) Solid earth geophysics

- Geodynamic evolution of the Western Ghats and deep lithospheric and asthenospheric structures across shear zones in the South Indian shield.
- Broadband Seismological (BBS) Observations – Insights into seismic structure & deformation beneath the Princess Elizabeth Land (PEL), Antarctica and its correlation to the Eastern Ghats.
- Deciphering the subsurface structure, architecture and geodynamics of the Indian Ocean from the surface to the Core-Mantle boundary by utilising marine geophysical datasets such as ocean bottom seismometers, distributed acoustic sensing, gravity studies and modelling.
- Linkage between Indian Ocean tectonics and hazards in the Indian subcontinent focusing on Indo-Australian Diffusion Plate Boundary (IADPB) Zone, Indian Ocean Geoid Low (IOGL) and Andaman subduction zone.
- Near-surface geophysics for exploration of mineral resources, hard-rock aquifers, to locate potential slope failures and hazards such as soil piping.
- To install a network of BBS stations and contribute to the national network on seismicity.

1.1.B. Study of sedimentary cover sequences

- Understanding the chronology of evolution and tectonics of sedimentary

basins in Peninsular India and their impact in modifying the atmospheric oxygen in the Precambrian.

- Set up a dedicated geochronology facility for precise dating of the Quaternary stratigraphic framework of the coastal lands (COASTCHRON), which will be a first in India.
- Examine palaeoclimatic and palaeoecological conditions responsible for the evolution of the Indian coast and sea level predictive models from borehole/sediment cores using multiproxy studies involving sedimentological, palynological, micropaleontological, geochemical and isotopic tools.
- Composition (trace and REE) of placer heavy minerals from the source and sink to understand the provenance and mode of formation of placer deposits.
- Geoarchaeological investigations to understand the link between ancient human migrations/settlements in pre-historic India and geologic processes.

1.1.C. Study of near-surface processes

1.1.C. (a) Natural hazards

- Monitoring the present-day seismicity.
- Geophysical investigations in imaging the crustal architecture and mantle dynamics of southwest India, with a particular focus on seismological studies in regions of active tectonics to understand the earthquake patterns and their anthropogenic implications.

- Identifying active faults and potential zones of active tectonics in the Western Ghats.
- Identify critical areas of potential landslide/land-subsidence occurrences in regions of the Western Ghats and causative factors and prepare a hazard impact model.
- Modelling studies about various aspects of slope stability, scale modelling studies, and development of landslide instrumentation, such as low-cost early warning systems.
- Detection of surface disturbance owing to landslides and debris flow along the Western Ghats region using LIDAR, SAR interferometry, hyperspectral remote sensing and GIS.
- Understand the mechanism of formation of soil piping phenomenon and mitigation measures.

1.1.C. (b) Weathering processes

- Fe-isotope studies on laterite sections to assess the mobility of Iron and its influence on past climate conditions.
- Assess the mobility of elements in in-situ across weathering profiles of different lithologies.
- Geochemical exploration of laterites for critical minerals.

1.1.C. (c) Landscape evolution and uplift history of Western Ghats escarpment

- Study geomorphometric characteristics and tectonic properties of the passive margin landscape.
- Map geomorphic indices (relief, areal, shape and gradient parameters) of active tectonics to evaluate the relationship between tectonics and basin morphology on the regional or basin scale.
- Analysis of digital elevation model to extract information about drainage basins, networks and river profiles.

- Test the hypothesis of ongoing post-rift flexural uplift or neotectonic activity using apatite fission-track (AFT) and (U-Th)/He thermochronometry. These are expected to answer questions about geomorphic processes, such as rates of post-orogenic topographic evolution, weathering, denudation, and distribution of geomorphic processes in space and time.

1.2 Deep mantle structure and geodynamics

- Investigating the structure and deformation of the deep mantle.
- Investigate the ubiquitous nature of the deep mantle discontinuities.
- Geodynamic modelling of deep mantle processes.
- To understand the heterogeneities in the deep mantle and their tectonic impacts.

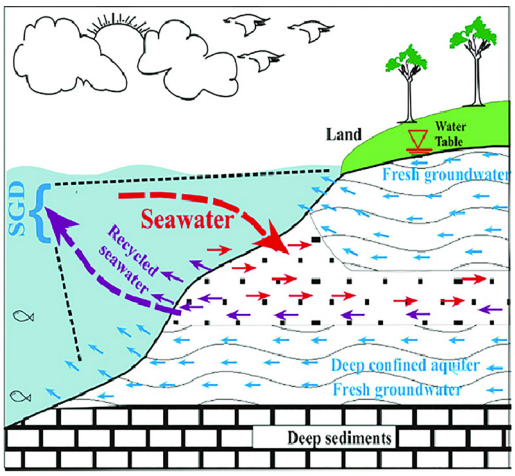
2. MARINE SCIENCE STUDIES

2.1. Integrated studies on estuaries, beach and inner-shelf dynamics

- Formulating methodologies to collect reliable real-time data on nearshore waves, wave breaking, surf zone waves, rip currents, longshore currents, longshore bar, rhythmic morphology, sediment characteristics, etc., for a beach-surf zone system.
- Characterisation of geomorphological, hydrological and sedimentological settings of the coastal, estuarine and inner shelf areas along the west coast of India.
- Investigate the provenance and REE potential of heavy-mineral-rich sediments in the southern peninsular Indian rivers.
- Unravelling the nature of the basement in Kerala-Konkan and Laxmi basins with emphasis on the sea-floor evolution and past climate.
- Reconstruct the paleoenvironmental conditions to understand past climatic, vegetation, and oceanographic changes, aiding the prediction of future changes from coastal archives.
- Reconstruct the submarine volcanic activity events in the Andaman Sea and evaluate their environmental impacts on the land.

2.2 Submarine groundwater discharge across the Indian sub-continent

- Quantify the volume of SGD that can be sustainably extracted from the coastal aquifers across India.



- Establish the long-term dynamics of the seawater-freshwater interface and quantity of water and solute fluxes through SGD zones and the modelling approaches.
- Study the environmental implications of SGD-coastal biota, nutrient inputs, pollution, etc.
- Establish the role of SGD in influencing Indian Ocean salinity and temperature.

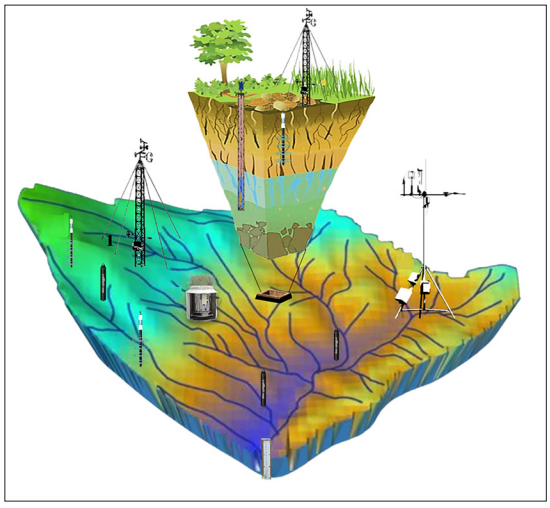
3. HYDROLOGICAL AND BIOGEOCHEMICAL STUDIES

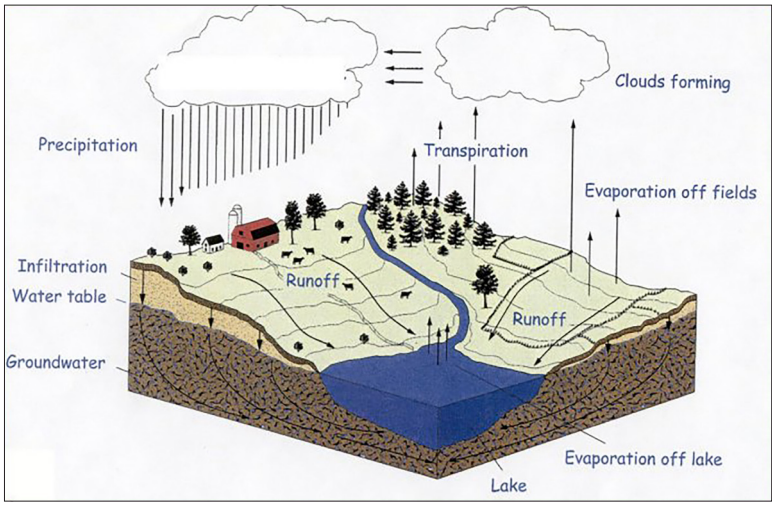
3.1. Critical zone research across environment gradients

- Establish terrestrial (Critical Zone) observatory network/test beds under the TERRAIn network across different environmental gradients of India and generate high-resolution data of land surface variables.
- Characterise the changes in the land-atmosphere interactions across the environmental gradients.
- Understand the resilience and sustainability of Critical Zone to natural and forced changes in different climatic zones in the country.
- Plan climate change adaptive strategies for ensuring ecosystem services, freshwater management and sustainable agriculture.

3.2. River basin hydrology

- Establish hydrological observatories in the small river catchments and develop a long-term hydrological dataset of the Western Ghats rivers.
- Assess the hydrological characteristics of rivers draining through different geologic terrains of the Western Ghats (in the river basin concept) and factors that influence them to evolve strategies for sustainable development and management of the rivers.
- Develop integrated surface-subsurface hydrological models for understanding the resilience of river basins to climate and land use changes.
- Develop flood models and early warning systems for selected river basins/cities.





3.3. Hydrometeorology

- Stable isotope-based studies on moisture recycling in the Indian monsoon.
- Evapotranspiration studies to assess its role in sustaining monsoon rainfall.
- Analysis of precipitation patterns with a focus on the Western Ghats.
- Development of high-resolution temporal estimates of the recycling ratio (RR) for improved monsoon predictions.

3.4. Biogeochemistry studies

- Use stable isotopes for identifying sources, quantifying fluxes, and assessing the seasonality of organic and inorganic forms of carbon and nitrogen in terrestrial and marine aquatic systems.
- Complement isotopic data with elemental composition of water, sediments, and suspended particulate matter to enhance understanding of nutrient cycling, organic matter degradation, and ecosystem health.
- Assess the influence of seasonal changes on the elemental cycles and their role in climate-driven environmental changes.

3.5. Geothermal spring research

- Integration of isotopic and geochemical data to understand geothermal fluid dynamics, including source and evolution.
- Developing sustainable geothermal models to provide data-driven insights that support sustainable energy policies.
- Addressing challenges such as mineral precipitation, scaling issues, and water storage volume to optimise geothermal energy extraction.
- Employ geophysical methods to characterise geothermal reservoirs and assess their potential.

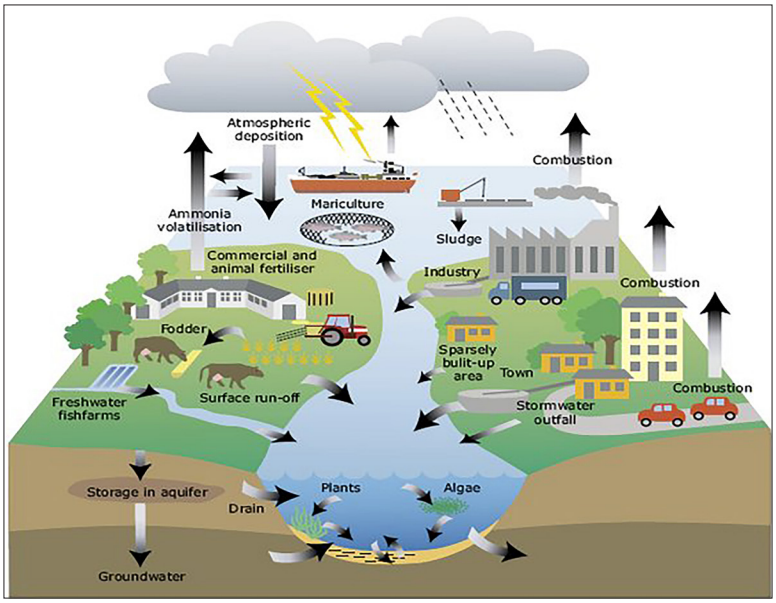
4. ATMOSPHERIC SCIENCE STUDIES

4.1. Cloud microphysics and thermodynamics studies over the high-altitude regions

- Establishment of atmospheric observatories over Southern Peninsular India (Testbeds, climate reference stations in Western & Eastern Ghat terrains).
- Investigate the impacts of enhanced CCN concentrations associated with aerosol intrusions on the microphysical, dynamical, and precipitation characteristics of the tropical clouds.
- Understand the pathways of aerosol interaction with clouds and influence precipitation over the Western Ghats.

4.2. Mesoscale atmospheric processes: Thunderstorm research

- Establish state-of-the-art observatories for natural hazard research in key regions: (i) Lakshadweep Islands, (ii) Andaman and Nicobar Islands, and (iii) Himalayas.
- To develop deep learning models such as Convolution Neural Network (CNN) and Generative Adversarial Network (GAN) architectures for analysis and nowcasting of thunderstorms using Doppler Weather Radar (DWR) observations.
- Deploy a high-density rainfall measurement network (mesonet) and weather stations across the vulnerable Western Ghats and southern India.



- Develop and implement innovative methodologies and a community-based rainfall observation system to monitor real-time rainfall in regions of the Western Ghats that are highly susceptible to heavy rain in the complex mountainous areas, contributing to better disaster preparedness and response.
- Establish a National Training Centre for Natural Hazards, focusing on advanced technologies such as digital twin models, drone, aircraft and satellite sensor development, and artificial intelligence methods. A satellite for lightning monitoring is proposed in collaboration with ISRO.

4.3. Polar weather and climate studies: Investigating the lower atmospheric dynamics over Antarctica

- Establish state-of-the-art atmospheric observatories to understand the lower atmosphere and boundary layer studies at the Indian Antarctica Research Stations.
- Mobilise a high-density snow gauge and automatic weather station network across Ice sheets and Ice shelves near the Indian Antarctic research stations to understand the mass balance and Ice sheet and shelf dynamics.
- Design and implement innovative methodologies for real-time monitoring of weather conditions in regions prone to extreme cold.
- Partner with national and international agencies to enhance understanding of polar weather, ice sheet dynamics, and other mesoscale phenomena.

4.4. Past climate modelling of the Indian monsoon: Unravelling past patterns and future projections

- Integrating paleoclimate data and proxy records from natural archives to enhance the temporal scope of monsoonal reconstructions and to identify long-term monsoonal trends, and the impacts of anthropogenic activities on regional climates.
- To initiate collaborations with national and international partners for the study of past monsoonal climates, and for the development of robust mitigation and adaptation strategies against future monsoonal variability and extremes.

SHORT-TERM GOALS
Targets for 2030

- Enhance our understanding of the lithospheric structure of the Indian peninsular shield and its geodynamic evolution and establish the precise chronology of different tectonic events and their linkage to mineralisation.
- Enhance our understanding of the shallow and deeper Earth structure beneath the Indian continent and surrounding oceanic regions through geophysical investigations to unravel the geodynamic evolution and tectonics of the area.
- Develop a strategy based on geophysical and geochemical studies to identify and use potential critical mineral-enriched zones in land.
- Address global environmental changes and develop action plans and decision support systems for future sustainable land and water (surface water and groundwater) management for the country with special emphasis on the Western Ghats.
- Quantify direct discharge of groundwater to sea through coastal aquifers along the east and west coast of the country and identify potential discharge zones as sustainable resources to cater to the ever-increasing demand for potable water.
- Quantify the fluxing of elements from the mountainous catchments (Western Ghats and Himalayas) to the oceans (cycling of materials such as water, carbon, nutrients,

metals, ions, etc.) in the context of Anthropocene-forced climate change.

- Create an Indian network to investigate critical zone processes through time in different geological, ecological, climatic, and anthropogenic terrains in the country to tackle the adverse effects of climate change and for future predictive models.
- Develop and implement landslide and flood early warning systems to make the highlands and Indian cities/towns/villages climate and flood-resilient and develop AI-ML-based predictive tools for tackling natural disasters such as landslides, coastal flooding, and groundwater depletion.
- Improve forecasting for lightning/thunderstorms using AI-ML, thereby providing early warnings.
- Establish state-of-the-art, permanent Geo-Environmental Observatories for NCESS in environmental hotspots such as the Western Ghats (Geoenvironmental Reference station) to assess the influence of trace gases and atmospheric constituents in near-surface processes and biogeochemical balances.
- Establish state-of-the-art analytical facilities for planetary research, including non-traditional stable isotope geochemistry and hyperspectral remote sensing.
- Act as a geodata provider for establishing renewable energy establishments in the country.
- To assist the government in deciding policies for sustainable development and management of earth resources.

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