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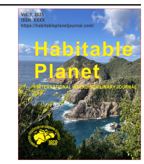

Editorial

Habitable Planet Earth: Secular evolution and sustainable future

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ABSTRACT

The secular evolution of the Earth involved slow, long-term and step-wise changes since its formation, driven by internal processes of differentiation, whole mantle convection and overturn, changes in style of plate tectonics from mobile lid to hot and shallow subduction, and finally to cold and steep subduction of oceanic lithosphere. This was complimented by tectonic activities that resulted in building continents and supercontinents, cleaning up toxic oceans and archiving important metals as mineral deposits, and evolving a life-sustaining atmosphere as well as a nutrient supported environment for the birth and evolution of the biosphere. Planetary evolution, a dynamic process that dictates the formation of planets over time, and sustainability, which deals with protecting the planet without endangering its environment and life, are interrelated aspects. The launch of the new Journal, “Habitable Planet” is aimed at providing an appropriate platform for the scientific community to publish scholarly research on multidisciplinary themes related to the evolution of Earth and challenges on sustainability during current transitional phase of the planet with population explosion, resource depletion, environmental degradation, and climate change.

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Research highlights

- Secular evolution of Earth’s internal and external systems
- From Magma Ocean to life-sustaining environment and habitats
- The link between planetary evolution and sustainability
- Launch of the new journal, “Habitable Planet” to bridge multidisciplinary research

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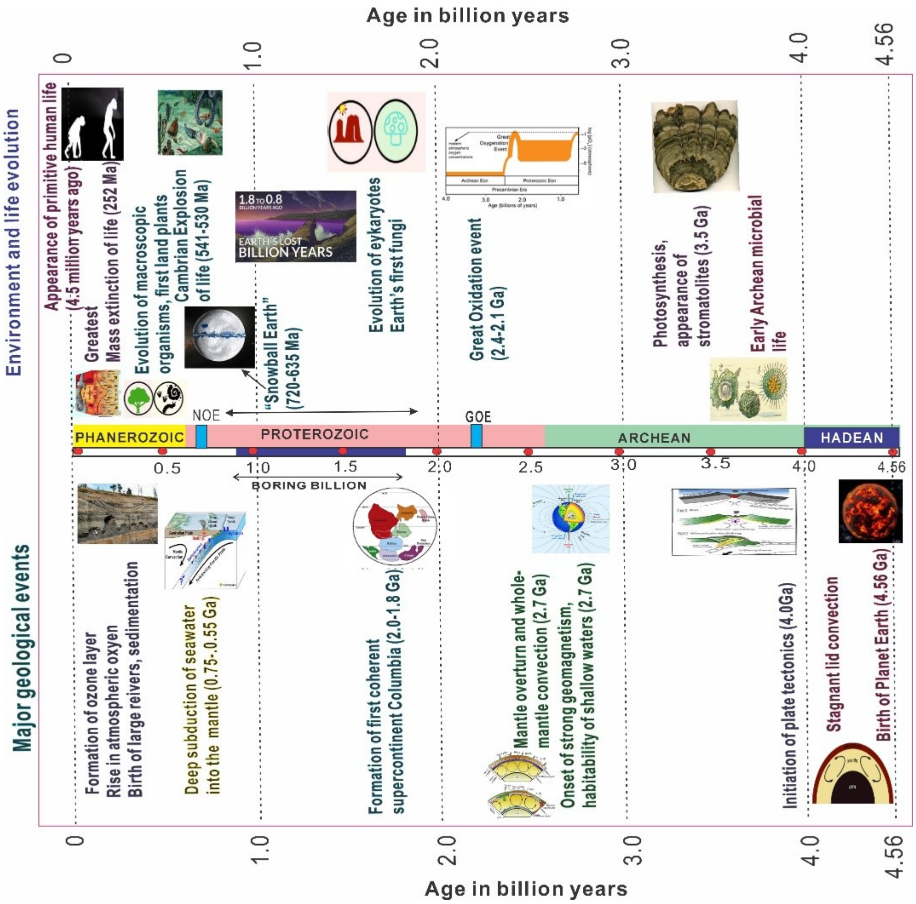

Fig. 1. Secular evolution of Planet Earth through major geologic and tectonic events complimented by environmental changes and onset of modern life. See text for discussion.

1 Introduction

Earth is the only planet in the Solar System with several unique features including dynamic plate tectonics, land-ocean-atmosphere system, and diverse life forms. The secular evolution of the Earth involved slow, long-term and step-wise changes since its formation, driven by internal processes of differentiation, whole mantle convection and overturn, changes in style of plate tectonics from mobile lid to hot and shallow subduction, and finally to cold and steep subduction of oceanic lithosphere. This was complimented by tectonic activities that resulted in building continents and supercontinents, cleaning up toxic oceans and archiving important metals as mineral deposits, and evolving a life-sustaining atmosphere as well as a nutrient supported environment for the birth and evolution of the biosphere.

Following the 'magma ocean' stage after the birth of Earth ca. 4.56 billion years ago, our planet went through complex stages of geological and tectonic evolution that made the Earth habitable (e.g., Maruyama et al., 2013; Santosh et al., 2017; Santosh et al., 2024; Mukherjee et al., 2025) (Fig. 1). The Hadean hot Earth was characterized by stagnant lid convection, following which the early crude phase of plate tectonics began by the dawn of Archean. The onset of strong geomagnetism and habitability of shallow waters are speculated to have occurred during Meso- to Neoarchean times. Subduction initiation and formation of arcs, followed by arc–arc and arc–continent collision, and continental amalgamation created the globe's first coherent supercontinent Columbia at ca.1.8 to 2.0 Ga. This was followed by a prolonged period of relative tectonic quiescence, termed as the 'Boring Billion' from late Paleoproterozoic to early Neoproterozoic. The early Neoproterozoic witnessed a major change in plate tectonic style from hot shallow subduction to colder and steeper subduction of oceanic lithosphere, leading to seawater leaking into the mantle and sea levels to drop. This eventually led to a series of changes including emergence of new coast lines, birth of large rivers, sedimentation, rise in atmospheric oxygen, and the building of the ozone layer, finally making the land habitable.

In conjunction with these major tectonic transitions through Earth history, several important changes also occurred with respect to environment and life (Fig. 1).

Transitioning from Early Archean microbial life, photosynthesis and appearance of stromatolites were initiated by ca. 3.5 Ga. In the early phase of Paleoproterozoic, between ca. 2.4 and 2.1 Ga, the Great Oxidation Event set in. This was followed by the evolution of eukaryotes and the Earth's fist fungi. The early Neoproterozoic was marked by another major oxidation event, the NOE (Neoproterozoic Oxidation Event). During the period from 720–635 million years ago, the Sturtian and Marinoan glaciations converted our planet into a snowball which eventually disappeared with Earth emerging as a Spring Ball. The extreme climatic and environmental perturbations, and the formation of the Gondwana supercontinent marked the birth of modern Earth. Thus, during the dawn of Cambrian, the globe witnessed the 'Cambrian Explosion' of life, following which a series of modern life forms started evolving. Macroscopic organisms and the first land plants appeared. At around 252 million years ago, during Permo-Triassic, one of the greatest mass extinction events occurred. Finally, at around 4.5 million years ago, primitive humans appeared on Earth. The ocean water was anoxic and toxic during the early Earth, and land was uninhabitable due to harmful radiations. The Earth went through multiple and complex steps to become a habitable planet after remaining nearly barren during the first four billion years.

2 Launching "Habitable Planet"

The International Association for Gondwana Research (IAGR) is a non-profit global academic society and a member of the Union of International Associations. IAGR has more than three decades of history in promoting high quality research on the themes and processes related to Solid Earth, Resources and Environment, through organizing annual international conferences, and bringing out its first publication, "Gondwana Newsletter" which evolved into IAGR's official journal, *Gondwana Research* (GR). GR is now one of the highest ranking journals in its field, published in partnership with Elsevier. Planetary evolution, a dynamic process that dictates the formation of planets over time, and sustainability, which deals with protecting the planet without endangering its environment and life, are interrelated aspects. Thus, I have long had the dream of creating an outlet for our scientific community that publishes scholarly research on multidisciplinary themes related to the evolution of Earth and challenges to sustainability during this transitional phase of the planet with population explosion, resource depletion, environmental degradation and climate change.

In late November, 2023, during one of my regular visits to Kochi, Japan with colleagues Darren Lingley and Cheng-Xue Yang, we visited Cape Ashizuri on the western tip of Shikoku Island, now a national Geopark. On our excursion, we climbed a rocky cliff projecting out into the Pacific Ocean amidst incredibly strong winds that were so strong they seemingly threatened to blow us away. Here we had a spectacular view of continent, ocean and atmosphere which are the key elements for sustaining life on Earth. Land, or continents serve as the home for terrestrial life and also supply nutrients to the biosphere and sustain life. Oceans play the role of supplying water, oxygen, nutrients and climate control. Atmosphere acts as the shield from harmful radiation, maintains temperature and also is the source of gases for life. Sunlight acts as the principal source of energy for the life sustaining process. Standing atop that Ashizuri granitic cliff, the conjunction of this natural trinity was clearly visible as shown in Fig. 2, a photograph that I took at Cape Ashizuri that day. This spot is rich in fisheries and indicates how the continental margin with its rich nutrient supply from appropriate source rocks is a paradise for life. This photograph was adopted as the cover image of our new journal, *Habitable Planet*, which was born early this year (2025) when we formed an editorial team including Preetha Warrier, who was the Editorial Secretary for many years during the initial years of publishing *Gondwana Research*, to join hands in creating a platform celebrating the environmental bounty of planet Earth. We are also grateful to the Gondwana Institute for Geology and Environment (GIGE) for the initial support in launching *Habitable Planet*.

Habitable Planet, as the sister journal of *Gondwana Research*, is a peer reviewed international interdisciplinary open access journal from IAGR that aims to promote high quality research publications across diverse fields of Earth and Environmental Sciences covering the history of the evolution of planet Earth, resources, hydrosphere, biosphere and atmosphere, particularly focusing on the planet Earth's habitability. Interdisciplinary topics of natural hazards, environment/energy-related socio-economic issues, and intercultural aspects in the context of sustainability are also considered. The Journal also welcomes contributions on studies related to planetary equivalents. *Habitable Planet* aims to promote and disseminate scientific information among researchers, students, academics as well as policy and decision makers with a view to serving the global community.

3 Articles in the opening volume

This opening issue of *Habitable Planet* includes 20 articles that cover a wide range of topics related to Planet Earth's evolution, including numerical analysis of mantle convection, formation of early continents and supercontinents and evolution of early life, mass extinctions, soil evolution and onset of land plants, ecosystems and climate change, critical metals and their importance in the energy transition era, groundwater potential and sustainability, formation of laterites through tropical weathering, energy security—sustainability—global policies, natural

Fig. 2. Cape Ashizuri in Shikoku, Japan, illustrating the trinity of continent, ocean and atmosphere that are the key for sustaining life on Earth. Photo by M. Santosh.

hazards such as tsunamis and earthquakes, environmental degradation from anthropogenic activities, and geologic processes shaping potential geo sites. A summary of these papers is given in the following sections, mostly quoted from the abstracts, with representative figures adapted from the articles.

Global mantle seismic tomography has revealed large-scale horizontal structure of the mantle, although the structure of the outer core of the Earth remains not well defined using seismic wave analysis because of its liquid nature. Yoshida (2025, this volume) employs an ultra-high resolution numerical simulation of two-layer convection with a viscosity contrast to reveal the thermal coupling mode in mantle-outer core region (Fig. 3). Based on spatiotemporal analysis of convection, the thermal coupling mode in the two-layer convection is shown to be primarily driven by downwelling plumes. The study suggests that the coupling mode effectively cools Earth's core and releases heat from the interior to the surface.

Microbial interaction processes between rocks and micro-organisms plays an important role on the chemical exchange between ocean water and the oceanic crust. Furnes (2025, this volume) focuses on submarine alteration of basaltic glass in pillow lavas and hyaloclastites and show that bio-related granular and tubular alteration structures occur in originally basaltic glass of pillow lavas that are as old as ca. 3.5 Ga (Fig. 4). This provides crucial information about the earliest life on Earth. Element mapping of these bio-related textures reveal that even the oldest samples contain traces of carbon. The carbon imprint as well as the isotope data of the glassy pillow rims and crystalline material exhibit are consistent with microbial influence during alteration of the basalt glass.

Once continents appeared on the globe, the continental fragments were amalgamated into larger continental masses, disrupted and re-amalgamated, defining what is popularly known as the supercontinent cycle. The formation of continental crust is highly debated with episodic crustal production versus supercontinent-linked preservation. Puetz (2025, this volume) summarizes that the major components of scientific research include metaphysics, scientific paradigms, scientific hypotheses, scientific data, and tolerance toward various ideas. Based on these, six guidelines are established for geological research: awareness of underlying assumptions, development of falsifiable hypotheses, testing hypotheses, tolerance of competing hypotheses, replicating results, and obtaining representative samples. The author employs these guidelines on a case study that reviews the empirical tests of the episodic crustal production hypothesis and

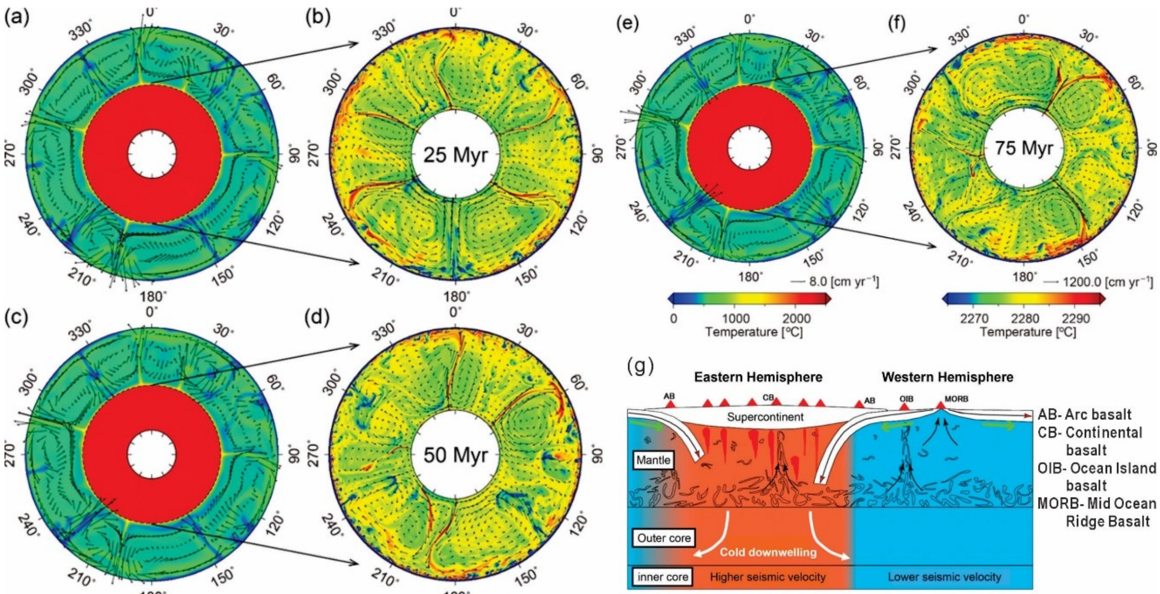

Fig. 3. Snapshots of temperature and velocity fields in the HVL and LVL (a, c, and e), with close-up views focusing on the interior of the LVL (b, d, and f). (g) Schematic illustration of "top-down hemispherical dynamics" of the Earth's interior from geochemical and geophysical observations and the possible existence of large-scale cold downwelling in the outer core of the Eastern Hemisphere (after Yoshida, 2025).

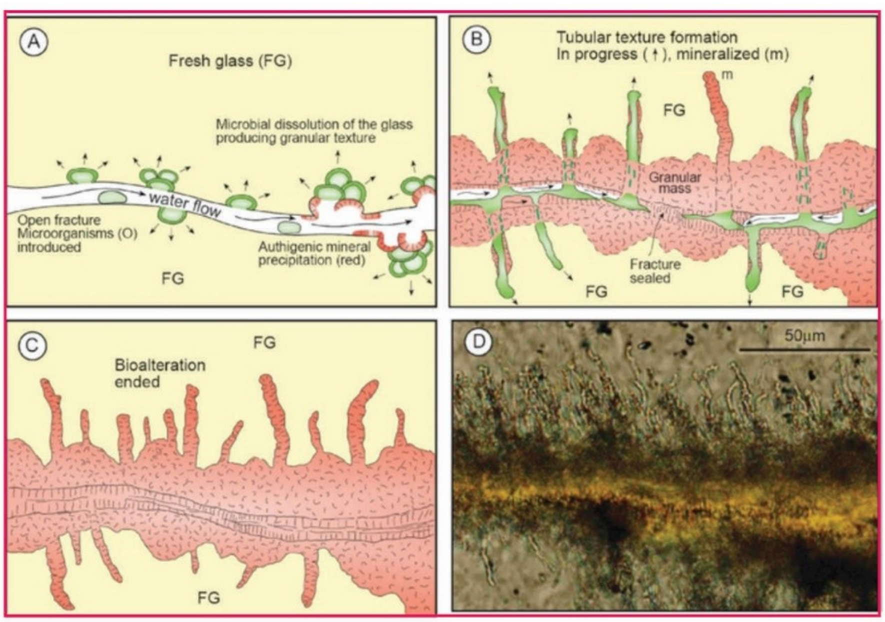

Fig. 4. Schematic model illustrating depicting bioalteration producing granular and tubular textures. (A) Initial colonization of individuals to aggregates of microbes causing dissolution of the basalt glass. (B) Increased authigenic mineralization inhibits granular growth, and tubular textures form. (C) Circulation of fluids is cut off and the alteration process culminates; (D) A typical sample with granular and tubular textures. (After Furnes, 2025.)

the supercontinent-linked selective preservation hypothesis. The results are in support of the episodic crustal production model, whereas they falsify two key postulates of the selective preservation hypothesis.

Archean cratons of the world preserve important records of the evolution of continental crust in the Early Earth. Aadhiseshan and Jayananda (2025, this volume) provide a detailed synthesis of Archean crustal evolution

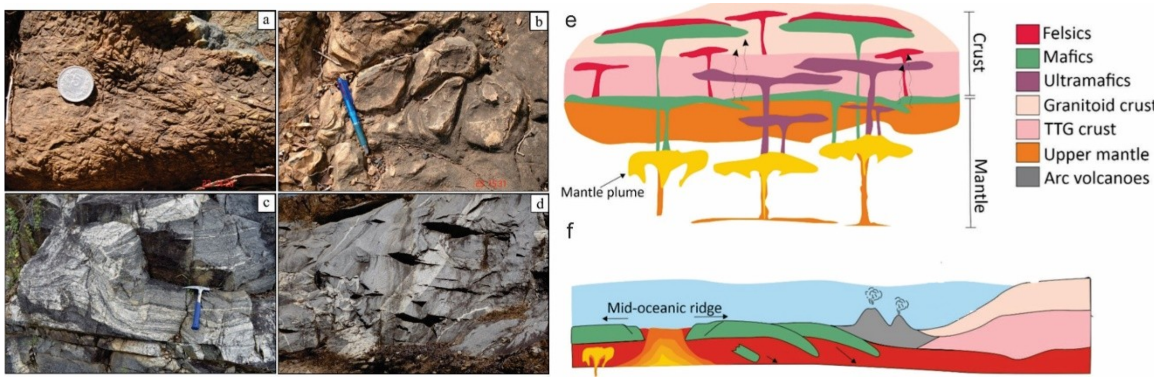

Fig. 5. (a–d) Field photographs of representative rock types from the Western Dharwar Craton. (a) Spinifex textured komatiite; (b) pillowed komatiite; (c) TTG type gneiss; (d) TTG type basement granitoid (from Aadhiseshan and Jayananda, 2025). (e) Paleo-Mesoarchean mantle plume activity generating ultramafic-mafic crust, and tonalite-trondhjemite-granodiorites (TTGs) formed through mafic crust subduction; granites and felsic volcanics form by partial melting and fractional crystallization (after Manikyamba, 2025).

and building of habitable continents based on their studies in the Western Dharwar Craton (WDC) in India. They also address related processes of surface environments, oxygenation and microbial activity. The ca. 3600–2600 Ma crustal record in the WDC include tonalite-trondhjemite-granodiorite (TTG gneisses), volcanic-sedimentary greenstones and potassic granites (Fig. 5a–d). Based on isotopic geochronologic data, the authors indicate that the TTG accretion and greenstone volcanism contributed to episodic continental growth during ca. 3450 to ca. 2500 Ma. The older greenstone volcanics were derived from primitive to deep mantle reservoirs in plume, whereas the younger one originated in shallower undepleted mantle triggered by asthenosphere upwelling, and the youngest suite was generated through melting of depleted to enriched sources in arc settings. Collision of arcs with eventual slab breakoff led to the formation of potassic plutons in the basement or in between the volcanic arcs. The sedimentary record reveals a dominantly anoxic environments during ca. 3400–3000 Ma whilst ca. 3000 Ma onwards there was a shift from anoxic to minimum oxygen levels on the ocean surface with periodic organic production linked to the microbial activity and oxygenation. The authors suggest that the building of habitable continent might have occurred a few hundred million years prior to the Great Oxidation Event.

The co-evolution of Earth's surface, atmosphere, oceans and biosphere from Hadean to Archean geological records traced from geochemical and isotopic proxies is presented by Manikyamba (2025, this volume). Due to the higher mantle potential temperatures in the Archean, and owing to higher levels of radioactive decay, core formation, and residual heat from Earth's accretion, the mantle viscosity was reduced, promoting vigorous convection, widespread mantle plume activity, and rapid generation of oceanic crust, particularly during the Paleo- to Mesoarchean (Fig. 5e). The intense volcano-hydrothermal activity and related tectonics aided in nutrient supply and circulation, thus supporting microbial life. The bio-essential elements such as Fe, Mn, Mo, P, Ni, Co, and U show trends that indicate a robust link between elemental cycling and early life processes. The ancient microbial activity under varying redox conditions in the early Earth can be traced from the Archean passive margin sedimentary successions in the Dharwar Craton including stromatolitic carbonates, banded iron formations (BIFs), manganese deposits, and carbonaceous shales. The growth of cyanobacteria and oxygen release led to the deposition of Fe and Mn as oxides at shallow shelves. The author outlines that these processes detoxified the ocean, rendering the planet habitable for the growth and diversification of advanced life forms. It is also speculated that the geological similarities of Mars and Venus with Earth might indicate that life supporting conditions may have existed for a short time on these terrestrial planets.

The globe has witnessed several mass extinction events at different periods in Earth history, leading to the disappearance of life forms. Mass extinctions have both ultimate and proximate causes, the former being the trigger that precipitates the biocrisis, and the latter being one or more specific climatic and environmental changes that are the immediate cause of biotic mortality (Algeo and Xie, 2025, this volume). It is predicted that the Earth stands on the brink of another global biocrisis, termed the Sixth Mass Extinction (SME) following the Big Five Phanerozoic mass extinctions that have episodically transformed the biosphere through time. In comparison with the earlier extinction event, the ongoing biocrisis is distinct in being related to carbon-release event with a bioevolutionary trigger. Technological advancements have given humans

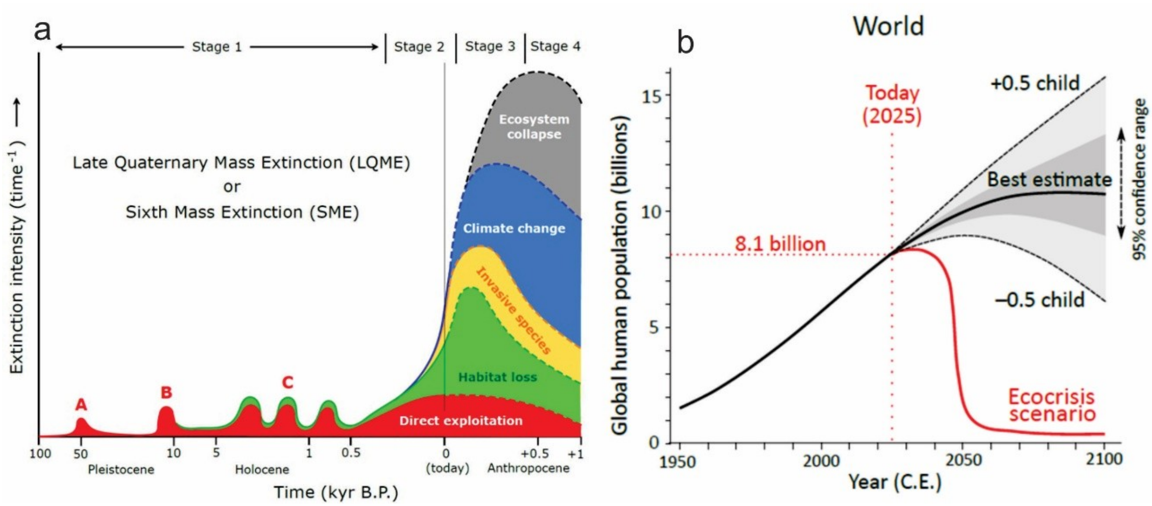

Fig. 6. (a) The four stages of the Late Quaternary Mass Extinction (also known as Sixth Mass Extinction). A, B, and C represent megafaunal extinctions in Australia, the Americas, and the Indo-Pacific region, respectively. Both axes in the figure are in log scales; the y-scale is unquantified and relative. (b) Projected global human population trends to 2100, including best estimate with 95% confidence range, and a broader range representing a global increase/decrease in fertility of 0.5 child per woman. The "ecocrisis scenario" envisions a population crash driven by the catastrophic effects of global warming (from Algeo and Xie, 2025).

a strong influence over the Earth's climatic, environmental, and biospheric systems. Algeo and Xie (2025) note that following the initial slow and punctuated beginning of the SME, the pace accelerated sharply in the last 100–200 years and may continue to do so in the future, thus indicating that the peak of the biocrisis may be no more than a few hundred years away. The four stages of the SME are (Fig. 6a) as proposed by Algeo and Xie (2025) are as follows: Stage 1—hunting and overexploitation (∼50–0.25 ka); Stage 2—habitat loss (∼0.25 ka to present); Stage 3—climate change and alien species invasions (∼0.1 ka to the near-future); and Stage 4—ecosystem collapse. Each of the first three stages was associated with a technological development that initiated and contributed to coeval biodiversity declines, e.g., advances in early human hunting technology (Stage 1), the spread of agriculture and animal husbandry (Stage 2), and industrialization and combustion of fossil fuels (Stage 3). The fourth stage, ecosystem collapse, is expected to come out spontaneously in response to widespread, intense degradation of habitats and biotic communities by human pressures. The "ecocrisis scenario" (Fig. 6b) envisages a population crash driven by the catastrophic effects of global warming (from Algeo and Xie, 2025).

Soils serve as the foundation of plant life and ecosystems, and are critically important as sources of food, clean water, and biodiversity. They also play important role in regulating climate, and storing large volumes of carbon to fight climate change. In his review, Retallack (2025, this volume) trace the diversification of soils through geological time with the evolution life on land, from microbes in Archean soils, to fungi and amoebozoa in early Proterozoic soils, and lichens in late Proterozoic soils. The nonvascular land plants lived in Entisols and Aridisols during the Ordovician period whereas trees created clayey subsurface horizons of Alfisols and Ultisols, and ferruginous horizons of Spodosols. The sod grasslands finally created distinctive surface horizons of Mollisols. Organisms can adapt to particular environments, or through natural selection to other organisms in coevolutionary pairs. Coevolution creates communities that can trigger environmental changes. An example is the ice ages resulting from the evolution of forests and of grasslands. Thus, Retallack (2025, this volume) defines the Darwinian evolution of soils and considers them to have been a starter system for organic-based life capable of natural selection.

Earth's hydrological systems are markedly influenced by rising atmospheric carbon dioxide (CO_2) levels Srivastava and Bhatia (2025, this volume) employ plant-derived proxy records from the Indian subcontinent to reconstruct hydrological patterns from the Late Cretaceous through the Paleogene. This is an important period as it marks India's rifting from the Gondwana supercontinent and amalgamation with Asia. Their study reveals a persistently warm and humid climate with high mean annual precipitation and pronounced seasonal rainfall during this period. The plant assemblages indicate heightened seasonality and prolonged dry periods despite global warming. The Early Eocene Climatic Optimum (EECO) sustained warm and humid conditions that supported stable tropical evergreen rainforests.

Fig. 7. (a) Mangrove dieback in the Neykurendhoo island, Maldives, due to climate change. (b) Major challenges faced by Mangrove ecosystems and their impacts. (After Sreelekshmi and Nandan, 2025.)

The Late Cretaceous to early Oligocene more closely resembled the present-day Indonesian–Australian Monsoon than the modern South Asian Monsoon, and the development of this climatic regime is correlated with the Himalayan uplift in the Neogene. Their study highlights the complex interplay between global warming, seasonal precipitation patterns, and vegetation dynamics.

Coralline algal beds that are calcified benthic biota in marine photic zones represent extremely productive habitats. Their systematics, productivity, net carbon flux dynamics and inputs to the oceanic carbon cycle remain debated. Sarkar (2025, this volume) presents an overview of the taxonomy, ecology and distribution of coralline algae in the shallow-marine ecosystems. The persistent occurrence of several coralline genera from the Cretaceous to the Holocene is considered to indicate high-end resilience across multiple extreme events including K–Pg extinction, PETM, EECO and MECO. Evaluating the response of corallines to past hyperthermals and climate change is important in the context of current global change phenomena like ocean warming, acidification and adverse sea-level fluctuations.

Climate change-driven stressors, including sea level rise, altered precipitation regimes, and increased storm intensity, threaten mangrove ecosystems by modifying hydrological and salinity conditions. These vital coastal ecosystems (Fig. 7) are also affected by direct human activities such as land conversion, pollution, and unsustainable resource exploitation contribute to habitat degradation and biodiversity loss. Sreelekshmi and Nandan (2025, this volume) trace the stressors that impact mangroves' ability to provide crucial ecosystem services, including carbon sequestration, coastal protection, and habitat for diverse species. For developing effective conservation and management strategies, a better understanding of the sustainability challenges in mangrove conservation is essential. The authors recommend a holistic approach integrating ecological, social, and economic factors to drive sustainable management practices, in order to ensure long-term health of mangrove ecosystems, particularly in the face of global environmental change.

Tsunamis are major natural hazards that pose immense threat to life and property. The 26 December 2004 mega-tsunami caused by the Mw 9.2 Sumatra earthquake is among the major tsunamis in Earth history. Prior to this, there was no tsunami warning facility in the Indian Ocean. The tsunami advisories issued by the Pacific Tsunami Warning Center and the Japan Meteorological Agency were later withdrawn, causing inconvenience to a large population residing along the east coast of India. Gupta (2025, this volume) traces the history of development of the Indian Tsunami Early Warning System (ITEWS). The global network of seismic stations allows the determination of the location and the magnitude of the earthquake within 5 minutes or so of its occurrence. Further, by placing ocean bottom pressure recorders in the immediate vicinity of the two regions capable of hosting a tsunamigenic earthquake, it is now possible to judge whether a tsunami has been really generated and what its magnitude is.

Earthquakes and volcanic eruptions are deadly natural hazards that are triggered by Earth's tectonic forces. Zaw and Park (2025, this volume) focus on the Sagaing Fault which is a prominent, right-lateral strike-slip fault that extends approximately 1,400 kilometers through central Myanmar (Fig. 8). This fault represents one of the most seismically active fault systems in world, and has been instrumental in generating large and devastating earthquakes including the most recent magnitude 7.7 earthquake. The triggering of this earthquake has been correlated to the rupture along the Sagaing Fault due to the Myanmar plate and Sunda plate sliding horizontally past each other. The authors discuss alternate geodynamic factors for the earthquake. They alert to the importance of regular monitoring for spotting early warning signs of natural hazards like earthquakes, landslides, and volcanic eruptions.

Fig. 8. Location of Mt Popa volcano, Myanmar, and volcanoes in Sumatra and Java in West Myanmar Terrane. Also shown are the locations of the devastating earthquake of Mv 9.1 and the tsunami in Sumatra in 2014 (from Zaw and Park, 2025).

Modern technology has placed considerable demand on rare earth elements, as they find important applications in the military, computer displays, sonar, hybrid vehicles, and digital cameras, among other fields. Carbonatites, comprising both intrusive igneous and hypabyssal rocks, are among the major reserves of rare earth elements (REE) on Earth. Pirajno and Yu (2025, this volume) review the REE minerals in carbonatites which include bastnaesite, monazite, xenotime, pyrochlore and apatite. The REE mineralization is usually associated with potassic rocks, carbonatite and nephelinitic rocks. The authors review the salient characteristics of carbonatites in Western Australia. Alkali metasomatism in anorogenic ring complexes produced unusual concentrations of REE, as well as F, Zr, Ba, Nb, Th, U, Ta and W.

Green technology applications heavily rely on critical metals like rare earth elements (REE), Li, Co, Cu, Ni, and platinum group elements (PGE) as these are essential components in rechargeable batteries, wind turbines, solar panels, electric vehicles, and for strategic applications. Particularly, the shift to a low-carbon economy depends on securing a stable supply of these critical metals. Balaram and Santosh (2025, this volume) present an overview where they summarize the different types of critical mineral deposits on land and in the deep oceans (Fig. 9). The terrestrial deposits include various types of magmatic, hydrothermal, and sedimentary deposits, which currently serve as the major sources for these critical minerals. Manganese nodules on ocean floor, ferromanganese crust deposits on seamounts, hydrothermal sulphide deposits in the mid-oceanic ridges, phosphorite deposits on the ocean floor along continental margins and submerged mountains, and REY-rich mud representing deep-sea sediment deposits constitute the potential marine mineral deposits. The authors summarize the challenges faced for the exploitation of marine mineral deposits including pollution and habitat destruction in the marine environment, as well as climate change, which can negatively impact the environment and the resources. It is essential to develop sustainable strategies, including recycling and diversification of supply chains, with emphasis on circular economy, for a smooth energy transition and low-carbon future.

The trilemma of energy security, environmental sustainability, and economic affordability, termed as the Energy Trilemma is the major challenge faced by global energy sector. Khan (2025, this volume) review the emerging trends, policies, and technological advancements that address this challenge. The role of top CO_2-emitting countries in navigating the energy trilemma, shedding light on their strategies and potential pathways for achieving a sustainable energy future are evaluated. Although these countries have achieved some success in their shift to cleaner energy systems, the approaches to policy frameworks, energy systems, and economic programs remain diverse. While China and India remain the world's fastest growing economies, reducing their coal dependence is important. The United States and Canada hold substantial fossil fuel reserves; however strategies aligned with home energy security requirements and global climate objectives are required. Some countries with abundant resources have not effectively incorporated sustainability into their plans for energy development. Khan (2025, this volume) emphasizes the need for integrated policies, increased investments in renewable energy, and international cooperation to achieve a balanced energy transition.

Abbas (2025, this volume) presents a review of the global trends and policy implications for decoupling economic growth from energy consumption. The need to

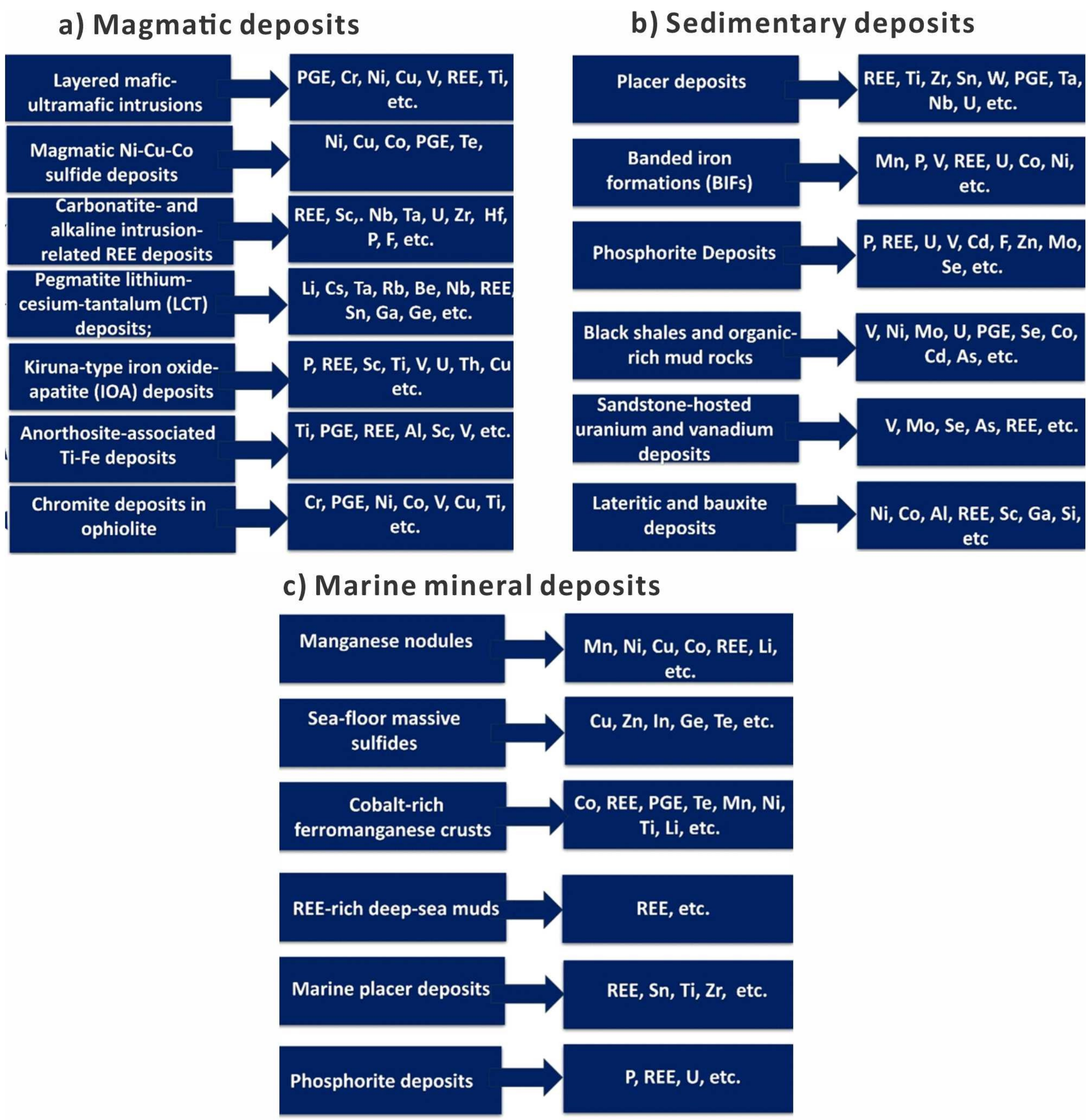

Fig. 9. A summary of critical metal deposits associated with (a) magmatic, (b) sedimentary, and (c) marine environments. (After Balaram and Santosh, 2025.)

reconcile the growth of the economy and environmental sustainability has become critical particularly in the context of global climate change. Thus, decoupling, and alleviating the negative footprint impacts of economic activity without endangering development objectives is the challenge. Based on cross-country comparisons and detailed case studies, this study eexplores how diverse income groups manage the balance between economic development and environmental responsibility. The review also outlines major drivers of climate action, including carbon pricing, investments in renewable energy, urbanization, and quality of governance, among other aspects. In addition, The emerging research gaps are also identified.

Groundwater is one of the major Earth resources that sustain terrestrial life, and the UN Sustainable Development Goals (SDG-6,13 and 15) focus on this theme.

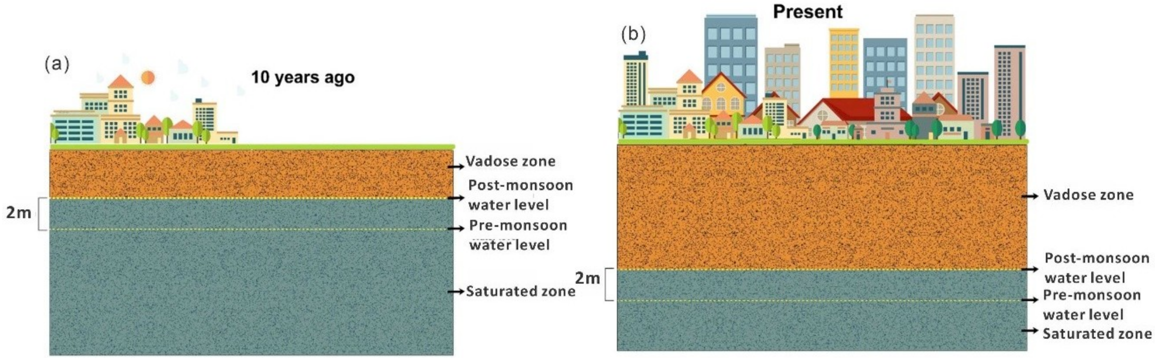

Fig. 10. A schematic comparison of the water table levels and depiction of aquifer desaturation with its impact on groundwater availability and changes over time. (a) 10 years ago and (b) Current water table. (After Shaji et al., 2025.)

Understanding regional groundwater characteristics is an important aspect for sustainability. Because of the high population and rapid developmental activities in India, groundwater plays a crucial role in meeting water demand for agriculture, domestic, and industrial purposes. Shaji et al. (2025, this volume) evaluate the characteristics of the major aquifer systems in the Indian subcontinent, with a systematic classification, and also the changes due to over-exploitation (Fig. 10). Among the 6,553 groundwater assessment blocks in India, 736 are over-exploited, where extraction exceeds annual recharge, 127 are saline due to saline groundwater in phreatic aquifers, and 4,793 are classified as safe. The sedimentary aquifers are severely over-exploited, and similar is the case with the metamorphic crystalline aquifers in some states and cities. Around 87% of India's groundwater is extracted annually primarily for irrigation purposes. Shaji et al. (2025, this volume) alert to the need for building efficient irrigation systems in mitigating climate-induced threats and to safeguard India's productive aquifer units as part of sustainability measures.

Laterites as products of weathering in tropical and subtropical regions are principal sources of bauxite, nickel, and iron ores. They are also important proxies for paleoenvironment and climatic regimes. Annie et al. (2025, this volume) investigated the laterite profiles in representative localities along the western margin of India, which define a flat topography. Through geochemical proxies, they trace the element mobilities during laterite formation. The degree of lateritization systematically illustrates samples from various depths according to lateritization intensity, with intense tropical weathering leading to the formation of laterites associated with gibbsite-rich layers. Their findings highlight the impact of prolonged tropical weathering and contribute to a better understanding of the region's geological evolution and resource significance.

Tropical beaches and adjoining lush green vegetation areas are common regions for tourism, recreation and leisure. The south-western coast of India is characterized by rainforests meeting serene beach profiles, with several beach resorts. The proliferation of recreational activities has brought irreversible and adverse impacts on the coastal environment. Ramkumar et al. (2025, this volume) investigate the coastal environmental, landuse and landcover change, and environmental dynamics in four selected beaches of Kerala in southwestern India. The absence of spatial variability of sediment characteristics and prevalence of platykurtic nature indicate the impact of anthropogenic interventions that have caused monotony. Their study indicates that the recreational and associated commercial-constructional activities have heavily impacted the natural environmental conditions of beach ecosystem, thus requiring appropriate remedial-reclamation measures.

Mount Popa in Myanmar with extensive forest coverage developed through conservation measures receives comparatively greater precipitation than surrounding towns within the central dry zone. Thang and Lin (2025, this volume) observe that in addition to the various geological formations here contributed by volcanic activity, this region is also a critical biodiversity refuge. The area has supported successive human populations, intertwined with enduring religious and anthropological significance. The recent seismic activity along the Sagaing Fault has prompted concerns regarding the dormant status of Mt. Popa, and underscores the necessity for comprehensive scientific investigations to sustain it as viable ecological and cultural refugium.

This opening volume of *Habitable Planet* provides a window into diverse topics for understanding the planet Earth's evolution, history of continents, oceans, atmosphere and biodiversity in the context of habitability and also addresses current concerns about sustainability.

4 Towards new horizons

We launched *Habitable Planet* on the Society's own system by using the platform and workflow of OJS/PKP. I would like to particularly thank Arunkumar at the production side for his valuable help and support at every stage including planning, launching, and managing the platform, PDF preparation, and publication, and Shaji at Cygnet Informatics for system maintenance. I would also like to thank all the contributors to the opening volume and our editorial team for their valuable efforts.

We were recently approached by Scilight Press to establish a publication partnership, and IAGR is pleased to announce that we have just entered into this partnership for *Habitable Planet*. From the forthcoming volume onwards, the Journal will be published in the Scilight platform.

We hope that *Habitable Planet* will be well received by the scientific community as an esteemed platform. The Journal aims to serve as a flagship in promoting and disseminating information among researchers, students, academics as well as policy and decision makers with a view to serving the global community in accordance with the aims and scope of the Journal, as well as adhering to ethical regulations. The Journal will also strictly follow the COPE polices as well as those of our global Society, the International Association for Gondwana Research (IAGR), to which it belongs.

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Credit author statement

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