TIMES evoke

THE HILLS ARE ALIVE

We think of mountains as places of pleasing beauty. Indeed, with their cool, dappled sunlight, the pines and heathers embracing their stones, the clouds caressing their cheeks and the snows crowning their peaks, they are this. However, mountains represent cold, hard science too. Mountains — which cover about 25% of Earth — emerged two billion years ago, created by tectonic plates colliding, pushing up formations that grew into the Himalayas, the Pyrenees, the Alps and the Urals, the Caucasus and ranges from East Africa to New Zealand. Their summits resembling cool islands amidst warmer climes, mountains harbour 25 of the world's 36 biodiversity hotspots, New Guinea's peaks alone holding 20,000 plant species which compose 10% of the world's flora.

Mountains also shape life beneath. Standing in the path of winds, they make air rise, cooling it and causing precipitation. Home to glaciers, they yield rivers, providing, as the UN finds, over 40% of the world's people with fresh water, the Himalayas holding the 'third pole', the largest volume of fresh water outside the Polar ice sheets, sustaining billions. Over time, high ranges have given us the resources of life while their beauty caused even the famously critical VS Naipaul to feel, as he saw snowy ledges and cold streams, bleached grey stone and elegant deodar trees, 'the special joy of being in the mountains'.

Today, mountains face climate change. As humans increase carbon emissions, the hills are feeling the heat. The IPCC notes faster melt rates of mountain glaciers than ever before, impacting water flows and generating volatile floods and landslides. Such changes — the World Economic Forum finds 'green areas' in the Alps have expanded by 77% since 1984, indicating huge melt — are impacting millions of lives, from farmers to snow leopards and hill hares. Yet, as Times Evoke's global experts emphasise, there are solutions — the most important is rooted in recognising why these formations of stone and snow, river, moss and soil, are vital to our lives. A host of mitigations, from renewable energy to sustainable agro-biodiversity, hill afforestation and mindful building, exist. However, they need our understanding that the hills are alive. Join Times Evoke on a journey of the mountains that make our lives.

'Rock formations are the archives of Earth — they help us explore the origins of life'

Andrew H. Knoll *teaches natural history and earth and planetary sciences at Harvard University. Speaking to* ***Srijana Mitra Das*** *at* ***Times Evoke****, he discusses how rocks and cliffs contain stories of our planet's life:*

What is the core of your research?

■ Much of my work is palaeontology or using fossils to reconstruct the narrative history of life through time. I also work as a geologist, studying the physical and chemical features in sedimentary rocks to piece together environmental history. I'm interested in how physical and biological Earth interacted through time, how evolutionary events may have caused environmental change and whether dynamic environments impacted evolution.

We think of them as mute observers — can rocks and mountains tell us about Earth?

■ The record of our planet's surface history is written in rocks. Indeed, my library would be the rocks we see in mountains and cliffs — without these, we wouldn't have a history to examine. Also, mountains may look mute or immovable but in fact, Earth is very dynamic in timescales that are much longer than human lives. The formation of mountains have a very strong effect on life and its environment as they play out through geologic history.

You describe oxygenation on Earth as occurring in degrees, first just enough to support an amoeba, then a beetle, etc. — what implications does this hold with atmospheric CO_2 rising now?

■ For the first 40% of Earth's history, the record in the chemistry of rocks suggests there was no permanent build-up of oxygen — then, around 2.4 billion years ago, we see evidence globally of oxygen appearing on Earth's surface, at around a percent or so of today's levels. Only about 600 million years ago, oxygen began climbing to its high values today — that is when we first start seeing large animals. This is the timekeeper for evolution.

Photo Courtesy A. Knoll

READING IN THE LIBRARY: Knoll works at deciphering 800 million-year-old rocks found in East Greenland, many capturing vital stories of Earth's surface, its interior and the evolution of its life forms

Photo Courtesy A. Knoll

A WHOLE NEW WORLD: Microbial reefs and shales alternate in sedimentary rocks dating back to the Neoproterozoic era of over 800 million years ago — these are carefully preserved within the folds of time in rocky formations across Spitsbergen, Norway

EVERY STONE IS A STORY

Now, the 21st century's global change is not likely to significantly affect this amount of oxygen in the atmosphere or surface ocean. However, the deeper ocean is losing oxygen now — in parts of the Baltic Sea and the Gulf of Mexico, oxygen at depth has been depleted to zero. These are called 'dead zones' and they're expanding globally, with consequences for life.

Are there similarities between the extinctions recorded in rock remnants from the end-Permian period and the Anthropocene now?

■ Yes. About 250 million years ago, at the end of the Permian period came the largest known mass extinction. It is estimated that 90% of all animal species in the oceans disappeared — this happened due to vulcanism, a million times greater than anything ever experienced by humans. This put a huge amount of CO_2 into the atmosphere, causing global warming, ocean acidification, a drop in the PH of sea water and a loss of oxygen in sub-surface water masses. Basically everything that caused such destruction then is happening now — the difference is, the source of the CO_2 today is human beings.

Also, when we explore the records of the Permian period, we find this increased CO_2 was added over many thousands of years — that's not the case today. The actual rate at which humans are adding CO_2 to the environment now is about a hundred times the rate of all the volcanos put together while being comparable to the CO_2 levels of the Permian mass extinction.

What caused Pangaea, the primordial supercontinent, to form and then split?

■ One of the interesting things about our planet is that the continents don't just stay in one place — there is 'continental drift'. Plate tectonics continually move the continents around Earth's surface. These are fuelled by convection in the mantle, which is always in motion — that causes new ocean crust to form in places like mid-ocean ridges. So, the Atlantic Ocean is spreading by about two and a half centimetres a year. In other places, the ocean crust is declining, as in the rim of the Pacific with its strings of volcanos. Earth's continents lie on these plates and sometimes, they collide, causing, for instance, the formation of Pangaea — but once this was formed, the continued workings of the mantle underneath tended to pull it apart. We can see such a process of splitting-apart happening today as well in East Africa's Rift Valley.

You have studied rock formations and mountains worldwide — which has been the most special one so far?

■ My favourite moment came early when I first established my own research program and got to work in the Norwegian Arctic island of Spitsbergen which has rocks that are about 800 million years old — these contain exceptionally preserved breath-taking microfossils. As we could determine the environment of those fossils preserved in these rocks, I could show the ecological distribution of early life. This is why rock formations are called the archives of our Earth.

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PEACEFUL, YET ROILED: Earth is constantly moving within itself, its forces pulling and pushing at continental masses, geologists studying such processes in East Africa's ancient Rift Valley (above)

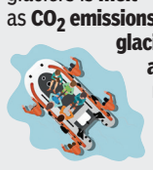
THEIR ICY CAP

- **Glaciers** are **massive bodies of ice, made of fallen snow** that was compressed over centuries. Despite their heft, mountain glaciers, **many being relics of the Ice Age**, don't just sit still — they **move down slowly**, pulled by gravity

- Most glaciers exist in **the polar regions across Greenland, the Canadian Arctic and Antarctica.** These are also found in **mountain regions near the Equator** — the **Andes** in South America contain some of the world's largest tropical glaciers while **the Himalayas hold over 30,000 square miles of glacial ice, which is surpassed only by the North and South Poles**

- Mountain glaciers are diverse, with **long valley glaciers** flowing down narrow gorges, **short, wide cirque glaciers** in amphitheatres cut into mountains, **transection glaciers** which fill entire systems of valleys and **piedmont glaciers** spread out at the foot of mountain ranges

- However, what's common to all glaciers is **melt** — scientists find as **CO_2 emissions warm the world, glaciers are melting at unprecedented rates.** Mount Everest's **Khumbu Glacier**, the world's highest, is **melting faster than ever now**, forming lakes as long as multiple football fields, its potential impacts including **floods**



- Studies estimate **5,500 Himalayan glaciers could melt or retreat by 2100**, with impacts from **sea level rise** to growing an **apple on a mountainside**

Research: The Smithsonian Magazine, Encyclopaedia Britannica, The Guardian, BBC, Scientific American

Photos: iStock

NATURE'S SKYSCRAPERS

- The **Nilgiri tahr** is **south India's only mountain ungulate** or hoofed mammal. Tamil Nadu's state animal, it once thrived across the Western Ghats — **now endangered**, it exists in fragments of its range, threatened by habitat loss and poachers. With stylish **curved horns**, the reclusive tahr **live at 8,000 feet**, hiding in cliff faces. While a herd rests, one stays alert — with **great eyesight**, the tahr can spot danger afar, producing a whistle-like alarm

- The beautiful **Himalayan monal** is Nepal's national bird and Uttarakhand's state bird — but despite its credentials, it is **a very shy being**. Like other pheasants, **the male is gorgeously coloured, females being more sober**. Found at **14,000 feet above sea level**, the monal inhabit **oak, conifer and pine trees** — with good looks, they have good sense too, **descending in winter to 6,000 feet so their chicks survive** while the parents dig snow for shoots

- The **marmot** lives **at 16,000 feet above sea level** — creating dens 30 feet deep in the ground, marmots **burrow for six months a year.** Their toes have concave claws that let them burrow efficiently. **This is a social animal, helpful as it lives with relatives**, each keeping the other warm. Females often burrow longer with their young — **any danger elicits low-pitched alarm calls repeated by watchful marmots**

Research: National Geographic, WWF, IUCN

'Mountain formation shows us movements in deep Earth'

Maureen Long *teaches earth and planetary sciences at Yale University. Speaking to* ***Times Evoke****, she maps out what lies beneath mountains:*

Photos: iStock

I am a seismologist and study the structure and dynamics of the deep Earth — this is the portion of our planet we can't access directly. We can't drill down into Earth's mantle, the deepest we've ever drilled being roughly ten miles or so. I study parts deeper than that — this is important because many of the processes that go on in Earth's interior, such as mantle convection or the generation of Earth's magnetic field in its core, are key to what we see on the surface. Mantle convection, for instance, is intimately tied to plate tectonics which cause mountain building, the configuration of continents, earthquakes and volcanic eruptions — even the cycling of carbon between the atmosphere and Earth's interior are controlled by processes taking place deep within the planet.

The formation of mountains is a fundamental part of plate tectonics. Mountain belts contain rich deposits of ores and minerals and help control precipitation — exploring how these are formed helps us understand these resources as well. I also research subduction zones — some of Earth's oceanic crust, the lithosphere, makes up its tectonic plates. These sink back into the mantle, forming a subduction zone. The surface of Earth cools off through geologic time. As it cools, it becomes denser and eventually sinks. Now, these zones are the locus of many geologic hazards — the largest earthquakes, like 2004's Sumatra quake which also triggered a tsunami, occur in subduction zones.

Interestingly, this is also where material gets recycled back into Earth's mantle. Subducting slabs bring with them water and carbon, often as carbonate rocks from the ocean floor — carbon goes down into the mantle and much of it comes back up as volcanos. These processes played an important role in regulating Earth's carbon cycle and climate over billions of years. In a backdrop where humans are burning fossil fuels and adding CO_2 to the atmosphere in much shorter timescales now, we must learn about these processes.

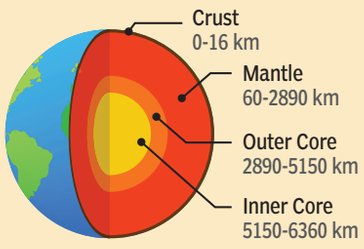
DEEP DOWN UNDER

I use observational seismology to study these — earthquake waves pass through Earth's inner regions, going down into the interior, sampling its areas. I take recordings of these from seismic stations all over Earth, study them and turn the information derived into images of Earth's interior. Earthquakes happen all the time too. Most are very small, remote or occur deep inside Earth. But quakes happen constantly and the challenge for seismologists is forecasting their location, probability and likelihood to help communities design more resistant infrastructure.

Many changes we are bringing about in the Anthropocene are actually making us more vulnerable to the hazards already present in Earth's mantle. Quakes triggering tsunamis is a consequence of Earth's fundamental processes — but we put ourselves at risk when we build cities in such areas or infrastructure around these coasts. We must appreciate the gravity of Earth's mantle and heed its signs.

I've worked in Peru when we were deploying seismic stations to study South American subduction zones — I was awe-struck by the magnificent Peruvian Andes. However, the Appalachian ranges are a little closer to home for me. These are an old mountain range formed several hundred million years ago due to a continental collision. Worn down by erosion, these aren't very high now. But while they may not be so spectacular, they contain fundamental stories about Earth. Learning these makes us grow more resilient as well.

THE STRUCTURE OF OUR WORLD



WHAT LIES BENEATH: We are often delighted by the beauty of mountain ranges, as seen here in the Appalachians — but these reflect huge churnings in Earth's interior which have implications for quakes and volcanic activity

'From rhododendrons to caterpillar fungus, life thrives in the Himalayas'

Kamal Bawa *is Distinguished Professor Emeritus at the University of Massachusetts, Boston. He tells* ***Times Evoke*** *about wonders in the Himalayas:*

I am a biologist and I can see the Himalayas, like most mountains in the world, witnessing unprecedented change now. This includes climate impacts and biodiversity decline, driven by social and economic factors. Understanding these crises and engaging policy makers and the public to adopt mitigations forms the core of my research. This work is interdisciplinary and involves ATREE, the Ashoka Trust for Research in Ecology and the Environment, which I founded 25 years ago, located in the Himalayas and Bengaluru. I've researched biodiversity in the Himalayas, mapped deforestation and land use changes, tracked climate change with satellite imagery, studied local perceptions of climate events and initiated projects to diversify agricultural systems which can support biodiversity and sustainable livelihoods.

The Himalayas are the highest mountains in the world — and the youngest on Earth. They are 40 million years old, compared to the Andes which are 60 million years and the even older Alps. The Himalayas were formed when a piece of a huge land mass, called the Indian Plate, broke away from the African Plate and began moving northwards, colliding with the Asian Plate — this collision resulted in the uplift of these mountains. With their altitudinal and climatic factors, they hold a complex topography, a vast amount of ice as glaciers and huge biodiversity.

Photo Courtesy: ATREE via K. Bawa

NATURE'S VIVID CANVAS: A fire-tailed sunbird, which is an important pollinator of rhododendrons, sits amidst Rhododendron glaucophyllum

Indeed, about two-thirds of India's biodiversity is found in the Himalayas. I've seen flowering rhododendrons, covering the whole mountainside in reds and pinks, primulas in the valleys carpeting entire forest floors, the efflorescent flowers of the six-foot-tall Sikkim rhubarb found at 15,000 feet, caterpillar fungus (which is half-fungus, half-insect) that occurs above 4,000 metres and plant pollination at 5,000 metres. At heights where you can barely breathe, there are incredible biotic interactions that inspired me to write 'Himalaya: Mountains of Life'. The diversity of just its plants — over 100 species of rhododendrons are found there — is fascinating.

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BLOSSOMS OF SNOW: Flowering pink rhododendrons frame icy Himalayan vistas

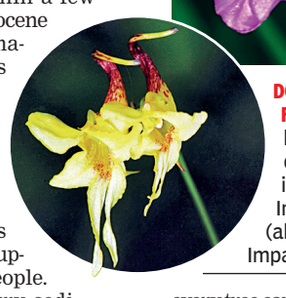
A HAVEN ON EARTH

But now, we face the loss of this tremendous treasure. This biodiversity evolved over millions of years but is being devastated within a few decades. The Anthropocene is impacting the Himalayas severely in terms of water, climate and the richness of life. The Himalayas, with their huge ice resources, are termed the 'water tower' of Asia, the source of its largest rivers which support over a billion people. These rivers also carry sediments which flow through the plains, providing nutrients and minerals that sustain agriculture in the lowlands. Mountains, for millennia, a source of spiritual and sacred enrichment, prove how we live in an interconnected world — what happens in a faraway Himalayan watershed will affect us all.

These ranges confront challenges from population expansion to unplanned construction, infrastructure development, deforestation, new roads and unchecked tourism bearing the gifts of littering. These are all impacting natural habitats and exacerbating climate effects. We have to urgently recognise the need for sustainable development where growth, conservation and equity are compatible and which can save millions of lives from impending disasters.

I owe the Himalayas much as they changed my life. Over 60 years ago, as a young graduate student, I took a ride in the toy train from Siliguri to Darjeeling. Raised in Punjab, with relatively little biodiversity, I was amazed as the train began to rise from the foothills. I saw an abundance of life I'd never imagined existed on Earth — almost every tree came from a different species. The slow-moving train would stop frequently and I could see glorious butterflies of many colours, hear birds with wondrous, diverse calls. I thought I was in a paradise. I would not want to see this paradise lost. The mountains have given us so much. We need to give the Himalayas our love and care now.

Photos Courtesy: ATREE via K. Bawa



DO STOP AND SMELL THE FLOWERS: The Himalayas hold over 15 species of the delicate Impatiens plant, including the magenta Impatiens glandulifera (above) and the golden Impatiens stenentha (L)

READERS WRITE

Dear Times Evoke,

What a wonderful article on tech saving marine animals (10th September)! I was astonished to see the use of algorithms here. Please keep publishing such fascinating articles!

—MK Goel, Delhi

I was amazed to learn about the giant sea bass, this wonderful, endangered creature which can gulp down a shark but is in fact both harmless and curious. Aesthetic and thought-provoking, I love Times Evoke!

—Sneha Paul, West Bengal

Douglas McCauley's work was presented so beautifully! With climate change, tech must be used for more than putting filters on selfies. What a powerful article, TE!

—Namita Upadhyay, Lucknow

I really liked TE's article on Douglas McCauley's research being a prime example of how AI, drones and relevant scientific tools can make a real impact in saving crucial species from extinction and finding solutions to human-generated crises. Thanks to TE, I found myself motivated to make our planet a better place for all beings to live.

—Kuntal Dutta, Kolkata

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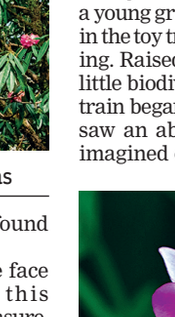

Dear readers, we are delighted that Times Evoke's 'To Nature, With Love' has sold out in its second print run! The TOI volume embodies our readers' deep care and our experts' inspiring vision. Together, we are all writing the greatest story on Earth, with your TE evoking our best nature!