Annual Review of Earth and Planetary Sciences, 2019. Raymond Jeanloz and Katherine H. Freeman (eds). Annual Reviews, 4129, El Camino Way, P.O. Box 10139, Palo Alto, CA 94303-0139, USA. vol. 47. xiv + 606 pages. Price: US$ 116.

This volume opens with an introductory article by Hoffmann, a renowned Precambrian geologist, wherein he explains the significance of the Proterozoic Eon (2.5–0.54 Ga). A neglected part of Earth's history for long, this interval is defined by many important milestones in the evolutionary history of our planet. For example, it was during this time-period that plate tectonics took its modern form resulting in a supercontinent formation and its dispersion later. The early part of this interval also saw the development of eukaryotic cells, chloroplasts and sexual reproduction. The end of the Proterozoic Eon is marked by repeated build-up of glaciers covering the entire Earth's surface, known in the literature as Snowball Earth. Hoffman's article narrates these unprecedented happenings during this dramatic part of Earth's history – that personally he likes to call this as a story of his 'love affair' with an eon.

Continuing the trend set by the Hoffman's introductory article, the volume also features a couple of articles that look at the continental formation and fragmentation, and how such geologic events impacted the Earth's evolution as a habitable planet. Wu and co-authors address triggering mechanisms for the destruction of stable cratons. They evaluate the data gathered on the destruction of North China Craton in the Mesozoic and find that development of mantle plumes and oceanic subduction play the major roles in decratonization. Turchyn and DePaolo discusses the evolution of seawater chemistry through Phanerozoic – a time interval that started 550 million years ago and extending to the present, essentially constructed using proxy data from sedimentary rocks. Changes in seawater chemistry (concentration of major ions) and sea level correlate with supercontinent formations and their dispersals, age of the ocean floor and width of the continental shelf area. In two other articles also, the theme continues to be tectonic activities and their long-term role in global changes. Krause *et al*. mainly use fossil discoveries from the Late Cretaceous of Madagascar and trace the biogeographic and lineage history of terrestrial vertebrates that is impacted by the fragmentation of the Gondwana supercontinent in the Mesozoic. Clapham and Renne review the role of carbon dioxide that outgassed into oceans and atmosphere during the repeat episodes of basalt extrusions, which coincided with environmental disruption, oceanic anoxic events, global warmings (called as hyperthermals) and mass extinction events.

The basalt extrusion episodes in the Earth's history are linked to mantle plume activity, which in turn is related to the processes taking place in the lower mantle. Nakagawa and Nakakuki focus on numerical modelling of the mantle transition zone and the uppermost lower mantle. They mainly evaluate how the water circulates in the deeper parts of the Earth and how this deep-water circulation facilitates the evolution of lower mantle and thermo-mechanical interaction across core–mantle boundary. As we have seen in the case of the Earth, an important aspect of any planet's evolution is the formation of the atmosphere or the lack of it. Researchers have hypothesized since the 1950s that the terrestrial atmosphere was created by gases emerging from the interior of the planet. Mukhopadhyay and Parai evaluate the mantle's degassing history, the style of mantle convection, and the outgassing exchange between the Earth's interior and the atmosphere. Extracting small amounts of mantle gas from dredging mid-oceanic ridges and oceanic islands using sensitive mass spectroscopy allows geochemists to determine the ratios of the isotopes in the mantle.

The evolution of atmosphere continues to be the theme for several other chapters in this volume. These articles look beyond the Earth and the solar system. For the past several years, we have been hearing about the discovery of planets circling the nearby stars called as extra-solar planets or exoplanets. These are categorized as Jupiter-like (high mass), Super Earths and mini-Neptunes (low-mass planets). Owen explores atmospheric evolution of exoplanets, although the comparison between observations and simulations remains obviously limited. The work suggests that the escape of light gases over time controls the overall evolution of the planets. Jontof-Hutter discusses 'compositional diversity' of low-mass exoplanets. Like what we see in our solar system, these low-mass exoplanets have diverse bulk compositions: those with deep gaseous atmosphere and also primarily rocky worlds. More precise data are expected from new missions that will enhance our understanding of the properties of the low-mass exoplanets. Advances in satellite technology make the relevant data-gathering abilities better regarding exoplanet atmospheres and their cloud formation dynamics. Helling delves into the cloud formation mechanism in exoplanet atmospheres by generating models which exhibit a wide chemical diversity described as mineral clouds, in contrast to the predominant water clouds on Earth. Gladstone and Young outline what has been learnt on the nitrogen-rich atmosphere of Pluto, a dwarf planet in the outer solar system, based on the data obtained by New Horizons' mission. The atmospheric processes, as they suggest, are comparable to Titan, although a satellite of Saturn, that has a planet-like dense atmosphere but dominated by nitrogen. McLennan *et al*. review the work on the sedimentary cycle of Early Mars, which had both similarities and differences with that of the Earth. The most important giveaway of the work conducted over the past two decades is that the environment of Mars in its infancy was habitable and the planet's sedimentary record is likely to have preserved biological markers.

Hazard warning, whether it is of short or long term, has become a part of public imagination these days. Earthquake early warning (EEW) systems are now popular among the stakeholders in many countries that are under greater threat of damaging earthquakes. Allen and Melgar evaluate both the scientific and infrastructural progress made globally in the past 10 years on EEW systems. The key is how far is the earthquake source, which determines the time the S-waves take to hit the target area. The countries like Mexico, Japan, Taiwan and South Korea have real-time alarms of impending shaking in place that are issued to the public, enabling shutdown and evacuation of buildings. Alerts to select user groups are issued in the United States, Turkey, Romania and India. Mention is made on a network of 84 accelerometers deployed by IIT Roorkee in districts across Uttarakhand. Global Positioning System (GPS) satellite constellation has been put to use widely to record crustal

deformation rates from the plate motions and ground movements due to large earthquakes. Beyond these applications, new unexpected uses have also been developed. For example, terrestrial water storages, soil moisture and snow accumulation can be estimated using GPS signals. Now that more of such satellite constellations by Russia, Europe and China are becoming active, Larson who reviews these developments, mentions that contribution from GPS networks will further enhance the warning capabilities for tsunamis, landslides, storms and volcanic eruptions. Uchida and Burgmann summarize the current understanding of repeating earthquakes in various tectonic settings. The recurring earthquakes share some common characteristics. Authors suggest that repeat earthquakes represent recurring seismic energy release from distinct structures such as slip on a fault patch. Repeaters are most commonly found on creeping plate boundary faults, where seismic patches are loaded by the surrounding slow slip.

Several articles in this volume address the themes that have gained importance in the backdrop of spiking greenhouse gases and global warming. In these changing environmental scenarios, the soil resources are under unprecedented threat due to landuse conversion and these changes end up in desertification, decline in organic carbon and physical loss of soil due to erosion. Banwart *et al*. assess soil properties and how they function within the critical zone – the rock and biotic realms. But one salutary take-home message is that the global degradation is reversible, if timely positive steps are taken. Like soil, water resources are also under unprecedented stress. Bowen *et al*. summarize the advances made in isotope data collection the last 20 years in the understanding of the water cycle at spatial scales from cities to the globe. The isotopic composition and its variation can be used to trace the water source and the water cycle process, and isotope hydrology provides investigative tools for many environmental problems. The review evaluates contributions using large-scale isotope data to understand water cycling within the atmosphere, between the land surface and atmosphere, within land-surface hydrological systems, and in human-managed water distribution systems. Systematic isotope sampling is being conducted at regional and city scales. Recent work on water distributions in Rajasthan and the findings that issued cautionary warnings on high levels of both anthropogenic and natural pollution is an example of such studies that come to our minds. Neuzil addresses the questions regarding how shale, clay and other argillaceous lithologies control fluid flow, mass and heat transfer in the upper crustal parts under various geologic settings. Studies show that petro-physical properties and geological environments provide major controls on the clay and shale permeability.

The current satellite technology can provide estimations on global carbon dioxide concentrations. Jiang and Yung explain why both modulations in global circulation patterns and small-scale surface emissions like wild fires, volcanic eruptions and droughts can cause atmospheric CO_2 concentration to increase rapidly. Rapid melting of large sheets of glaciers in high latitudes is now attributed to rising CO_2 levels that cause the Earth to warm. Melting of ice sheets is causing the sea levels to rise globally. Pitcher and Smith synthesize the studies on the growing frequency of supraglacial streams and rivers on glaciers, ice sheets and ice shelves. Supraglacial rivers link surface climatology with ice dynamics and are an important component of how glaciers and ice sheets respond to climate variability. The advances in remote sensing enhance the ability to monitor dynamics and hydrological processes of super-glacial rivers in a much better way. The rising sea level will impact many of the coastal ecosystems like salt marshes. FitzGerald and Hughes assess the vulnerability of coastal salt marshes in the backdrop of accelerated sea level that may outpace their ability to sustain the marsh processes, most importantly, the ecosystem services like sequestration of terrestrial carbon. Future rate of sea-level rise is a major determinant in deciding the fortunes of salt marshes. Brando *et al*. evaluate the toll these stresses emanating global change take on tree mortality and how that will accelerate soil respiration and fire occurrence. Globally forests store 90% of the total carbon in natural terrestrial ecosystems contributing to stabilizing the global climate. Forests are also estimated to remove ~27% of the total anthropogenic carbon emitted into the atmosphere. But the intensity and frequency of droughts and fires are taking a huge toll on forests. The recent massive fire within the Amazon forests is an example. If such challenges continue to increase in their magnitude, the ecosystem properties will respond in such a way that alternative states are more likely, impacting forest carbon stocks in our rapidly warming world.

The latest volume of *Annual Review of Earth and Planetary Sciences* can claim a balanced theme representation of both Earth-based and planetary studies. Most importantly, and justifiably so, some of the articles in this volume offer a fresh perspective on the fraught global ecosystems. The readers will realize that what used to be mere assumptions or projections on climate change some decades ago are now transforming into realistic models driven by actual data and validated by observations. Sceptics and deniers will have a hard time challenging climate warriors like Greta Thunberg who are now armed with such data.

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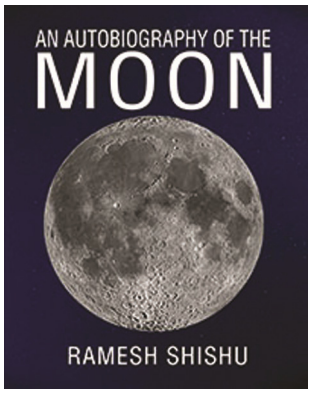

An Autobiography of the Moon. Ramesh Shishu. Vigyan Prasar, Department of Science and Technology, A-50, Institutional Area, Sector-62, Noida 201 309. 2018. 118 pages. Price: Rs 250.

This book consists of 16 small chapters, each answering one particular aspect of the moon. It is written in the format of an autobiography. It is very readable in view of its language as well as the font