Annual Review of Earth and Planetary Sciences, 2014. Raymond Jeanloz and Katherine H. Freeman (eds). 4129, El Camino Way, P.O. Box 10139, Palo Alto, CA 94303-0139, USA. Vol. 42. 795 pp. Price: US$ 101.

The 2014 volume of the *Annual Review of Earth and Planetary Sciences* features 30 reviews and as the editors claim, they range 'from well beyond the solar system down to the deepest mysteries of Earth's inner core'. True to their claim, as it has been in the past, the publishers have prepared a veritable scientific treat covering an exciting range of topics. Reviews always have a major functional role not just in articulating the status of current understanding; they also have a role in spreading the excitement of doing science, and celebrating the major scientific milestones. Equally important, they make us aware of the gaping holes in our knowledge. As in other branches of science, the last several decades have witnessed phenomenal growth in our understanding of Earth processes accompanied by giant leaps in probing the planets and the deep space beyond them.

The spectacular technologic feat of landing on a comet, about 510 million km from Earth between the orbits of Mars and Jupiter after a space odyssey of 10 years by the robot explorer Philae attached to its mother spacecraft Rosetta, represents the recent pinnacle in a series of accomplishments made in space exploration in the last decade. These interplanetary and space explorations not only help in expanding the understanding of galactic roots of our existence, but also bring in a deeper perspective on the sustainability and fragility of our home planet – defined eloquently by Carl Sagan as a 'pale blue dot' within the vast black lifeless expanses of the space. The importance of understanding the Earth processes cannot be overstated, especially at a time when the future of human civilization is perceived to be hung in a balance. Sustainability is no longer a theme that you hear only in the conference halls, but it is being discussed with increasing passion even in the drawing rooms. The present volume does justice to these and other exciting fields by including a genre of articles that deals with workings of Earth's interior, early Earth, tectonics, earthquakes, mountain building, mineralization, energy, climate, extrasolar planets and early solar system, and also on evolutionary pathways of organisms and the relative importance of biotic and physical driving mechanisms.

The book opens with an article by Hiroo Kanamori, a living legend in seismological research. Romantically titled as 'Falling in love with waves', the article provides a bird's eye view of the current status of the seismological research centred on major subduction zones. (The first seven pages of this prefatory article are missing and I do not know if this 'missing page' problem is universal or just restricted to my copy. If this applies to all the copies, I hope the publishers will find a way to reach the reading community to redress this problem.) A take-home message from Kanamori's article is that the broadband seismic and GPS data have revolutionized our understanding of subduction zone earthquake processes. He also mentions that the scientific community has been able to make successful forecasts of some subduction zone earthquakes in the recent past (e.g. 2010 *Mw* 8.8 Maule, Chile and 2012 *Mw* 7.6 Costa Rica). He says that the progress made in GPS and broadband seismology along with the increased understanding of frictional characteristics of the plate boundary interfaces and palaeoseismology allowed this to happen at least along some homogeneously coupled and less complex plate boundaries.

Suetsuga and Shiobara in their article 'Broadband ocean-bottom seismology' review the recent developments in the area of broadband seismic receivers and on the progress in the understanding of ocean bottom structures – the mid-oceanic ridges, subduction zones and associated earthquakes, hot spots and ocean lithosphere–asthenosphere boundary. Bürgmann and Chadwell summarize the recent advances in seafloor geodetic measurements to capture both small scale and regional deformation associated with the seafloor. Advances in this field especially made in the subduction zones in Japan and Cascadia, have led to further constraints on deformation related to oceanic plates and earthquake cycles. Nishimura *et al*. review global positioning system (GPS) and GPS acoustic observations – insights into slip along the subduction zones around Japan; GPS is a powerful tool to constrain Earth's surface deformation. The recent progress in GPS acoustic techniques ushered a new momentum in understanding subduction zone-related deformation cycles immediately above the slip regions in the offshore areas. The article by Nishimura *et al*. summarizes the findings around Japan based on onshore and offshore GPS observations in the background of the 2011 *Mw* 9.0 Tohuku-oki earthquake. Seismology is the subject matter of yet another article. Brodsky and van der Elst review the current understanding on the dynamic triggering of earthquakes. The 1992 *Mw* 7.3 Landers earthquake in southern California is known for generating dynamically triggered earthquakes in faraway locations and the regional earthquake rate was elevated for days since the Landers earthquake. More than 30 earthquakes have been known to be associated with dynamically triggered earthquakes. These are caused by the passing surface waves and are different from the regular aftershock series. The mechanisms of dynamical triggering are still being debated. Tanaka brings out the increasing importance of applying particle physics technology in deep probing of Earth's interiors. This article reviews the recent progress made in applying quantum techniques (e.g. quantum neutrino probe) for probing Earth's interior and to obtain a finer resolution than what is obtained through current geophysical and seismological methods.

This volume has included a series of articles on cosmological research, early Solar System, early Earth and Mars. Jura and Young review the current understanding of the elemental composition of extrasolar planets, which are being identified with an increasing frequency. The compositional evolution of extrasolar planets can be compared with the evolution of planets of the inner Solar System. Brownlee reviews the progress made on the understanding of the early Solar System based on the mineralogical and geochemical data from a comet, collected by NASA's Stardust Mission. In an article titled 'How did early Earth become our modern world', Carlson and co-workers examine the processes that led to assemblages of dispersed dust and gas in the solar nebula into a planet. The first-order features of modern Earth such as its bulk composition and the differentiation into crust, mantle and core were all seeded during the processes in the first 100–200 Ma of the history of the Solar System. Ehlmann and Edwards discuss the

mineralogy of the Martian surface. The last 15 years of orbital exploration facilitated these insights into the composition and evolution of Mars. The red planet globally has a basaltic upper crust with regionally variable quantities of plagioclase, pyroxene and olivine. One outstanding question is related to the apparent absence of the relative proportions of intrusions and volcanism in the midst of basaltic crust. Martian surface shows remarkable evidence of mineralogic interaction with water and related aqueous environments resulting in the deposit of clays, carbonates, sulphates and chlorides. Asphang in his article 'Impact origin of the Moon', evaluates various theories on the origin of the Moon. The dominant theory of Moon formation that relies on an early giant impact on Earth and consequent differentiation of Moon from the mantle of the impactor is on an uncertain footing. This is because lunar rocks show much similarity to Earth in chemical composition rather than to the mantle composition of the impactor. New models are proposed but all of them require further validation.

Evolution and some newly found properties of Earth's core are the focus of another article in this review. Duess discusses the heterogeneity and anisotropy of Earth's inner core. He draws on seismic observations which suggest that the inner core is anisotropic with larger velocity in the polar region than in the equatorial direction. But there are also many fundamental questions on the thermal and compositional structure that need to be resolved. Badro discusses transitions in the electronic spin state within the lower mantle as a function of increasing pressure and its role in influencing the thermochemical state and dynamics of the mantle. Cartigny *et al.* review the processes of diamond formation from a stable isotopic perspective. They say that diamond is a metasomatic mineral that results from the oxidation or reduction of mobile C-bearing liquids that react with the pre-existing lithologies like eclogites and peridotites. Gehrels summarizes the recent development in detrital zircon geochronology and its application in determining sedimentary provenance, constraining depositional age, and most importantly, as a tool to gain insight into the Archean tectonics and early Earth the crustal evolution. Kohn discusses recent advances in metamorphic petrology of Himalaya. He visualizes that closer geochronologic constraints and elucidation of temperature–pressure paths will revolutionize our understanding of the metamorphic and exhumation processes in the Himalaya. An article titled 'Hydrogeomorphic effects of explosive volcanic eruptions on drainage basins' by Pierson and Major underscore the devastating impact of volcanic eruptions on the landscape and the long-lasting impacts on geomorphic and hydrologic regimes in their vicinity. Using different global examples of Mount Pinatubo (the Philippines), and Mount St Helena (USA), the authors discuss the post-eruption hydrologic and geomorphic recovery methods.

Barrett analyses the evolutionary pathways of dinosaurs and how they became dominantly herbivorous. The environmental and biological drivers for this change still remain unclear. Hunt and Rabosky in their article 'Phenotypic evolution in fossil species: pattern and process', bring out the issues involved in evolutionary changes at the species level. Evolutionary scientists find that the details and finer resolution required to capture the transformation of the species are lacking in fossil records. In fact, late Stephen J. Gould subverted this issue and suggested that species-level transformation seldom takes place, once it is established. Gould and co-workers introduced the concept of punctuated equilibrium against much established theory of a steady accumulating change called phyletic gradualism, which is being fiercely debated. Fortelius *et al.* in their review 'Evolution of Neogene mammals in Eurasia: Environmental forcing and biota interactions – biotic interactions or physical forcing', discuss the relative importance of biotic elements and physical forcing in driving evolutionary change. This is a longstanding question, and can be summed up as follows: species with evolutionary novelties emerge under harsh environmental conditions triggered by climate forcing (e.g. climate change), whereas mild environments may set the stage for strong competition and eventually the fittest will survive. Rodriguez-Tomar discusses the usefulness of growth rings in trees and shells and varves and rhythmic bands in lake deposits to resolve cyclic orbital climate changes on sub-annual to millennial scales.

Zhu and co-workers in their article 'Earth abides arsenic biotransformation' focus on the most dominant toxic element that causes severe health problems. Biotransformation of arsenic is reviewed from the perspective of the formation of Earth and the evolution of life. This perspective is summed up in one of their introductory statements. 'Why does arsenic perturb life?', and as a reply, they state: 'At a deeper level it is the difference between the chemical properties of arsenic and phosphates that creates biological problems and prevents arsenic from being utilized in DNA and other high-energy biological molecules….' Blum *et al.* discuss mass-dependent as well as mass-independent fractionation patterns in mercury isotopes. This interest stems from the fact that mercury becomes a potent neurotoxin in the environment and mercury isotopes can be used to trace environmental exposure to this pollutant. Miot *et al*. discuss 'Microbes and mineral interaction'. Microorganisms can trigger mineral formation, transformation and dissolution through diverse chemical reactions. Recent advances in X-ray and electron microscopy have set the stage for major advances in this field.

Pierrehumbert focuses on short-lived substances like methane, hydrofluorocarbons, black carbon (aerosols) and ozone, whose atmospheric lifetimes are under a few decades, and their contribution to radiative forcing and the consequent climate change. He cautions against the emphasis on the materials that are broadly short-lived climate pollutants

Examples of downstream sedimentation caused by erosion of volcanic sediment from disturbed basins.

rather than on reducing long-lived carbon dioxide emission to zero without delay. This article is relevant in the background of the recent UNEP report which mentions that by 2100, all greenhouse gases must fall to zero, or the world will face what IPCC scientists have described as 'severe, widespread and irreversible' effects of climate change. But the emphasis, according to the author, should be on carbon dioxide and not on short-lived pollutants. Two articles in this volume throw light on new methods and understanding in energy research. The role of organic sulphur compounds in the formation and thermal degradation of sedimentary organic matter is known. The recent advances in sulphur isotope analytical methods have now enhanced our understanding of this process. Armani reviews the recent developments in sulphur isotope analyses, which revealed natural isotopic structures reflecting microbial and thermal sulphur–carbon reactions affecting oil sources and reservoirs. Betrand and Horsfield review the thermal maturation shale-gas systems. Being different from traditional petroleum reservoirs, characteristics of these shale-gas systems are complex because of their depositional and diagenetic nature. Understanding of thermal and geochemical histories of these reservoirs has improved, as revealed in the mineral and organic properties at the sub-micrometre scale. But key questions remain regarding the fundamental physics governing transport and retrieval mechanisms. Most importantly, mitigation of the environmental hazard of oil and gas production from shale still remains elusive. Readers may check out the news feature in *Nature* dated 14 December that advocates a reality check on the actual potential of shale gas production. It cautions that much of the energy industry may be vastly overestimating how much natural gas can actually be produced in the coming decades.

All in all, the articles in this volume make a representative cross-section of current research advances in Earth as well as planetary research. The bulky volume contains articles widely ranging from exoplanets to paleobiology, and the editors may do well to pool up these varied titles subject-wise, and categorize the articles under various individual sections at least in future issues so that it helps the readers to target their attention according to their specific interests without being overwhelmed by the diversity of topics and sheer fecundity exhibited in the pages.

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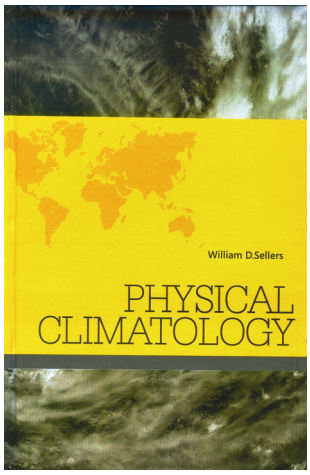

Physical Climatology. William D. Sellers. New India Publishing Agency, 101, Vikas Surya Plaza, C.V. Block, LSC Market, Pitam Pura, New Delhi 110 034. 2015. viii + 272 pp. Price: Rs 1550.

The first version of this book[1], which originated from a course of lectures taught at the university level, is among the most valuable textbooks available on this topic and has been widely used for nearly five decades. This book was designed to provide the basics of physical processes relevant to climate system. It has a concise collection of topics sequentially organized in 13 chapters suitable for both graduate and postgraduate level curriculum. It provides theoretical basis for radiation, water and energy balance, turbulence, surface energy transfer, and the hydrological cycle enroute to basis for the theories of climate change. Although other textbooks have emerged on the same topic, it should be mentioned that the presentation style of this book, which is more descriptive and less mathematical, still caters to a heterogeneous readership and its information cannot be simply ruled out as rudimentary.

The first six chapters of this book deal with radiation and transport processes from hemispheric viewpoint and atmospheric radiative balance perspective. Further chapters exclusively address the physical processes relevant to water balance, turbulence transfer and surface energy exchanges and introduce a pathway to paleo-climatology. There is also discussion on bottlenecks in the synthesis of climate change. The discussion on water balance and evaporation is presented at length compared to contemporary textbooks. Although the discussions on current debate relating to climate change and climate sensitivity synthesis cannot be seen much in this book, it should be mentioned that it was published in an era when numerical weather prediction was given more prominence, with less attention to climate model development and synthesis.

All in all, this book is well-written, well-illustrated, and is a good contribution to those interested in understanding and pursuing research on physical climatology. We recommend this book, both as an introductory text and a comprehensive review of the physical climatological processes. This is one of the well laid out books and is extremely readable, except for the use of obsolete units.

1. Sellers, W. D., *Physical Climatology*, The University of Chicago Press, 1965, p. 272.

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