

possible 'water wars'. Simply put, the struggle over water is not only about water; it is also about land and more extensively, about democracy and rights.

Examining corporate control over water and the ensuing struggle for water resources worldwide, Gonzalez and Yanes join the activists in saving water from overt and covert privatization. This book is a grim reminder and a wake-up call to liberate water from the predominant notion that 'whoever controls water controls society'. Exposing the complex arguments surrounding water, the book makes technical and scientific case for pushing back the market fundamentalism in favour of equity and social justice. All this is present in a single drop of water.

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'Philosophers are people who know less and less about more and more, until they know nothing about everything. Scientists are people who know more and more about less and less, until they know everything about nothing.'

– Konrad Lorenz

Recently I happened to read an article written by Gavin Schmidt (in a book entitled *What's Next*, Quercus, London, 2009), a climatologist and presently the Director of NASA's Goddard Institute of Space Studies in New York. The article discusses the increasing tendency in modern science to balkanize itself into smaller sub-disciplines often discouraging cross-cutting synthetic research. Schmidt develops this theme from his turf of interdisciplinary field of climate – study of an interactive system consisting of atmosphere, oceans, land and ice – their dynamics, chemistry and composition. The author exemplifies the critique by pointing at the study of ocean drill

cores (a branch called palaeoceanography), which actually provides a 'time sequence at a specific point, and they can be difficult to compare in detail with other cores, because of the uncertainties in assigning an age to any particular depth'. Thus, Schmidt says, 'the vast bulk of papers in the field discuss transient changes at specific locations rather than making much more difficult assessment of the geographical patterns of changes at any one time'. The problem here is that of verticality – how the data from a vertical core translate into a study of changes in a horizontal way. Palaeoclimatologists might disagree with this critique, but the point made here is valid in understanding how a sub-discipline (which applies to many branches of science) gets cocooned over the period with its hardened band of practitioners, isolated sub-culture defined by specific jargon and language, making it difficult for others outside the field to interact. Schmidt likens this to 'tragedy of commons' in economics – 'the collective impact of rational individual decisions can lead to undesirable outcomes'. There are many more examples like this in Earth Sciences: for example, the mantle geochemistry and the mantle geophysics, and never the twain shall meet. The fabled Indian story of blind men describing the elephant is apposite in this context. These thoughts rushed back to me when I saw this book under review, whose stated objective is to 'encourage cross-disciplinary research while helping scholars keep up with the flurry of new developments across our field'. True to their mission statement, some of the articles in the volume make excellent synthesis of the significant developments in various sub-disciplines in Earth and planetary systems to develop a cogent picture of our seemingly disparate knowledge encompassing the dynamic, chemical, physical and biological processes of the Earth, extending to other planets.

The first scientific article in this volume that follows the prefatory article (an in-depth interview) on James Morgan, a pioneering scholar of water chemistry, in fact offers a befitting solution to the issue of need for interdisciplinary linkages, raised earlier, specifically on climate studies. This review is a masterful example of how the quantitative studies of modern monsoon and palaeoclimate reconstructions from various parts of the globe are integrated to develop robust

models of global monsoon variability across various spatial and temporal scales. Written mostly by Chinese scholars led by An Zhisheng (a palaeoclimatologist), this review goes through a wide spectrum of cross-disciplinary climatic studies (including contributions from Indian researchers like Sulochana Gadgil, J. Srinivasan, R. S. Nanjundiah, A. Chakraborty, B. N. Goswami, among them), to understand global monsoon dynamics. The greatest challenge in this field now is to understand the future global monsoon behaviour in view of the new bully on the block – the human impacts on ocean and atmosphere energy budgets, and their negative consequences on global monsoon system. Besides the anthropogenic influence on monsoon dynamics, there is increasing evidence that the human activities also lead to accelerated glacial shrinkage both on the north and south pole regions. Alley and co-authors (Sridhar Anandakrishnan, Penn State, among them) summarize the geophysical and computational database to isolate the feedback constraints on the forcing of polar ice-loss, which will have dramatic consequences on the global sea level. For instance, calculations show that a loss of most of the West Antarctic ice sheet may cause >3 m of sea level rise for the coming century – a worrisome scenario, indeed. The culprit identified here is the warming ocean water that melts the underbelly of the continental ice, but the greater challenge is to know whether the threshold of melting is already reached or not.

Evolution of early humans in Africa was linked to the long-term tectonic, environmental and climatic variables. These factors in combination shaped the selection pressures on early humans and thereby acted as drivers of evolution of our ancestors. How did the vegetarian apes living on trees make a transition to ground-dwelling meat-eating hominids, about 4.5 million years ago? Naomi Levin addresses this question and reviews the linkages of tectonism and climatic evolution in developing the local hydrologic and ecological niches in the development of human traits. One of the first papers that needed my curiosity early in my career about the relation between tectonic environment and human evolution was published in the *Journal of Geophysical Research* back in 1994. Geoffrey King, Geoffrey Bailey and Derek Sturdy published this study on

the linkages of active tectonics and human survival strategies, and suggested that increased aridity and lack of tree cover in Africa's savannah (grasslands) along with active tectonism and volcanism within the rift valley are the major drivers of this transition. The first two authors of the 1994 paper address this question again in their subsequent paper of 2006 in *Antiquity*. These exciting papers (my bias, possibly) are surprisingly missing from the citation list of Levin's otherwise comprehensive review.

The transition from tree-living apes to bipedal hominids was momentous from the perspective of the evolutionary trajectory of the cosmos itself. As the most successful species ever, we are able to multiply enormously and crowd the planet. One of the negative consequences of this unprecedented and unparalleled growth is that of the anthropogenic destruction of biomes and ecosystems across the globe, supplemented also by climate warming and ocean acidification. Dietl *et al.* in their review address the usefulness of conservation palaeobiology, an emerging field that provides us insights into biotic responses to environmental stressors by relying on both near-time and deep-time (fossil records) approaches. This is an example of how classical methods in palaeontology can be contextualized for conservation and restoration of biodiversity and ecosystem services. Apart from loss of biodiversity due to human interferences – a relatively recent phenomenon, Earth's past, however, is also replete with cases of taxonomic diversifications and extinctions due to natural causes. This is what Fraass *et al.* review by focusing on the studies of macroevolutionary history of planktonic foraminifera. Evolution of these microscopic organisms is known to have been affected by the bolide impact at the end of the Cretaceous and also during the major reorganization of climate and ocean circulation during the Eocene–Oligocene transition. Palaeoenvironmental reconstruction using ancient soils (paleosols) is the theme of another article by Tabor and Myers. They present the progress made in the last decade to understand palaeoclimate and environment (rain, temperature, vegetation and atmospheric (CO₂) levels through time) using palaeosol morphology, mineralogy, chemistry and stratigraphic architecture. The volume also has an article by Bird *et al.* that reviews our current under-

standing of the formation of pyrogenic carbon (PyC for short) – a potentially slow-moving component in the global carbon cycle. PyC is a general term for 'thermo-mechanically altered carbon' sourced from biomass burning and combustion of fossil fuels. It is understood that a major part of PyC transforms in comparatively short timescales, although some part of it is highly recalcitrant and stays in the environment for millennia. The article taps on the recent interest on this topic as the charred PyC may provide a way for long-term carbon sequestration that may offset a significant part of anthropogenic emissions. Like carbon, the biogeochemical sulphur cycle has an important role in regulating Earth's surface conditions. The article titled 'Re-thinking the ancient sulphur cycle' by Fike *et al.* reviews the ancient record of marine sulphates and sulphides, which are linked to the prevailing microbial ecosystems reflected by specific isotopic signatures. The advances in analytical techniques have helped in improving the precision of such isotopic measurements.

In spite of the observational studies of the exhumed granulitic terrains, the composition of much of the lower crust remains enigmatic. By probing the variations in the compositions of the lower crust, Hacker *et al.* in their article suggest that the lower crust in many regions is felsic in composition rather than mafic. Being lighter and less dense, felsic material may rise buoyantly and cause material to be added (laminated) at the base of the lower crust. Crustal-evolution continues to be the theme of three other articles which discuss how continental crust evolved from magmatic arcs around continental margins. Ducea *et al.* review the evolution of magmatic arcs of continental lithosphere as exemplified by the western margin of the Americas. The cycles are accompanied by measurable geochemical interactions between mantle and crust. Jagoutz and Kelemen discuss how compositional and physical processes built continental crust within two Mesozoic arcs, one in south Central Alaska (Talkeetna Arc) and the other in Northern Pakistan (Kohistan Arc). Although formed in an intraoceanic setting, combined seismic and compositional data suggest that these arcs had a complex evolution encompassing both subduction and collisional processes at various phases of their development. Observational geodynamics is entering into

a new phase of discovery with rapid advances in geomagnetic and geodetic data acquisition. Xiao *et al.* review the geologic history of the Central Asian accretionary system, based on new structural age, and palaeomagnetic data. Continental accretion and growth at the Central Asian Orogenic Belt began in the Neoproterozoic and culminated in the Permo-Triassic.

Harlow *et al.* review the occurrences and origins of jadeitites, associated with high-pressure/low-temperature metabasaltic rocks (e.g. eclogites and blueschists) within the subduction systems. By studying the fluid compositions within this mineral, we will be able to understand the geochemical processes within the ancient subduction zones. Pressure gradient-driven flow within the asthenosphere and plate boundary forces determine the rate of change of plate velocity. Iaffaldano and Bunge, based on current observations, review the present understanding of rapid plate velocity variations and their impact on dynamic topography (e.g. transient uplift events, episodic burial and exhumation of passive continental margins, evolution of rift basins, etc.). In a somewhat stand-alone article, Gonnermann chronicles the complex phenomena of magma fragmentation and generation of pyroclasts. The subject matter complexly involves both solid and fluid mechanics and has scope for future research even on a planetary scale, as many of the planets and moons of the solar system exhibit explosive magmatism.

In an article titled 'From geodetic imaging of seismic and aseismic fault slip', Avouac throws light on the importance of dynamic modelling of the seismic cycles using the examples of three seismically active areas that he is familiar with: the Nepal Himalaya, the longitudinal Valley fault in Taiwan, and the Sumatra megathrust. Besides the seismic slip, observations suggest that aseismic slips (smooth creeping movement) are also common between the fault blocks. Recent surge of interest in the latter type of movement is due to the promise it holds for better understanding of the dynamics of interseismic coupling. Tectonic geodesy and InSAR provide high-resolution tools to understand the slow-slip kinematics. The key element in this narrative is that friction on the fault is spatially heterogeneous with 'interlacing rate-weakening and rate-strengthening

patches'. The fault ruptures seismically in areas where the 'rate-weakening patches' are closely interconnected and the movements are aseismic in areas where the rate-strengthening patches dominate. The presence of clay-rich zones, high temperature and elevated pore-pressure within the fault zones tends to promote aseismic slip. I think the 2004 megathrust rupture makes a perfect case to test this theory to understand how this bimodal behaviour played out. That the rupture lost its steam, as it reached the Andaman segment, suggests the possibility of the dominance of rate-strengthening patches in that area. An important challenge is to constrain such combination of movements along the fault zone covering an entire seismic cycle. Two end-member modes of deformation – the elastic–brittle and viscous behaviour – are well established with regard to the plate movement on the Earth or rigid outer shells of other planets as well as the convection cells within the interiors. Between these end-members, a transient anelastic deformation and energy dissipation has also been recognized. Experimental data at mantle temperature and seismic frequencies show that grain boundary sliding is a key process by which this transitional deformation mode occurs between elastic and viscous behaviour. This is the subject matter of the article written by Faul and Jackson that deals with experimental studies on transient creep and strain energy dissipation, causing the attenuation of seismic waves as they pass across the Earth. They discuss the experimental results obtained from a variety of materi-

als, from ice and ceramics to minerals and rocks, that cover a frequency and temperature range applicable for seismic wave propagation in planetary interiors. These experimental studies are important for developing seismic velocity models of planetary bodies and also to improve the existing models of our planet.

Advancements in planetary science are the topics of discussion in two review articles in this volume. One article (by Heng and Showman) discusses the state-of-the-art of the exoplanet studies, while the other (by Tien) summarizes the recent observations on the evolution of planetary atmospheres. The first exoplanet was detected in the 1990s and now they number in the thousands. The astronomical observations (from the Earth and space) on mass, radii and bulk chemistry of exoplanets lead us to newer understanding of their atmospheres and habitability. Seeing the excitement bubbling up around the study of exoplanets, we may agree with the authors that the coming decade 'holds promise of ground-breaking advances in the study of exoplanets'. The dissipation of proto-atmospheres (atmospheric escape) during the early phase of terrestrial planets of the solar system is an important step in the later evolution of atmospheres. Tien reviews the mechanistic models for the loss of molecules, elements and ions from the outermost layers of an atmosphere belonging to terrestrial planets of the solar system and exoplanets. The author is optimistic that this field of research may be entering into a new phase of further discoveries with the accumulating observations on exoplanets and the

advent of new space telescopes dedicated to their discovery. Transmissions from the Space Telescope Imaging Spectrograph of the Hubble Space Telescope must have contributed a lot to these researches.

Before I wrap up, I must record my appreciation for the delightful interview with James J. Morgan, who has an iconic presence in environmental chemistry, published in this volume as a prefatory chapter. Self-effacing to a fault, his conversations will make one realize that the recipe for good science as a modern cooperative enterprise lies in a simple combination of a few variables: strong fundamentals, ability to frame the right questions, untiring efforts, smart colleagues and bright students. With this interview as an appetizer and rest of the material that followed, this volume is able to educate and enlighten us by offering panoramic views of some of the current areas of research in Earth and planetary sciences. About 76 authors were involved in preparing 20 articles in this volume and that includes about 26 Chinese scientists (funded by the Chinese Government through their National Science Foundation), and hardly any representation from India. What does it tell us about the Indian research efforts in Earth and planetary sciences?

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