Annual Review of Earth and Planetary Sciences, 2010. Raymond Jeanloz and Katherine H. Freeman (eds). Annual Reviews, 4139 El Camino Way, P.O. Box 10139, Palo Alto, California 94303-0139, USA. Vol. 38. 599 pp. Price: US$ 89.

The major paradigms that shaped the solid earth sciences over the past several decades are 'essentially geodynamics concepts', so says a report on a workshop on Computational Geophysics held at Caltech in March 2009 (Grand Challenges in Geodynamics, Draft #2, National Science Academy, 29 December 2009). The first of these is the well-known plate tectonics – basic phenomenon that underlines the crustal evolution. The second paradigm is the mantle convection – the most influential process that controls the internal workings of a planet. The third paradigm, according to the report, is the 'dynamical relationship between faulting and earthquakes', and the fourth is the geodynamo that controls and sustains the magnetic field. All researches in solid earth sciences derive their motivational strengths essentially from the above-mentioned paradigms. Although the set of processes emblematic of these paradigms explains varied earth observations, it is sobering to remember that there are many unresolved questions that are associated with these processes. The major questions are centred on the linkages of geodynamics and other earth processes, including climatic evolution and variation or even the evolution of life. The crystal-ball gazing will tell you that these challenges are certainly going to form the do-list for the 21st century earth sciences. The book under review is reflective of these imperatives. Out of 20, there are about 12 articles in this volume that directly or indirectly deal with geodynamical problems. The volume also contains a couple of articles on planetary science and palaeontology. And, of course, a few articles on climate, and given the topical interest, their inclusion is no surprise.

The article by Uwe Ring *et al.* on the Hellenic subduction system in the eastern Mediterranean, a veritable natural field laboratory for retreating the subduction zone, presents the recent understanding of the processes related to subduction, accretion, arc magmatism, exhumation and large-scale continental extensional tectonics. A question that naturally comes to me is that how do the observations from a geologically younger fossil subduction zone with high-pressure metamorphic events compare with some of the lithologies and structures identified in the Precambrian terranes that may be possibly related to ancient subduction zones. One major issue in the Hellenic region seems to be roll-back of the subduction front – a feature the authors relate to the possible interaction of the subducted slab with the 660 km discontinuity between the upper and lower mantle. In a region comprising Anatolia (Turkey), Eurasia and Mediterranean Sea, Le Pichon and Kreemer use the regional GPS measurements along with the geological and geophysical data to constrain the dynamics of one of most geologically complicated terrains. They propose a complex geodynamical scenario that explains the present rapid circular counter-clockwise motion. At the end of the article they present a 'possible dynamic scenario' to explain the circular counter-clockwise motion. Much of this scenario appears to be speculation and requires further studies to strengthen the suggested hypotheses.

In two other articles, Molnar *et al.* and Willett present the link between tectonics and climate, using the examples of the Himalayas and the Alps respectively. Molnar *et al.* aver that the rising of Tibet over the geological timescales determined the Asian climate and it acted simply as an orographic obstacle, rather than offering a surface that heated the overlying atmosphere (as a heat source). The article in fact deconstructs much of the previous findings, including some of the earlier conclusions of Molnar himself. The rewriting of the Tibetan story became necessary, I think, because of the new findings from the palaeoclimate proxies in the region, especially by the Chinese workers. Sean D. Millet, in his article links the enhanced Late Neogene (a time interval spanning approx. 7.5 m.y. ago to present) erosion to the increased exhumation rate of the Alps. This also coincides with global cooling trend with periodic ice-volume fluctuations associated with the northern hemisphere glaciation (a brief hiatus of warming during Pliocene). The increasing trend in the orographic relief can be ascribed to the isostatic rebound as a response to erosional unloading even as the episodic tectonic processes have slowed or stopped in the Alps. This is an antithesis to what is happening in the Himalayas, which, unlike the Alps is a tectonically active mountain chain, responding to the heavy monsoon rain-induced erosion. The southern flank of the mountain which suffers the brunt of the monsoon grows in stature with concomitant increase in tectonic activity, internally resonated by the southward channel flow of deep crustal material from underneath the Tibetan plateau to the range front. I would have loved to see the discussion of such amazing linkages of surface processes, climate and the internal processes in the article by Molnar *et al.* (and Molnar is a pioneer of such studies), which somehow chose to stay clear of such hair-raising issues.

We will have no difficulty in identifying the most important earthquakes in the last decade. The 2004 Andaman–Sumatra and the 2008 Sichuan, China earthquakes figure prominently in that list owing to their unprecedented nature of the extent of rupture and style of faulting. A major question with regard to the 2004 earthquake is whether there was a small slip component in the northern segment. The jury is still out on that question, I think. The paper written by Sheare and Burgmann concludes that bulk of the slip was 'fast enough to radiate seismic waves', and they conclude that the 2004 earthquake is not different from other mega-subduction earthquakes. But why the northern segment is non-tsunamigenic is an issue that did not seem to have attracted much attention, which I believe it deserves. The paper by Zhang *et al.* is a detailed post-mortem report on the 2008 Sichuan earthquake, which attracted worldwide attention from the seismologists as much for its ferocity unleashed from a not-so-familiar fault, as for its complex faulting style. Surprisingly, the pre-earthquake GPS measurements indicated slow strain accumulation – a question that is being addressed in the paper. The fact that the rupture involved more than one fault with differing geometries, with distributed deformation partly answers that question. This paper is a testament to the sophistication that the Chinese scientists have acquired over a short period in seismological research.

The Ethiopian and Afar rifts in northern Africa are the only places where the transition between the continental and oceanic rifting is exposed onshore. The area offers an ideal natural laboratory to understand the continental break-up processes (mainly magma intrusion and dyke-induced faulting), which seem to be highly localized on the discrete segments along the rift axis and temporally restricted. Cynthia Ebinger *et al.* use the seismic geodetic and petrologic data to determine the length and timescales of magmatism and faulting, and the nature of strain partitioning. A fresh sequence of rifting episode consisting of diking and earthquakes that commenced in the Afar region in September 2005 helped the researchers to understand the processes in real time. Fisher *et al.* in their article 'The lithosphere–asthenosphere boundary', present seismological models to constrain the properties to differentiate the lithosphere from the astennophere. They see major differences in materials properties between the oceanic and the cratonic lithosphere–asthenosphere boundaries.

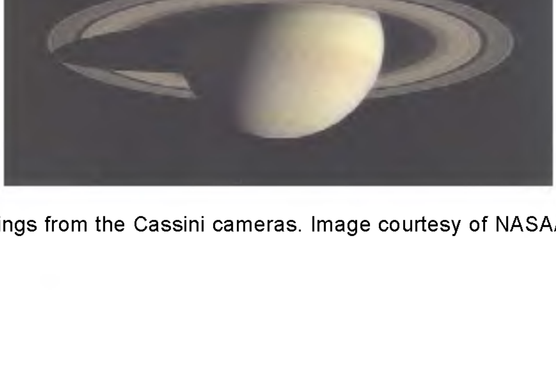
Geologists are familiar with 'pseudotachylites' within the fault zones that are the rock melts formed due to frictional heat during fault movement. Frictional melting processes on the planetary materials can be produced also by other processes like meteorite impacts. The physics of the frictional and shock-induced melting in planetary materials is elucidated in Spray's article, mainly based on laboratory simulations. A new class of seismic phenomena called glacial earthquakes is discussed by Nettles and Ekstrom. These are produced by the calving of glaciers and the technique can be developed into a major tool in climate studies as the calving of glaciers can be linked to accelerating mass loss and melting of glaciers. The physical and chemical properties of aerosol particles (sulphates, sea salt, mineral dust, biogenic particles like spores and pollen, carbonaceaous particles, etc.) are the subject matter of the article by Posfai and Buseck. Aerosols can scatter and also absorb sunlight, thereby reducing the energy flux reaching the earth's surface. There is a paper, which I consider pure fun in this volume (Hunt and Vriend). This paper is about 'booming sand dunes' and it elucidates geophysical field studies and laboratory studies to constrain the conditions by which sand can produce booming and even melodious tones while building certain kinds of desert dunes.

William M. White reviews the work on mantle plumes from a geochemical angle. Mantle plume theory always has met with a trenchant, although by a small group of critics. Despite such criticisms, the geophysical (seismic tomography) evidence suggests the existence of deep mantle plumes, at least in some sites – the oceanic islands are considered to be a standing testimony to the deep-seated plumes. However, chemical and isotopic analyses of the oceanic island basalt give out mixed signals as to its deep origin at the mantle–core interface, more specifically the 2700 km discontinuity called *D″*. In another paper, Gabriel J. Bowen introduces the concept of isocapes – a GIS-based technique of producing the spatio-temporal distribution of isotopes in the environmental materials, which in turn can be used to test biogeochemical fluxes. This method is based on the understanding that varying environmental conditions – climatological, geological, biological and hydrological – can exert an influence on isotope distribution. The papers on palaeontology deal with the origins of whales and the Devonian fish. Both give comprehensive reviews of the subject matter. By the way, the earliest whale fossils were discovered in the early Eocene deposits in northwestern India, pioneered by Indian researchers. The papers on the planetary science deal with evolution of Saturn's rings (Larry W. Esposito) and early evolution of planets from planetesimals (Chiang and Youdin). Esposito's article presents a review of observations derived from the Cassinni mission, and the article on planetesimals reviews the physics of formation of the protoplanetary disks. The desiccated river valleys discovered on the Martian surface suggest that it once rained on Mars. The question is what could have been the mechanisms that generated the rain and the consequent morphology. Toon *et al.*, by employing numerical models based on terrestrial analogues, have reached the conclusion that large impacts did the trick. The authors caution that the terrestrial analogues may not be exactly appropriate for the Martian conditions. The present volume also contains what appears to be a customary prefatory article of personal overview of a leading earth scientist. This time the honour went to Ikuo Kushiro, who is a leading experimental petrologist (he would prefer to call his field as 'magmatology') at the University of Tokyo, Japan.

So how do we rate this book. As it is the practice, the content this time is also a mix of fundamental research and topics of practical interest, including earthquakes and climate. On the whole the book represents a cross-section of major recent milestones in earth and planetary sciences. But the range and breadth of earth and planetary studies have become so complex, that it is not easy for any *Annual Review* to be truly representative, and much also depends on the proclivities of the editorial board. So there is always a certain give-and-take between the publisher/editor and the reader. A major omission comes to my mind. The last few years have witnessed some major leaps in the understanding of the core–mantle boundary and the processes within the core. The discovery of phase transition of the magnesium silicate mineral, perovskite to postperovskite at the core–mantle boundary is one such development. This may have major implication on the internal workings of the earth, particularly on the triggering and buoyancy of deep-seated mantle plumes. However, reviews of such studies have not found a place in this volume.

C. P. RAJENDRAN

Centre for Earth Sciences,
Indian Institute of Science,
Bangalore 560 012, India
e-mail: cprajendran@ceas.iisc.ernet.in



Saturn and its rings from the Cassini cameras. Image courtesy of NASA/JPL/Space Science Institute.