Climate change—environment and civilization in the Middle East

Arie S. Issar and Mattanyah Zohar

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In reflecting on human history and the causes of the rise, decline and fall of past societies and civilizations, many writers and thinkers—perhaps the majority—have long explained these in terms of social and political struggles—invasions, civil unrest, economic exploitation and the like. Add to this the modern concept of “ecocide”—the intentional destruction of ecosystems and species, the loss of topsoil, environmental pollution, new diseases, and human-induced climate warming, and there is no lack of drivers of history to choose from. In his new (2005) book, “Collapse: How societies choose to fail or succeed,” Jared Diamond details how many ancient communities and societies failed due to these and other anthropogenic pressures related to water quality and shortages, excessive hunting and fishing, ever-growing ecological footprints, energy shortages and population growth.

But there are also other non-climatic natural drivers of socio-political events, such as the recent Bay of Bengal tsunami, the effects of which will no doubt continue to be felt for many years. Though this is certainly not the first fault-generated tsunami to have hit the region, with today’s concentration of people along low-lying coastlines, it is the most catastrophic regional disaster in terms of loss of human life and rapid landscape change. Had there been distinctive societies living on small islands they might well have been wiped out entirely. Indeed, the view that many major large-scale socio-political events were driven by natural (non-human) climatic and other catastrophic events such as floods and volcanic eruptions, is once again gaining popularity, particularly as new information about environmental conditions of the recent past is revealed. It seems rather bad timing that Diamond’s impressive analysis of environmental problems downplays natural hazards as drivers of history.

Issar (a hydrogeologist) and Zohar (an archaeologist) provide an important service by reviewing and summarizing the wealth of information on the Middle East where society after society waxed and waned since the first dispersal of hominids from our common birthplace in Africa. The authors begin their review of the major climate changes that have affected the Middle East throughout the Holocene by positioning themselves squarely behind what they call the “neo-deterministic paradigm.” While acknowledging that human stresses can also drive social,

cultural and political change, they show that major changes in civilizations coincided with major climatic variations. According to them, the advent of agriculture came about as people reacted inventively to warming and drying-out of the Near East, whereas the “urban revolution and flourish” (sic) of the Early Bronze and the “prosperity” of the Middle Bronze and Iron ages resulted from “abundant precipitation that allowed resources to be accumulated.”

The science behind paleoclimate reconstructions is outlined in Chapter 2. After a brief description of global and regional climate systems, the authors review how past climates can be reconstructed using proxy data from coastal sediments, isotopic composition of rainwater, groundwater and wood, dendrochronology, speleothem and cave deposits. The authors prefer to identify causes by cutting through the mass of scientific data with Occam’s Razor, rather than to follow “humanistic scholars (who) are happy to describe the picture in all its complexity and avoid the vexing question of why or what caused it.” Indeed, throughout the book, the authors take swipes at conventional archaeologists who prefer socio-political causes to climatic changes for the decline and destruction of the ancient societies. They argue that the paleoclimatic approach can yield a “more balanced anthropogenic paradigm... reducing the burden of blame on human society.” In short, human forces have been “trumped” time and again by natural processes.

The rest of the book takes the reader on a journey through time from the last glaciation through to modern times. The transition from hunter-gatherers to sedentary agriculturists is explained as a natural consequence of climatic stresses that forced people “into niches where survival depended on the development of irrigated agriculture.” The “destiny of the human race” was shaped from the outset by climatic changes and their impact on the landscape, with arid periods forcing the people who had moved northeastward out of Africa into desert oases where they developed skills in farming and irrigation.

The detailed tour begins with the “great transition from farming villages to urban

centres” (6000–3000 BCE, i.e. the Neolithic, Chalcolithic and the dawn of the Bronze ages), and the “urban revolution and the dawn of history” (3000–2300 BCE from the early Bronze Age to the great civilizations of Egypt and Mesopotamia). The warming and aridification of the second half of the 3rd millennium BCE (the Bronze Age from 2400–1200 BCE) brought crisis and decline to the Middle East, but the end of the Bronze to the Early Iron age (1200–900 BCE) with its colder climate was accompanied by waves of migration from Eurasia. Finally, the authors review the “Age of Iron and Empires (900 BCE–800 CE)” right up to the present. Each period so defined had its own climatic and hydrological character, which determined where and how people lived. Not surprisingly, the greater archaeological and historical evidence of later times allows anthropogenic forces to be more clearly outlined. There is evidence aplenty of human drivers, such as the technological innovations that have allowed the development of groundwater-based irrigation and reduced the link between climate and public welfare.

The authors, both of whom live in Israel, avoid discussion of current Middle Eastern tensions, apart from one swipe at “conservative autocratic and often oppressive” Muslim nations. However, they dismiss the once popular idea, earlier supported by Issar himself, that desertification of coastal areas was the result of Arab conquest: sand dunes here were clearly transported by wind from the Nile Delta. There is now obvious conflict over surface water rights, and although nature as a driver of history has receded for the present, it may well re-appear again as global warming increases.

The book is well referenced with footnotes, and a short glossary of important terms and concepts. This reader might have found his way more easily through the rather dense and sometimes awkward writing had the authors included more and clearer graphics, and maps with the national and political boundaries of today shown on them. Though not inexpensive, this is a book for historians, archaeologists, anthropologists and other researchers interested in the human responses to climate change. Those who read it cannot fail to be impressed with the wealth of data and information dealing with climatic causes of social change. No one alert to climate change today—and certainly no government—can afford to be ignorant of the massive evidence, such as presented by Issar and Zohar of natural forces in driving social and political change throughout human history.

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A geologic time scale 2004

Edited by Felix Gradstein, James Ogg and Alan Smith

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Since 1960 and 1961, when the first realistic calibrations of the geological time scale were put forward by Arthur Holmes and J. L. Kulp, successive updates have appeared like clockwork every few years. Despite this remarkable frequency, this is not a task to be taken lightly, and the present work is anything but a lightweight. Only a few months old and already sporting a popular nickname, "GTS-04", at a full five pounds (2.3 kg), weighs half again as much as the outsize "Chronology of the Geological Record" (London Geological Society, 1985), and in length it exceeds the retired champion, "Geochronology, Time Scales, and Global Stratigraphic Correlation" (SEPM, 1995), by 200 pages. The scale of this time scale is indicated by the fact that the list of references alone, at 98 pages, would fill an entire issue of most journals. A very large wall chart, folded into a rear plastic pouch, is crowded with an integrated summary of stable isotope and sealevel curves, continental configurations and paleomagnetic polarity reversals tied to the new calibrations. Finally, within the covers, the reader will find a thorough, well-designed and well-documented update to the time scale that may be one of the most comprehensive treatments yet in what can only be called the march of time. Compliments for achieving this feat are due to Felix Gradstein and Jim Ogg, the chairman and secretary of the International Commission on Stratigraphy, respectively, and to Alan Smith, who was also an editor of the very first group-think, the London Geological Society's "A Phanerozoic Time Scale" in 1964.

Two distinctive aspects of GTS-04 (apart from its size) are important to note. Firstly, the period-by-period documentation has a shifting, flexible focus on the specific challenges in each time interval that adds great strength to the work as a whole. This is due to the fact that GTS-04 is essentially a status report on the ambitious campaign of the ICS to define and date all global chronostratigraphic boundaries in terms of modern stratigraphic guidelines, based on the work of separate international subcommissions for each period. Although most of the period-chapters are editorial reviews of subcommission progress rather than formal reports, there remains a very strong sense of transition in passing from one jurisdiction to the next. Some users may find the lack of thematic coherence unsettling, but I rather enjoy

the way that each chapter dawns on a new world.

The second thing that sets GTS-04 apart is the pervasive and I would say enthusiastic application of statistics to reduce bias and uncertainty in assigning ages to those unit boundaries that have not been directly dated. Since we speak here of very nearly 100 percent of unit boundaries, every time scale so far published has relied on some form of estimation to get from dated strata to boundary age—mostly eyeballing a convenient round number (or, in the case of the Harland et al. timescale of 1982 by abandoning hope and simply giving the same duration to all stages of a period). Neither the casual nor the hands-off approach was acceptable for the organizers of GTS 04, who have applied quantifying treatments wherever possible, both to stratigraphic correlation and to boundary age interpolation. These are discussed in two key methodology chapters, with Gradstein reviewing deterministic (graphic correlation) and probabilistic (CASC-RASC interpolation) correlation procedures in the chapter on biostratigraphy, and F. P. Agterberg discussing the consequences of fitting reported ages to cubic spline curves and other grave mysteries in the chapter on geomathematics. Further mathematical processing is employed in the chapter on the paleomagnetic polarity time scale by Ogg and Smith, which updates the 10-year old Cande and Kent spreading model with cyclostratigraphic tuning and a few new radiometric ages to add to the precious few previously available, and in a stimulating chapter by MacArthur and Howarth on the use of secular variation in the ratio of stable strontium isotopes as a Phanerozoic dating tool.

The upshot of all this, predictably, is a time scale in which boundaries are dated to four significant figures with 2-sigma values usually less than 1%. The base of the Carboniferous, to take a random example, is dated 359.2 Ma $\pm$ 2.5 myr. This may strike chronostratigraphic eyeballers of the old school as bordering on the preposterous, but to dismiss these numbers as mere precision, masquerading as accuracy, is to miss the point. The excruciatingly exact figures

derived for time scale boundaries in GTS-04 are not claims to knowledge that is 100 times better than that which supported a date of 360 Ma, no decimals, in the Harland et al. timescale of 1982; instead, they reflect the development of tools to optimize the approximation process by orders of magnitude, compared to techniques employed 20 years ago—the difference, let us say, between writing your name with a paint roller and a ball-point pen—and which will be far more sensitive to new data in the approximations of the future. The section (ch. 23) on "construction and summary of the geologic time scale", a comprehensive review of method and materials that I do not remember seeing in any other such publication, makes it clear that new levels of discipline, using optimization tools such as those noted above, will be needed henceforth as information becomes ever more complex, multi-sourced, and precise.

One cannot help being struck by the amount of information in this volume. Each period-chapter is headed by a graphic of continental organization at the time that incidentally shows the paleogeographic locations of defined GSSPs. Also included for each period are standardized curves for geochemical trends (oxygen, carbon, and strontium isotope ratios) and a documented list of radiometric dates. We even have the complete numerical specs for the color coding of time-rock units in both the Paris and USGS color sets. At either end of the scale, the Precambrian and the Quaternary are given special treatment in recognition of their irregular chronostratigraphic status.

And finally, a complaint. Only a truly perverse logic could justify presenting the Geological Time Scale on 22 color pages with the oldest period first (i.e., left to right as one turns the pages) but with the pages for each period arranged with the youngest page first (i.e., right to left)! So much for perfection, but other than this, GTS 04 is a triumph of scholarship that will serve the profession and the public well—for the next few years. It is instructive to look over the past 40 years of time scales in the introduction, where there is no perceptible trend towards closer levels of agreement, and understand that the only true statement in science, is that there are no true statements. Nothing, it would seem, proves this humbling point better than the grand pursuit of probability that is a geological time scale. As the ultimate reward for their labor, I feel sure that its editors hope that the laborious assembly of approximations in GTS 04 will not be the last.

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Renewable energy in nontechnical language

By Ann Chambers

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PennWell, a well known publisher in the fields of energy and petroleum, has produced several books in their "Nontechnical Language" and "Nontechnical Guide" series over the past decade. I have benefited from reading some of these books, including *Deepwater Petroleum Exploration & Production: A Nontechnical Guide* (2003) which I reviewed for *Episodes* (September, 2004).

Renewable Energy in Nontechnical Language is Ann Chamber's eight book published by PennWell. A journalist specializing in energy technologies, Chambers, in her new book, discusses various sources of renewable energy; the book is comprehensible to the educated public. Renewable energy resources have two advantages over fossil fuels and nuclear power; first, they replenish themselves; second, they are relatively clean and non-polluting.

Chapter 1 of the book reviews the contribution of renewable energy resources to the generation of electricity in the world. In the USA, the renewables provide about 12% of electricity supply, of which 10% comes from hydropower, 1% from biomass and municipal solid waste, and the remaining 1% from geothermal, solar and wind power. The latter are insignificant numbers compared to those of coal (56%), nuclear power (21%), natural gas (9.6%) and petroleum (3.4%). Therefore, there is much potential for development of renewable energy technology and utilization, especially in the USA, a single country that consumes a quarter of world's energy. Take, for example, the solar power. The amount of solar energy that reaches the Earth's surface each day can support the energy consumption of world's 6-billion people for 26 years if only we can tap it. Although solar energy is too diffuse to be tapped entirely, even a portion of this free and clean energy can make a huge difference in world's energy economy and environmental preservation.

Chapters 2 and 3 report respectively on successful cases of energy supply by photovoltaic devices (that convert the solar energy directly into electricity) and wind turbines.

Biomass energy (discussed in Chapter 4) is a general term for various forms of energy stored in woods, wood products and wastes, agricultural crops, and animal wastes. Wood was the first form of energy used by humans, but the modern technology can convert biomass into more efficient bio-

fuels such as ethanol, methanol, biodiesel and gasoline.

For centuries people living in regions underlain by hot magma have used hot springs for bathing and cooking. Chapter 5 argues that today geothermal energy can be better utilized for space heating and electricity generation. In the USA, geothermal electricity amounts to 2700 megawatts, sufficient to provide electricity to 3.5 million homes. Currently, it costs \$0.05 to \$0.08 kilowatt-hour. However, the USGS estimates that generation of geothermal electricity can be multiplied with more exploration and better production systems.

Chapter 6 informs readers of recent developments in hydropower. Worldwide, hydroelectric power plants have a total production capacity of 700,000 megawatts, and annually produce over 2.3 trillion kilowatt-hours. Top ten countries producing hydroelectricity are Canada, USA, Brazil, China, Russia, Norway, Japan, India, Sweden and France.

Fuel cells are the subject matter of the final chapter of the book. This chapter should draw more attention because hydrogen fuel cells for automobiles have become a trendy source of energy in recent years as gasoline prices have increased.

Overall this book is a tour of the renewable energy resources with emphasis on their present status and statistics. Industry contact list and a glossary of technical terms have been given as appendices. Chambers has tried to cover a lot of ground, and her book is a good starting point for understanding the renewable energy. What is perhaps lacking is a bibliography on renewable energy resources for further reading. Given the importance of the renewable energy and rapid developments in this field, one can foresee a second revised edition for this book.

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Heterogeneity in the crust and upper mantle: nature, scaling and seismic properties

Edited by John A. Goff and Klaus Holliger

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This book is an outgrowth of a special session on "Characterization of Small-Scale Crustal Heterogeneity, at the 1999 AGU Fall meeting in San Francisco. There were many excellent presentations at the meeting, and a number of those presenters are contributors to this book.

This is a monograph that presents current thinking on the development and applications of quantitative geophysical models to relate geophysical observations to realistically complicated geology. This book is first to unify three different views of crustal and upper mantle heterogeneity. It brings together the geological view, which is derived from the analysis of crustal exposures and deep boreholes; the stochastic view, which attempts to find order and structure in these seemingly chaotic data; and the seismological view, which considers the end product of the complex interaction of seismic energy with the heterogeneous structure at depth.

Totally 13 chapters and 1 index make the monograph an unparalleled reference for professional and students in Earth science fields, especially in geology, geostatistics and geophysics. At the end of each chapter, the references are listed.

Chapter 1 describes the ductile instabilities and structural heterogeneity in the lower crust, written by Cheryl Waters, Basil Tikoff, Laurel B. Goodwin and Timothy A. Little, in which the need for a generalized framework for understanding the development of structural heterogeneity in the crust is addressed. The authors give an example of Mt. Hay Region in Central Australia. The structural heterogeneity and competency contrast is analyzed. Mechanical instabilities are regarded as the link between competency contrast, patterns of deformation, and heterogeneity.

Chapter 2 refers to the petrological causes of seismic heterogeneity in the continental crust, written by Scott B. Smithson and Roy A. Johnson, which examines some of the processes and factors involved in crustal evolution that lead to the development of complex, discontinuous geometries in crystalline crust and ultimately to the heterogeneity observed in crustal seismic profiles. The crustal composition and compositional evolution, rock properties, seismic het-

erogeneity of igneous rocks, seismic heterogeneities of metamorphic rocks, features of anisotropy, and the results from boreholes and other places are covered.

Chapter 3 introduces some results from seismic modeling of lower and mid-crustal structure as exemplified by the Massiccio dei Laghi (Ivrea-Verbano Zone and Serie dei Laghi) crustal section in Northwestern Italy, written by Ernest Rutter, Katharine Brodie, Tony Jones, Derek J. Blundell and David A. Waltham. Regional geology and the deterministic forward seismic modeling are described in detail.

Chapter 4 compares the geologic and seismic structure of the uppermost fast-spreading oceanic crust and provides insights from a crustal cross-section at the Hess Deep Rift, written by Jeffery A. Karson and Gail L. Christeson. The authors review the geologic structure of a major outcrop of oceanic crust created at the East Pacific Rise and exposed along a major tectonic escarpment at the Hess Deep Rift and evaluate the potential for imaging the boundaries between major rock units and their internal structures for the type of crust exposed at the Hess Deep Rift. The discussion of correlation of geologic units and seismic layers is also involved in this chapter.

Chapter 5 focuses on a generic model for the $1/f$ -nature of seismic velocity fluctuations, written by Klaus Holliger and John A. Goff. The authors review the fracture-based $1/f$ -scaling model proposed by Holliger (1996) and present a generic model that evaluates the respective roles played by brittle faulting as well as by compositional variability in determining the scaling laws evidenced by upper crustal sonic log velocity fluctuations. The compositional effects on velocity fluctuations are modeled as a superposition of a variety of random processes with differing scale parameters based on evidence from natural gamma logs, petrophysical measurements and core records.

Chapter 6 describes the fractures and physical heterogeneity in crustal rock, written by Peter C. Leary, including power law scaling in crustal fracture systems, physical analogues for power-law scaling in crustal rock and modeling power-law scaling crustal fracture systems. The authors argue that power law scaling in crustal fracture distributions is physically linked to the failure of stochastic crustal models to capture the true spatial unpredictability of in situ flow and failure system. The physical analogy between crustal fracture systems and critical point thermodynamic systems is developed and the reservoir modeling is discussed.

Chapter 7 examines the statistical characterization of spatial variability in sedimentary rock, written by Scott Painter. The author summarizes various efforts to construct non-classical models and compares the success of various approaches using several example datasets. The reproducible statistical features of sedimentary rock and some

statistical models for spatial variability comparison with data are involved in this chapter.

Chapter 8 focuses on the multifractal modeling and analyses of crustal heterogeneity, written by David Marson and Christopher Bean, including discussions on the construction and properties of multifractals and multifractal analyses of borehole logs and fracture patterns. The authors derive from a series of observations an image of a strongly heterogeneous crust, with medium properties fluctuating at many different scales. Such complexity is found to be both due to and responsible for the complexity of crustal processes, and the tectonic deformation, fluid transport and seismic wave propagation are all found to exhibit complex and intricate behavior.

Chapter 9 describes the seismic imaging of lower crustal heterogeneity, written by Richard W. Hobbs, including the effects of acquisition, processing and the transmission path. The author reviews acquisition and processing methodologies, discusses how they affect seismic imaging of heterogeneous structure in the lower crust and demonstrates the effect of acquisition and processing of seismic data using a 2-D model. The role of heterogeneity in the travel path and its relationship to the quality factor Q are also discussed in this chapter.

Chapter 10 examines the heterogeneity of the crust and its effect on seismic wide-angle reflection fields, written by Robert Mereu, including the evolution of our perception of the structure of the Earth's crust and the seismic wide-angle reflection record sections. Totally 3 different conceptual models of the crust are discussed, i. e., a model of a simple, multi-layered or multi-block crust derived from ray theory and seismic tomography, a model of a complex crust with images derived from the data of near-vertical seismic reflection experiments, and a model of a very complex fractal-type crust obtained by adding random heterogeneities to a deterministic velocity model of the crust.

Chapter 11 describes the heterogeneities of the uppermost mantle inferred from controlled-source seismology, written by Mark Tittgemeyer, Trond Ryberg, Friede-

mann Wenz and Karl Fuch, including the studies of lithospheric scattering, Pn/Sn wave propagation, and modeling the long-range Pn. The authors attempt to demonstrate that random local fluctuations superimposed on those smooth large-scale velocity structures can be crucial for the understanding of seismic wave propagation.

Chapter 12 discusses the nature of crustal seismic heterogeneity through a case study from the Grenville Province, written by Charles A. Hurich, including the description, sources and scales of geologic heterogeneity, the spatial bandwidth, noise and spatial properties of the reflection wavefield, the spatial attribute mapping and the crustal heterogeneity in Grenville Province of Eastern Quebec.

Chapter 13 examines the spatial coherences of seismic data and the application to characterization of stochastic heterogeneities, written by Rushan Wu, including the observations on amplitude and phase fluctuations and their coherences, the theoretical basis of coherence analysis and inversion and the inversion for statistical characteristics of earth heterogeneities.

This book, primarily aimed at researchers, provides an excellent introductory overview to the subject, which should be read by any Earth Scientist wishing to gain an insight into the characterization and imaging of crustal and upper mantle heterogeneity. It is indeed an essential part of any reference collection.

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