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Climate Change and Groundwater

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Rob Butler and Rod Graham present two articles fondly recalling, Mike Coward's penchant for organizing spontaneous undergrad – grad field trips to classic areas. These *ad hoc* field schools achieved more educationally than more formal methods, and illustrate a tragedy of the modern university. Such a gifted and inspirational teacher eventually left the struggle against burgeoning bureaucratic sclerosis (UK universities are further down this highway to hell than those in Canada – but we're catching up fast!) and moved into consulting for industry.

Mike Coward was not just interested in theoretical or descriptive studies of continental deformation, he was also a foremost advocate of the practical application of this knowledge. His latter day career in academia, then as a freelance consultant, took up the challenge offered by the availability of superb seismic reflection profiles from the BIRPS consortium, then from companies exploring in the North Sea and NW Atlantic shelf. His earlier work on the Moine Thrust belt led naturally into interpretation of the MOIST profiles across the Scottish Highlands and Hebrides. This led into radical reinterpretation of the post-orogenic Orcadian Basin. Eventually he would bring this experience to the interpretation of profiles across the Archean of South Africa, especially the Witswatersrand Basin with its huge gold deposits.

The papers in this volume reflect the trajectory of Mike Coward's own career, while paying tribute to his inspirational role as teacher, advisor and research colleague. The first group of papers (Wheeler; Tatham and Casey; Cosgrove; Alsop and Holdesworth; Butler et al.; and Holdesworth et al.) revisits Mike Coward's first stamping ground: the Moine Thurst belt and Lewisian foreland of NW Scotland, addressing issues from the outcrop to the crustal scale. A second series of papers (Vitale et al.; Treloar et al.; Al-Wardi and Butler, Bard et al.; Daly; Robertson et al.; Nemčok et al.; Acosta et al.; and Cobbold et al.) deals with analysis on scales ranging from orogens to entire continents, both in areas with which Mike Coward was familiar (e.g. the Himalayas, Alps and Irumides), to areas where his influence proved fruitful (the Andes, Cyclades and Carpathians). A third group of papers is more eclectic, ranging from Davidson's and Stewart's contributions on salt tectonics, through Mattioni et al. on basin inversion, Sepehr and Cosgrove on the Zagros Fold Belt, Cooper's world-wide review of hydrocarbons in thurst belts, and Beach and Smith, and Jolley et al., on the Witswatersrand Basin. They all emphasize the practical application of these studies in exploration.

This volume will be of interest to many readers, whether strictly 'structural geologists' or those who are simply dealing with deformed rocks by happenstance. It should be compulsory reading for those who regard structural geology as an abstract, academic exercise with no practical significance; for those seduced by computer-aided geo-pornography and deny the need for field work; for those beavering away to remove 'expensive' scientific disciplines from universities (we can hope!); for anyone who still respects teaching as a vocation at the university level that can have results not reduced to cost-outcome analysis or 'teaching-learning outcomes' (the very language betrays the intellectual aridity); and for those who believe geophysics alone can pronounce the final word on crustal deformation and evolution and consider a high-resolution seismic reflection profile an end in itself rather than a fruitful beginning. In short, it is highly recommended.

Climate Change and Groundwater

Edited by W. Dragoni and B.S. Sukhija
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Climate Change and Groundwater is a compendium of thirteen papers by various authors selected from the special session on 'Impact of Climate on Groundwater Resources' organized by the International Association of Hydrologists working group during the XXXII International Geological Congress held in August, 2004 in Florence, Italy. These papers describe the groundwater situation in different areas of the world, climate change being the common link. Several papers consist of simplified versions of previously published scientific papers, and are therefore easy to read and accessible to diverse readers.

As underlined in the article by Seiler et al., few issues have raised as much scientific and political attention and controversial debate as the effect and consequences of greenhouse gases on global warming. Warming will continue to create environmental problems, among the most severe of which will likely be related to water resources. Although climate scientists agree that surface temperatures have increased, the extent and spatial distribution of modifications in precipitation and other components of the hydrological cycle over the globe are much less well understood (Rivard et al. 2009). As noted by Jyrkama and Sykes (2007), the relationship between climate and groundwater is indirect and complex, and thus, difficult to quantify. More-

over, the intrinsic difficulty of estimating recharge and human activities (e.g. changes in land uses and in water exploitation) make the assessment even more complex, which is probably why much more attention has so far been focused on the effect of climate change on surface water. This book is, therefore, a very welcome initiative.

Groundwater constitutes the largest freshwater resource on earth, mainly because aquifers have a large storage capacity and offer protection from evapotranspiration, which represents a large component of the water cycle in arid countries. Therefore, groundwater is often viewed as having a key role in the future, either to alleviate severe drought situations (Dragoni and Sukhija) or to solve problems of water supply (Sinha and Navada). Some of the papers in this volume provide suggestions for alternatives to conventional water supplies, such as exploitation of deep aquifers containing fossil water (or for which the recharge rate is smaller than 10 mm/y), artificial recharge, and recycling procedures. In cases where deep aquifers were studied (e.g. Seiler et al.; Sinha and Navada; Sukhija), evidence indicates that they are unaffected by climate change and that they may be resilient to such changes over millions of years. The role of geology (i.e. aquifer types) may therefore, in some cases, overweigh the climate effect (Benderev et al.), demonstrating that groundwater can indeed be a strategic resource even in extreme or highly variable climatic conditions.

The volume contains three general papers. The introductory paper by the editors (Dragoni and Sukhija) provides a good overview of approaches that have been employed to study the effect of climate change on groundwater. The second paper (Seiler et al.) discusses the transient response of groundwater systems to climate change and its implications for water resource management. The last general paper (Salgot and Torrens) focuses on the use of reclaimed water, given that climate change will aggravate water scarcity in many regions and therefore increase the need for alternatives to conventional pumping of water.

The remaining ten papers present case studies on a variety of subjects, focusing on 1) historical data to study the evolution of spring discharge and identify drought periods (Benderev et al.; Ducci and Tranfaglia; Rapti-Caputo and Helly), and to evaluate statistical trends (Polemio and Casarano); 2) quantifying recharge in the future using numerical modeling (Scibek et al.); 3) spectral analysis to study the effect of oceanic – atmospheric patterns on groundwater levels in order to detect the presence of short and long-term cycles (Luque-Espinar et al.); 4) isotopic analyses applied to paleoclimate studies of groundwater in deep aquifers that were recharged during humid episodes 3000 – 9000 years BP (Geyh and Ploethner; Sinha and Navada; Issar); and 5) exploitation of deep aquifers and use of artificial ponds to adapt to an expected increase in droughts (Sukhija).

This series of papers clearly highlights the major difference in concerns between regions with high and low precipitation. In humid areas, people worry about future climate changes, whereas in arid countries, concerns mainly focus on actual (deficient) supply, and scientists mainly study past climate change (up to several thousands of years ago) in an attempt to find freshwater or to explain the presence of fossil water and variations in spring discharge rates. In fact, only the Canadian paper (Scibek et al.) uses synthetic climate forecasts from global climate models to study and quantify the impacts of future climate change on aquifer recharge. Most of the papers are devoted to studies conducted in arid to semi-arid countries, where water stress is already present, such as Greece, southern Italy, India, Pakistan (Thar Desert), Israel, and the West Bank.

The book covers a broad range of topics presented as case studies that examine varied climatic, geological, and hydrogeological conditions, from the history of deep aquifers containing fossil water, to ancient water supplies and their strong link with the development of civilizations, to past, actual and future recharge and discharge rates. Numerous graphs, tables, maps, and figures (although in black and white) have been included to provide visual support to the reader.

However, the book contains some minor flaws. First, the title of the book may be misleading for people from countries with high or moderate precipitation, as one may be led to believe that the book focuses on the quantification of future aquifer recharge and potential. It is regrettable that there are no papers focusing on Oceania or Africa, two areas where climate change has had well-documented, dramatic effects. In addition, it is somewhat disappointing that none of the papers discusses the use of an integrated (coupled) surface water – groundwater approach, particularly in view of current and forthcoming water cycle changes. The inclusion of a world map indicating the location of each study would have been an asset to the publication.

The paper by Benderev et al. has some problems regarding language use. More rigorous editing could have helped prevent misconceptions arising from awkward word usage, but this does not negatively affect comprehension of the paper. Only one paper (Scibek et al.) appeared poorly suited to the purpose of the book. The paper is very long and the level of scientific detail is close to that of the original research from which it was taken, in contrast to the other papers. In the authors' defense, this is the only paper that dealt simultaneously with climate models, downscaling, weather generators, and infiltration and groundwater flow models, although the uncertainties in the use of these synthetic data are high.

What emerges from the book is that recharge is critically decreasing or is low in many areas, and that overexploitation of groundwater resources has led to the deterioration of groundwater quality and quantity. However, regardless of whether these observed changes are part of long-term warming cycles or not, water resource availability has become problematic in many parts of the world, especially in arid and semi-arid regions. Research to predict changes and to find potential sources and adaptations, as outlined in this volume, is therefore crucial.

Overall, the book has a good balance of statistical and deterministic studies, scientific data, presentation of

current groundwater conditions, and potential solutions to decreasing supplies. It focuses on climate change without a protracted discussion of global warming causes, but with innovative analyses of the consequences of groundwater withdrawals and changing climates over geological time-scales. Finally, Dragoni and Sukhija underline an important issue in their paper: the need for a high quality network of data collection, including groundwater-related data such as water levels and withdrawal or discharge rates. This has also been mentioned in other publications, but it is well worth restating.

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History of Geomorphology and Quaternary Geology

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This Geological Society Special Publication resulted from the 2006 annual conference in Vilnius, Lithuania, of the International Commission on the History of Geological Sciences (INHIGEO), which is affiliated with the International Union of Geological Sciences (IUGS) and the International Union on the History and Philosophy of Sciences (IUHPS).

The conference volume, which sells for US $170.00 in North America, will be attractive to those who happen to be interested in one or more of the papers, all of which are on quite specific topics. Furthermore, there are several thorough and thoughtful papers that will serve as models for review and analysis of the history of topical and regional themes in these fields.

Topics addressed by the various papers include origin of the term Quaternary, several biographies, the history of ideas in regional geomorphology and glacial geology, Australian geomorphology, peneplains in China, as well as Japanese Quaternary history.

Individual papers deal with an introduction, Adolphe von Morlot's contribution to the term Quaternary, the Spokane Flood debates, pluvial lakes of the US West, evolution of the theory of continental glaciation in Europe, development of ideas on Pliocene and Quaternary glaciations in Europe, Kropotkin's 1876 monograph on the Glacial Period, Quaternary research in the Baltic countries, glaciomorphology research in Lithuania and Poland, work on the Quaternary of Lithuania, early ideas about erratic boulders and glacial phenomena in the Netherlands, planation surfaces in China, the Palaeo-Tokyo Bay concept, Cenozoic history of Australia, desert dunes in Australia, early ideas on the development of the river systems in eastern Australia, early geological investigations of the Pleistocene Tamala Limestone in Western Australia, a Charles Cotton biography, and glaciation and earth movements in New Zealand.

The introduction by D.R. Oldroyd of the University of New South Wales and R.H. Grapes of Korea University is thorough in its review of past work on the history of geomorphology, including discussion on the pivotal roles of Davis and Penck in the discipline, and a review of historical analyses of their work, those that preceded them, and those that came after. They similarly review the roots of Quaternary geology. To complete their introduction, Oldroyd and Grapes then carefully discuss each of the disparate papers in the volume.

Broad reviews begin the volume, and the review of the term Quaternary by M. Klemun is timely, given recent discussion on usage of the term. V. Baker's paper on debates regarding catastrophic flooding in the US Northwest is an important case study in the way thinking can evolve that, at least, is relevant to geomorphology. The review of work on western US pluvial lakes by A. Orme is well structured with respect to its review of phases in the research back to initial recognition prior to 1870, while also examining current developments such as linkage of pluvial lake history to regional ecology and global climate. The paper on the evolution of the theory of continental glaciation in northern and eastern Europe by A. Raukas deals with early recognition of continental glaciation in Switzerland, as well as the influential figures who played a role in widespread adoption of this model.

Biographical papers and themes in European regional geology follow, beginning with an autobiographical account by E. E. Milanovsky that reviews his own work on the origin and development of ideas on Pliocene and Quaternary glaciations in northern and eastern Europe, Iceland, Caucasus and Siberia. T. K. Ivanova