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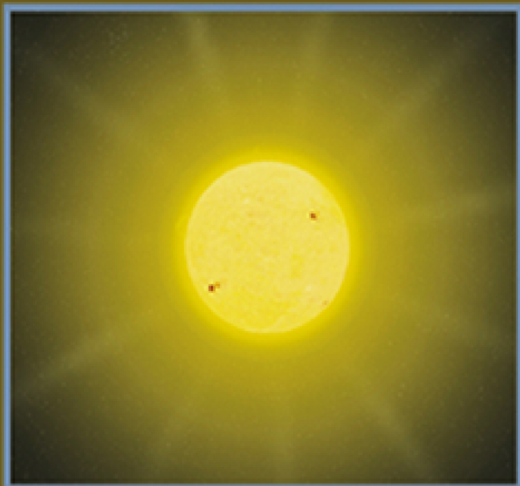
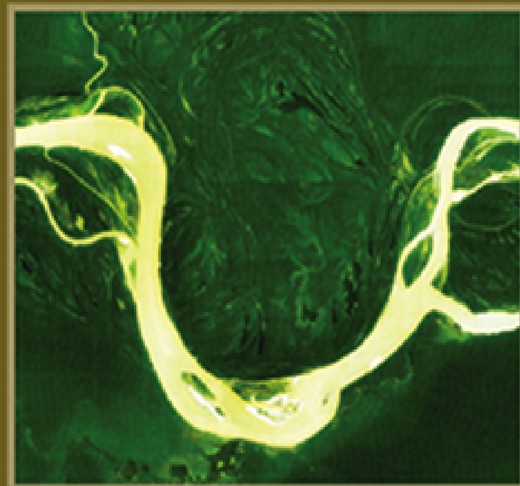

Liviu Giosan, Dorian Q. Fuller, Kathleen Nicoll,
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Editors

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Geophysical Monograph 198

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American Geophysical Union
Washington, DC

Library of Congress Cataloging-in-Publication Data

Climates, landscapes, and civilizations / Liviu Giosan...[et. al.], editors.

p. cm. – (Geophysical monograph ; v. 198)

Includes bibliographical references and index.

ISBN 978-0-87590-488-7 (alk. paper)

1. Cultural landscapes. 2. Landscape changes. 3. Climatic changes. 4. Human beings–Effect of climate on. 5. Civilization, Ancient.

I. Giosan, Liviu.

GF41.C54 2012

304.2–dc23

2012040662

ISBN: 978-0-87590-488-7

ISSN: 0065-8448

Cover Image: (top left) The Sun is the principal natural driver of Earth's climate (http://commons.wikimedia.org). The water cycle translates climate signals into diverse landscapes ranging from (top right) highly productive floodplains (http://commons.wikimedia.org) to (bottom left) completely inhospitable deserts (http://commons.wikimedia.org). In the process of becoming a geological-scale force, humans have conquered even the most hazardous landscapes and devised strategies for survival and rapid recovery. (bottom left) Reconstructed pre-

Columbian house structures built in El Baga National Park, Cayo Coco, Cuba. Photograph credit: Jago Cooper.

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PREFACE

The current volume brings together papers presented at the AGU Chapman Conference “Climates, Past Landscapes, and Civilizations,” held in March 2011 in Santa Fe, New Mexico. We wish to thank all participants and organizers of the conference and are grateful to all contributing authors, reviewers, and editorial staff who have helped to produce this book. The meeting was attended by more than 100 scientists, scholars, and journalists across the fields of Earth sciences, anthropology, and archaeology, with the overarching goal of enhancing the cross-disciplinary dialogue on the history of complex interrelationships between humans and their environment. Discussions, thematic group sessions, and answers to individual questionnaires revealed differences among disciplines on the design, methodology, and interpretation of research but also pointed out a strong collective interest to develop collaborative pathways toward bridging any perceived disciplinary divides.

Research on the history of interactions between humans and the environment is intrinsically interesting to diverse audiences and engaging for the wider public. The fate of past cultures also presents us with completed intricate experiments that provide a wealth of data for exploring models of the resilience and sustainability of coupled socioenvironmental systems. At a time when climate change, overpopulation, and scarcity of resources are increasingly affecting our ways of life, the lessons of the past provide multiple reference frames that are valuable for informing our future decisions and action plans. Despite this wide interest and investigational potential, collaboration across disciplines is uncommon, and adequate funding to explicitly support this style of interdisciplinary research remains scarce. The two broad fields of inquiry, Earth sciences and archaeology, have distinct customs and rhythms of publishing and discussion of new ideas, and hypotheses are mostly generated within nonoverlapping professional societies. Consequently, Earth scientists and archaeologists, experts in these fields analyzing the same phenomena at various temporal and spatial scales, rarely overlap effectively in planning and performing their research. Information outside each of these disciplines is used at a level below its potential, and in the process, the complexity of phenomena is diluted. Solutions to bridging this divide are not simple, but they are not beyond reach and may include a wider presentation of existing interdisciplinary research to multiple stakeholders and funding agencies and cross-disciplinary working groups within professional societies and dedicated meetings. Further progress may require integration and standardization of databases and establishing new organizations dedicated to interdisciplinary research on coupled socioenvironmental systematics. Both the differences and convergence of opportunities discussed during the Chapman meeting are reflected in the current volume and in other conference papers published outside this volume.

The early anthropogenic hypothesis provided a larger context for presentations at the meeting. The centerpiece of this hypothesis, developed by paleoclimatologist Bill Ruddiman in a series of papers since 2003, proposes that humans began to exert an influence over the global climate thousands of years ago through greenhouse gas emissions linked to the expansion of agriculture (see the introduction to this volume by Ruddiman and references therein). While archaeologists have always been concerned with the interactions between past cultures and their environment, the global scope and fingerprint of these interactions suggested by the early anthropogenic hypothesis introduces a new level of complexity in Earth sciences and provides a path for future interdisciplinary research. In the introduction to the present volume, Ruddiman argues for an increased role of archaeology and anthropology in validating competing models of land use. Novel use of historical information on social organization and resources and regional and global assessments of the scale and spatial distribution of past societies, as well as better criteria for discriminating between anthropogenic and natural landscapes, are just a few elements that are critical for advancing this goal. Along similar lines, Cadzow argues in his chapter for research on the primary drivers of long-term environmental impacts such as hunter-gatherers and agriculturists rather than focusing only on major sites or civilizations. The impact of these “unsung” societies, although more diffuse, may have left a more profound (and not necessarily harmful) fingerprint on landscapes and ecosystems.

The overlap of human agency and natural climate change on landscapes and ecosystems is often confounding and, in many cases, difficult to disentangle. The extinction of Pleistocene megafauna and the termination of the Clovis lithic technology/culture during the Younger Dryas is one example of such complex phenomena that has elicited an active debate recently. In this volume, Boslough and colleagues present new data and argue against a recent hypothesis that proposed that a large impact or airburst caused simultaneous climate cooling, extinction events, and cultural changes at the Younger Dryas around 12.9 ka. When climate changes can be detected and isolated from anthropogenic overprints, high-resolution records can reveal new relevant aspects for the socioenvironmental systems at fine scales. Along this line, Berkelhammer et al. present a high-resolution speleothem record of the monsoon regime from northeast India and document for the first time the 4.2 ka climate event on the Indian subcontinent against which the reorganization of the Indus Valley civilization can be assessed. Aharon and colleagues provide a high-resolution climate reconstruction from a speleothem from DeSoto Caverns in Alabama and address the role of instability rather than singular climate events on the fate of Mississippian chiefdoms in the southeast United States.

Sea level changes represent a cumulative and more gradual aspect of global climate variability, often with profound local effects on culture. Landscape formation in coastal settings is tightly constrained by sea level variability, leading to the progressive development of habitability niches. This is discussed by Amorosi and Morelli in their chapter on the fate of Neolithic Cardium Pottery Culture in the Mediterranean and by Rollet in his analysis of the advent of large-scale irrigated rice agriculture in the Fuzhou Basin of China.

Regional complexity requires synoptic reconstructions of climate changes and associated landscape responses for in-depth examination of their links to cultural events. Highresolution geospatial imaging, areal expansion of paleoenvironmental databases, their integration with archeological metainformation, and scenario-based modeling of coupled socioenvironmental systems are increasingly applied to advance these research directions. Maemoku et al. couples high-resolution terrain models with estimates of river flow and chronologies of eolian landforms to provide constraints on the interpretation of the Ghaggar-Hakra Valley as the lost, legendary Sarasvati River of the Indian Vedas. A common mechanism for regional climate change in the west Asia and Indian monsoon domain is proposed by Staubwasser, after analyzing the common pacing of reconstructed Indus River outflow and water column stratification in the Red Sea over the last 5000 years. Focusing also on South Asia, Lemmen and Khan model the transition to agriculture in the Indus Valley region, taking into account the biophysical forcing factors as well as sociotechnological innovation, migration, population, and subsistence changes. A modeling approach is taken by Berking and colleagues, who use downscaling of atmospheric general circulation model results to investigate the rise and fall of the city of Naga along the middle Nile during the first millennium before the Common Era.

The cause-effect relationships between climate and human history are often nonintuitive, and multidisciplinary approaches are required to reconstruct them. An unexpected relationship between climate and the Siberian Scythians is revealed by Panyushkina, who posits that a decrease in habitation in the Altai Mountains during warmer climate intervals may have increased mobility and possibly resulted in the development of transhumant pastoralism. In contrast, the civilizing value of prehistoric climatic stress leading to acculturation, social complexity, and relocation is discussed by Nicoll, who analyzes the effect of droughts on the Neolithic culture at Nabta Playa, west of the Nile Valley, and the rise of the Pharaonic culture in Egypt. Force and McFadgen discuss the role of active tectonics in landscape development over long time scales by providing diverse environments and also through creative destruction events that accelerate the development of cultural complexity.

A wide array of archaeobotanical, geoarchaeological, and philological data is synthesized by Riehl et al. to analyze the multiple drivers controlling the transformation of agricultural systems in northern Mesopotamia. A combination of environmental reconstructions, archaeological methods, and evidence from historical documents is also employed by Thurston and Plunkett, who reconstruct the “invisible” history of human activity under continuous pasture cover in Northern Ireland. In a review of resilience to storms in

Caribbean island communities, Cooper highlights the importance of examining cultural life cycles from a long-term perspective that brings forward the capacity for rapid recovery rather than strategies for robust resistance to disasters. Development of novel proxies, monitoring, and dynamical reconstructions are advocated in several papers in this volume. Adding to the increasing body of literature that recognizes sedimentary materials as important components of the archaeological record, Baade discusses irrigation-linked anthropogenic soils in two contexts where their identification contributes to our understanding of regional cultural developments: the high Himalaya and coastal Peru. Draut et al. address the role of detailed monitoring of sand transport and vegetation in analyzing the effects of climate variability on landscape dynamics and cultures in arid regions with eolian elements. Gatti and Oppenheimer address extreme events such as the Youngest Toba eruption, using a modeling method to better constrain the distribution of ash from the eruption while noting that the environmental effects remain largely unquantified due to the low resolution of the proxy data.

Covering the range from collapse to transformation, cultural responses to climate and landscape change may include abandonment, redistributions, and reorganizations of settlement types and patterns, recalibration of food procurement strategies, trade network development, migration and colonization, and technological transitions. Continuing discussions on this topic started at the conference, and in accord with many points raised in other papers in this volume, Aimers argues for developing and using dynamic models of cultural development in his analysis of the cultural transformations of the lowland Maya in the ninth century A.D. The author underscores the need for close collaboration between Earth scientists and archaeologists to understand the broad spectrum of cultural responses. Research design should approach this complexity with an open mind that moves beyond deterministic assumptions about civilization collapse and instead focuses on understanding the resilience strategies involved in past cultural transformation.

One key issue that emerged at the conference as a particularly important focus going forward is the need for developing increasingly precise chronologies for both paleoenvironmental and archaeological data. This is important at both the "site scale" of the archaeology as well as at the regional scale. Furthermore, it is essential that archaeologists, geologists, and environmental scientists working within the same region collaborate in data collection, assessment, and synthesis. This will help temper disciplinary biases and provide opportunities for new observations and theoretical developments based upon a better understanding of the complexities of human-environment interactions.

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Bridging a Disciplinary Gap

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This paper examines a perceived divide between two groups referred to as "archeologists" and "physical climate scientists." The former group encompasses field scientists in related disciplines such as geoarcheology, archeobotany, and those aspects of sedimentology and paleoecology that focus on the Holocene. Also included are human geographers who study written historical records of civilizations spanning the last 2 millennia. The latter group covers those working in fields such as atmospheric sciences, paleoclimatology, paleoceanography, hydrology, ice core and marine geochemistry, numerical (general circulation) modeling, and carbon-cycle modeling. Few scientists on the two sides of this barrier have successfully bridged this gap, even though the potential benefits of doing so are considerable. This paper makes the case that climate scientists, trying to understand the middle and late Holocene, need to consider how the spread of agriculture transformed past landscapes and potentially altered regional and larger-scale climate. It also points to ways in which archeologists can benefit from placing regional studies in the kind of "big picture" view common in climate studies.

1. INTRODUCTION

Several AGU members organized and held a March 2011 Chapman conference with the title "Climate, Past Landscapes, and Civilizations." Their intention was to bring together people in different disciplines to bridge disciplinary barriers related to these three topics. From my perspective, the conference was a successful step toward an important goal that deserves much more attention in the future.

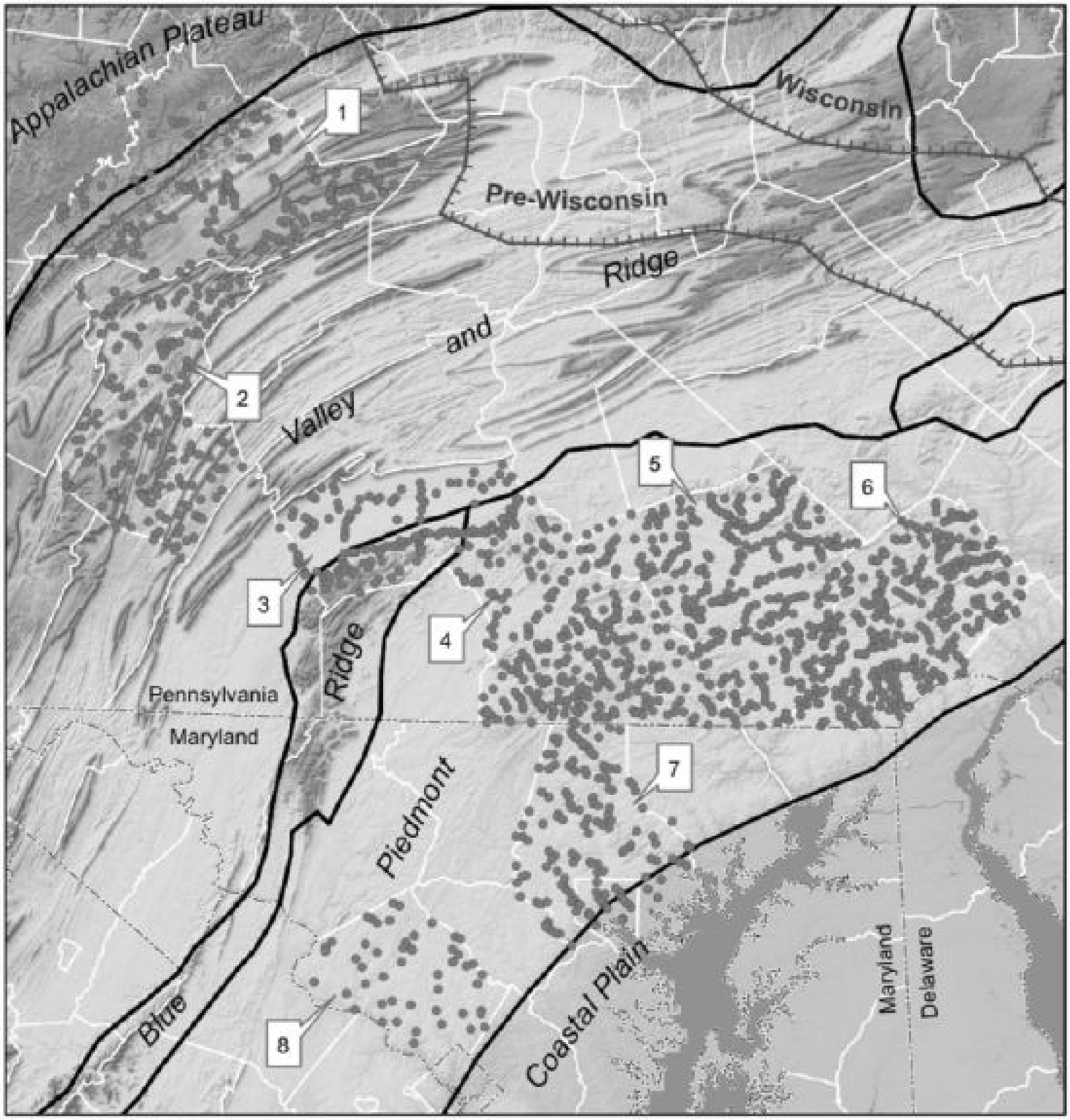
The first two parts of this chapter focus on examples in which physical climate scientists have at times shown a surprising lack of awareness of ways in which our own species has altered the face of the planet, even in relatively recent centuries. The last section suggests ways that archeologists could help to bridge these disciplinary barriers and provides examples of progress in that direction during the last few years.

2. FORGOTTEN MILL PONDS

In the 1950s, two highly respected hydrologists, Gordon Wolman and Luna Leopold, investigated a region of second- and third-order streams in the mid-Atlantic Piedmont of the United States. Acting under the assumption that these streams were natural in origin, they formulated the underlying physical laws that appeared to govern their behavior [*Wolman and Leopold*, 1957; *Leopold and Wolman*, 1960]. This research played a prominent role in the development of the science of fluvial geomorphology.

Half a century later, *Walter and Merritts* [2008] reexamined the same region and found a strong human overprint on the landscape (Figure 1). Logging of the piedmont had begun with the earliest European settlement in the late 1600s, accelerated in the 1700s, and continued into the middle or late 1800s. Small water-powered sawmills were built along these streams at average intervals of a few kilometers to process cut timber. Mills also provided waterpower for grain grinding, textile production, paper production, and iron forges. Each mill had an upstream millpond dammed by earthen structures to divert water for power. The piedmont region was well suited to mills because of its gentle stream gradients and location near navigable tidal water not far downstream.

Figure 1. Location of mid-1800s mill dams in eight mid-Atlantic counties based on historic atlases: in Pennsylvania, 1, Centre County; 2, Huntingdon County; 3, Cumberland County; 4, York County; 5, Lancaster County; 6, Chester County; and in Maryland, 7, Baltimore County; and 8, Montgomery County. From *Walter and Merritts* [2008] and *Merritts et al*. [2011].



Based on LIDAR (Light Detection And Ranging) surveys that showed flat-lying areas ("valley flats"), historical records, and field examinations, Walter and Merrits found evidence for at least 8000 mills and millponds along prominent creeks and streams in the Pennsylvania piedmont, and *Merritts et al*. [2011] also found numerous others across the Mid-Atlantic (Figure 1). Peak mill use occurred between 1780 and 1860, with more than 65,000 water-powered mills in the eastern United States by that time.

By the middle 1800s, more than a century of timbering (and agriculture) had transformed the mid-Atlantic piedmont into a largely humanized landscape. After the more accessible lowland forests were cut, later clearance removed forests from steeper and more remote hillsides, where erosion destabilized the soil and sent fine sediment into the streams and millponds. But as steam power gradually replaced waterpower, most of the mills were no longer needed. And with no more forest to cut, the wooden and steel structures in the sawmills were recycled to new locations farther west or south or to higher terrain where timbering was still underway. With the sawmills gone, the millponds filled in with eroded sediment, and with new forest taking over, the Piedmont began to revert to what looked like a natural state.

A century later, when Wolman and Leopold studied the region, they interpreted the landscape as natural, analyzing the meandering patterns of piedmont streams flowing mostly in single channels across the "valley flats" they thought were floodplains. But Walter and Merritts showed that these "floodplains" are actually the remnants of millponds that had filled with sediment, in some cases breaching the mill dams. The stream channels were meandering across these millpond deposits.

Based on historical accounts and on sediment deposits in a few undammed regions that survive today, Walter and Merritts concluded that the natural streams that had previously existed in the piedmont were small branching channels flowing through forested wetland (sedge) meadows separated by islands stabilized by alder trees and shrubs. Woody debris that jammed the stream channels helped produce these complex branching flows. Little fine sediment had accumulated in those natural pre-clearance channels, although they were rich in organic matter.

These remarkable papers serve as a stark warning to anyone studying the more distant past, including the effects of early Americans on the landscape prior to European arrival, as well as the long history of land use in Eurasia. If hydrologists in the 1950's had entirely "forgotten" the history from just one or two centuries earlier, what might have been "forgotten" about things that happened several millennia ago?

3. FORGOTTEN (OR OVERLOOKED) PREINDUSTRIAL RECORDS OF LAND USE

From direct personal experience, I offer here a second example of how scientists trained in physically based areas have been unaware of fundamental knowledge in disciplines that have traced the imprint of humans on Earth's surface prior to the industrial era. Assessing the magnitude of this past human imprint has implications that extend into other disciplines, including early emissions of greenhouse gases (CO_2 and CH_4) and their potential role in keeping late Holocene climate warmer than it would otherwise have been [*Ruddiman*, 2003].

Several attempts have been made to quantify the history of land clearance [*Houghton*, 1999; *DeFries et al*., 1999; *Ramankutty and Foley*, 1999; *Goldewijk*, 2001; *Joos et al*., 2004; *Pongratz et al*., 2008; *Strassmann et al*., 2008]. Most of these studies were based on estimates that per capita cultivation has amounted to just a few tenths of a hectare to one hectare [*Seiler and Crutzen*, 1980; *Goldewijk*, 2001; *Ramankutty et al*., 2002]. Several of these reconstructions