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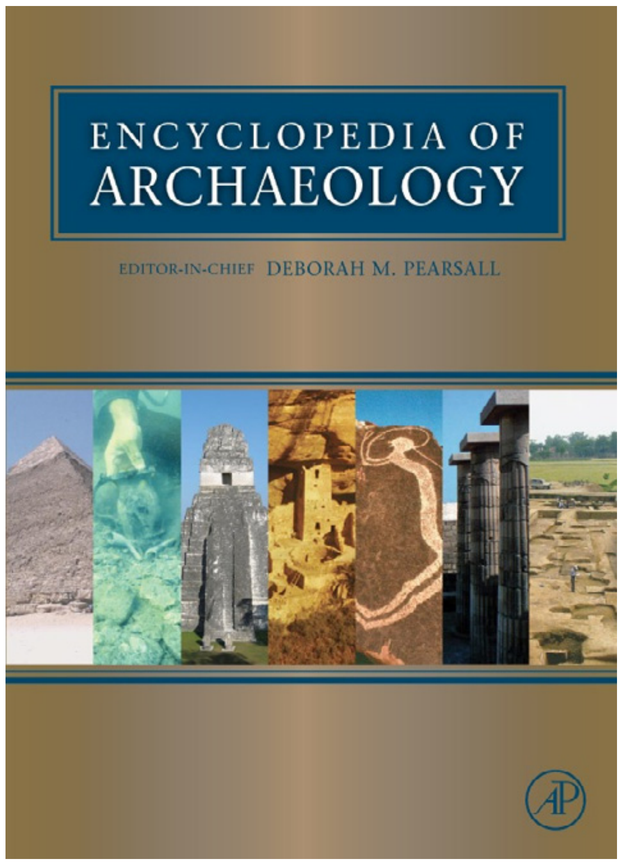

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Human Evolution *See:* **Modern Humans, Emergence of**.

HUMAN–LANDSCAPE INTERACTIONS

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Glossary

Akkadian A Semitic-speaking dynasty founded by Sargon the Great (Sharrukin, 2334–2279 BC) *c.* 2370 BC with Akkad (or Agade), an unidentified site, as his capital.

Anasazi A major cultural tradition of canyon dwellers found in the southwestern United States between AD 100 and 1600.

dendrochronology An absolute chronometric dating technique for measuring time intervals and dating events and environmental changes by reading and dating the pattern of annual rings formed in the trunks of trees.

Holocene A geological period that extends from the present day back to about 10 000 radiocarbon years, approximately 11 430 ± 130 calendar years BP (between 9560 and 9300 BC).

marine transgression Phenomenon in which sea-level rises (or land sinks) and large areas of land become inundated.

palaeoenvironmental reconstruction The determination of the prehistoric environment of an archaeological site, using the methodologies of geology, botany, palenology, and archaeozoology.

palynology The science that studies contemporary and fossil palynomorphs.

Introduction

The theme of 'human–landscape interactions' in the twenty-first century covers a number of very exciting new developments, insights, and debates in the fields of environmental history, palaeoenvironmental reconstruction, and landscape archaeology. The field of landscape archaeology is relatively recent and many of the baseline concepts currently used to address human–landscape interactions were not developed until the 1970s. In the last 5 years, a confluence, or parallel maturation, has taken place between advances in archaeological theory, evolution of new high-resolution palaeoenvironmental sequences, and the emergence of new geospatial technologies.

This survey first summarizes background assumptions and concepts underpinning modern approaches, highlights the major debates and areas of innovation about climate change, environmental causality and new research directions, and lines of investigation that have come to light as a result of these new insights. Then, in light of these developments, this article suggests several theoretical and applied technology avenues for future investigation in landscape archaeology.

From a pre-World War II (WWII) focus on individual archaeological sites as isolated entities, archaeology has moved to their treatment as parts of a broader network of interrelated sites. More recently (post-1970s), the discipline has incorporated the idea of environmental setting for a contextual treatment of archaeological data. Within only the last decade, the emergence of new high-resolution dating and analysis techniques has begun to yield important new sequences of environmental change. These have done

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nothing less than revolutionize traditional approaches to the study of man–landscape interactions in prehistory and history.

Archaeology has only recently begun to grapple with the fact that these 'environmental contexts' are neither static nor constant. Rather, they are almost continuously changing, both independent of, and in response to, human interaction with the environment. As discussed below, recent advances and initiatives are beginning to transform the field from a two-dimensional (2D), mostly static approach (i.e., from solely a diachronic sequence of transformations out of context) to a dynamic, three-dimensional (3D) treatment of archaeological data in a geospatial universe. In fact, such a geospatial perspective will increasingly incorporate both the environmental diversity of past landscapes together with processes of climatic and environmental change and transformation.

Technologically, the advent of such tools as highly resolved, decade-level sampling and dating capabilities, geographic information systems (GIS), and 3D modeling of ancient and modern landscapes, from real world bathymetric and topographic sources, provides the means to dynamically analyze and describe complex geospatial relationships between man and the landscape. This emerging integration of the concept of environmental change, spurred by high-resolution dating techniques and sophisticated 3D real world geospatial data control, is reorienting the field of landscape archaeology from a 'flat' 2D universe (as in flat paper maps) into the third dimension which is continuously changing in form and resource potential through time. These new 3D geospatial technologies are providing archaeology with the means to plan, target, and discover surviving (and often well-preserved) archaeological remains. These applied technology solutions are leading to the discovery of well-preserved high-integrity remains, even in heavily altered, or now inundated or land-filled, modern landscapes – based on what the environment *used* to look like, instead of what it looks like today.

Recent discoveries and debates dominate in five areas of concern, not all complementary or consistent in their findings: (1) the recognition of magnitude and effect of long-term human impacts to the environment; (2) the effect of climate change on human settlement and land use history; (3) the advent and relevance of high-resolution dated sequences of environmental change; (4) very recent recognition of the critical role played by sea-level rise in human history in general, and in the origins of early urbanism in particular; and (5) new insights into the previously ignored significance and potential for archaeological preservation in inundated coastal estuaries, bays, and marshes. In essence, this article is not about 'global warming' *per se* – it is in addition to it.

Most new developments in landscape archaeology, or as some now refer to as landscape ecology and/or paleoecology, stem from the use of new high-resolution palaeoenvironmental pollen, ice or soils sequences to argue that significant environmental and climatic events occurred immediately before or after major changes in settlement patterns, economies or demographics of prehistoric cultures. Instead of studying periods spanning hundreds or even thousands of years, current breakthroughs in both New World and Old World archaeology reflect a shift to new high-resolution temporal and analytical sampling units of 20–50 years, or less.

The most current topic of debate is interpreting the role of climate change in general and the impact of droughts, in particular. As summarized below, droughts have been blamed for the demise of important cultural phases in Egypt, Mesopotamia, the American Southwest, Mexico, the Mayan area, and Andean South America. Similarly, others have argued that droughts were the incentives, or triggers, for early sedentary, centralized settlements and stratified societies. Several theorists and practitioners argue strongly for or against the existence and reality of catastrophic floods in prehistory. And the newest model for the emergence of Mesopotamian civilization highlights the role of sea level rise. As a counter to the often deterministic tone of many of these arguments, several cases highlight the role of past human cultures in bringing about significant, ecologically traumatic, long-term changes to prehistoric and early historic environments. Finally, in response to the recent recognition of the role of Late Holocene sea-level rise, or marine transgression, this overview will conclude with a discussion of the archaeological potential and significance of now buried and/or inundated landscapes, and of the geospatial tools that are being deployed to reveal them.

Theoretical Origins and Assumptions

Baseline Geospatial Constructs

Modern landscape or environmental archaeology is an amalgam of techniques and ideas from several disciplines (geography, ecology, archaeology, palenology, paleoclimatology). Some of these were derived from social science and theory, others from hard sciences dealing with the earth and environmental history. This treatment focuses on the ecologically contextual, geospatial, and diachronic analysis of human–landscape interactions. The specialized topics

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of 'spiritual landscapes' and 'architectural landscape archaeology' are beyond the scope of this discussion.

Prior to WWII, it was not uncommon for archaeologists to spend their entire careers studying a single site, treated almost in isolation – isolation from other contemporary sites and in isolation from the environment and landscape features surrounding it. Furthermore, following the Linnaean tradition of focusing on the identification of new 'species' (and in the case of archaeology, new material culture and artifact 'types'), the study of prehistoric cultures was often done with little or no reference to current or past environment or topographic setting. Environmental context was not a baseline concern. In both the Americas and Europe, between the 1950s and 1970s, two streams of thought coalesced to form the conceptual and methodological building blocks of contemporary landscape archaeology. In the United States, the roots of a 'regional' approach in studying prehistoric settlements can be traced back to Lewis Henry Morgan's work on Native American village organization (1881) and to Julian Steward's 1930s study of the shifting hunting and gathering economy of the Shoshone Indians. Despite these early prototypes, modern American students did not begin to focus on the distribution and context of archaeological sites until the release of Gordon Willey's 1953 survey work in the Viru Valley of Peru. While many parallel studies were done in Mexico and North America, it was Willey's study of changing 'settlement patterns' in an arid coastal valley that set the form and direction of later spatial studies in American archaeology.

At the same time, other baseline assumptions that helped form landscape archaeology came from biology and early efforts to explain how organisms and multiple communities of animal and plants formed a system of interconnecting elements. In 1953, Eugene Odum published *Fundamentals of Ecology* and introduced the concept of nonstatic or dynamic 'ecosystem' into the biological lexicon. The same year, Odum's essay, Human Ecology, extended this biological concept to the study of human populations and culture. These intellectual constructs also served to infuse the idea of change and process to the often static treatment of human–landscape interactions.

In Europe, one of the first conceptual attempts to incorporate the notion of environmental context emerged with the introduction of the concept of 'site catchment area'. In 1972 this concept was borrowed and applied from earlier social and economic models by two archaeologists, Higgs and Vita-Finzi. The notion of site catchment area provided a functional, economic, and geographic framework to relate land-use patterns to environmental conditions and subsistence sources. It also assumed that these subsistence activities took place within a circumscribed environmental context that would diminish in intensity and importance with increasing distance from the core site area.

While the European 'ecological catchment' and the American 'settlement pattern' were spawned from different traditions, in the 1970s and 1980s archaeologists on both sides of the Atlantic borrowed freely and both concepts helped set the stage for later regional- and habitat-oriented treatments of archaeological data. Their adoption represented a paradigm, or conceptual, shift away from objects and 'things' (including 'sites'), in and of themselves, to broader contextual investigation of spatial associations and interrelationships 'between' things, artifacts, sites, and resource areas.

By the middle of the last decade, landscape archaeology began using constructs that attempted to weld process and landscape in a single model or paradigm. Archaeologists working in Mesoamerica adopted a new model, the Tropic Web, that integrates the 'spatial' aspect of 'site catchment' with the 'dynamic' elements of 'ecology' and change. This 'dynamic and geospatial' framework treats humans as elements of a network of resources and organisms that are intensely linked throughout their life cycles. A related concept, Task Space, was fielded by African archaeologists which treats landscape as a place where different tasks take place at specific times within a changing set of schedules. Both ideas also provided conceptual tools that began to 'fit' with the dynamic, real time, real world, 3D modeling capabilities of current geospatial technologies.

Applied Technology: Dating and Proxies

These mixed traditions and approaches resulted from two impetuses toward a regional geospatial and environmental perspective: (1) the availability, beginning in the 1960s, of high-resolution aerial photography; and (2) externally imposed legal mandates to undertake regional archaeological surveys as part of the emerging environmental impact and historic preservation movement in developed regions. These new tools and procedures, in turn, aided archaeologists in seeking and discovering new sites in environmental contexts they may not have been otherwise investigated.

Finally, just as the availability of low-altitude aerial photography in the 1960s provided archaeologists with handy geospatial tools for evaluating sites in an environmental context, the recent availability of high-resolution, radar-derived digital terrain models are today providing the capability to investigate and explore – remotely and safely – a study area from afar (Figure 1) (*see* **Cultural Ecology; Cultural**

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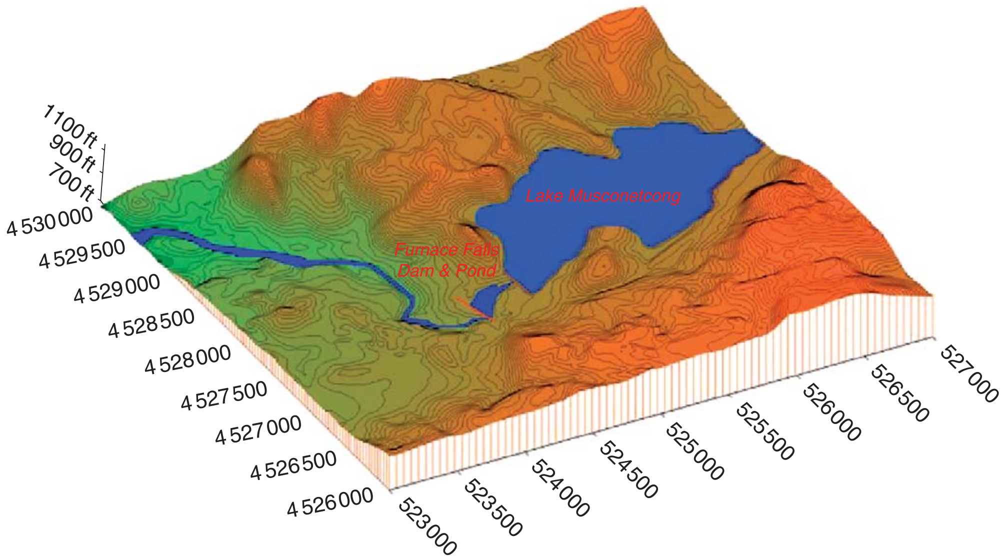

Figure 1 3D Digital Elevation Model (DEM) of a Highlands valley of New Jersey, U.S. The radar-derived coordinate and elevation data can be rendered as either two-dimensional contours, or as three-dimensional surface mesh models which permit the extraction of plan, profile and volume information for the analysis of the topographic and ecological context of historic and prehistoric sites within the drainage. (By Joel W Grossman, Ph.D., © Joel W Grossman, Ph.D. 2008. Published by Elsevier Inc. All rights reserved.)

Resource Management; Landscape Archaeology; Paleoenvironmental Reconstruction, Methods; Remote Sensing Approaches: Aerial; Geophysical; **Settlement Pattern Analysis; Settlement System Analysis; Paleodemography**).

The ability of modern landscape archaeology to measure either environmental change, and/or man's impact on it, partially resulted from the emergence of new dating techniques that have resolved increasingly finer units of analysis–from intervals of centuries, down to sampling and dating at 10–50-year intervals, or in the cases of tree rings, clay varves, and ice cores, intervals of 1 year. The majority of case studies highlighted below represent often radical reinterpretation of prehistoric man–landscape interactions, based on data from terrestrial and marine cores that are yielding both chronological and environmental evidence. These procedures, and the incorporation of techniques and data from other disciplines, are central to the following examples and case studies. Each in turn demonstrates the use of two elements: (1) subdecade-level dating with chronometric procedures (of these, perhaps the most important technological innovation was the advent of Accelerator Mass Spectrometry (AMS) radiocarbon dating in the 1980s which both addressed the crude dating of early C14 techniques and enabled high resolution age determinations from samples as small as a charred seed; or from the counting of tree ring, ice or sediment layers from long core sample) (*see* **Archaeometry; Carbon-14 Dating; Dendrochronology; Electron Spin Resonance Dating; Luminescence Dating; Obsidian Hydration Dating**) and (2) the use of what environmental scientists refer to as proxies. Proxies are subtle traces of minerals, radioactive elements, or organic compounds that show changes indicative of temperature or climatic shifts (*see* **Archaeometry; Chemical Analysis Techniques; Geoarchaeology; Neutron Activation Analysis; Paleoethnobotany; Pollen Analysis**). The following cases will stress the analytical basis for each set of climatic findings over individual theories or models.

Old Biases and Impediments

The emergence of modern landscape archaeology and the understanding of the delicate and dynamic balance between human and natural forces did not come easily. The new perspectives of landscape archaeology or environmental history could not emerge until several key deeply held biases and culture-bound Western assumptions had been set aside. These were (1) the concept that preindustrial environments were pristine and unspoiled, and that the Holocene, or last 10 000 years following the retreat of glaciers, underwent little change and was static and (2) that indigenous peoples lived in child-like harmony with their environment.

The notion of a pristine and stable or static past The first major barrier came from ingrained nineteenth- and twentieth-century assumptions that colonial environments were, prior to the recent impacts, stable and reflected habitats and groundwater conditions unchanged for thousands of years. A second major

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assumption to be set aside was that in addition to being pristine, little if any environmental change had taken place since the retreat of the ice sheets 10 000–12 000 years ago – what existed in the historic period had existed for thousands of years before. This notion arose in part from bias, and in part from imprecise available data control and dating techniques. It was only in the early 1970s that two pivotal document-based studies of the colonial environment of North America – Crosby's *The Columbian Exchange* and William Cronon's *Changes in the Land* – began to plant the seeds of reevaluation. Not only had the landscape been impacted by European contact in the early fifteenth century, but also that it had been altered, if not at times carefully managed, by Native Americans long before European introductions. Cronon even suggested that what many early explorers described in exotic travelogues as the 'natural untouched splendor' of America's eighteenth-century wilderness may have been artifacts of a generation of abandonment by Native Americans after their populations had been decimated by disease and/or pushed out of their traditional territory by European colonists. In fact, it now appears that the traditional use of these eighteenth-century documentary accounts may not be as accurate as the well-dated botanical remains from the seventeenth-century archaeological sites. As summarized below, both the excavation of archaeological plant remains from mid seventeenth-century deposits and recent pollen sequences from the Mid-Atlantic region of the Eastern United States have documented plants indicative of disturbed environments as early as 1650 (Figure 2).

The notion of the 'native in harmony with nature' Coupled with the misconception of supposedly stable pre-European environments of colonized territories in Africa, Asia, and America, was the associated bias that not only were the indigenous living in a 'stable balance with nature', but also that they were too 'primitive' and limited in numbers to cause any significant changes to their surroundings. That picture is no longer valid. Archaeological ground surveys and air photo analysis, for example, now suggest a

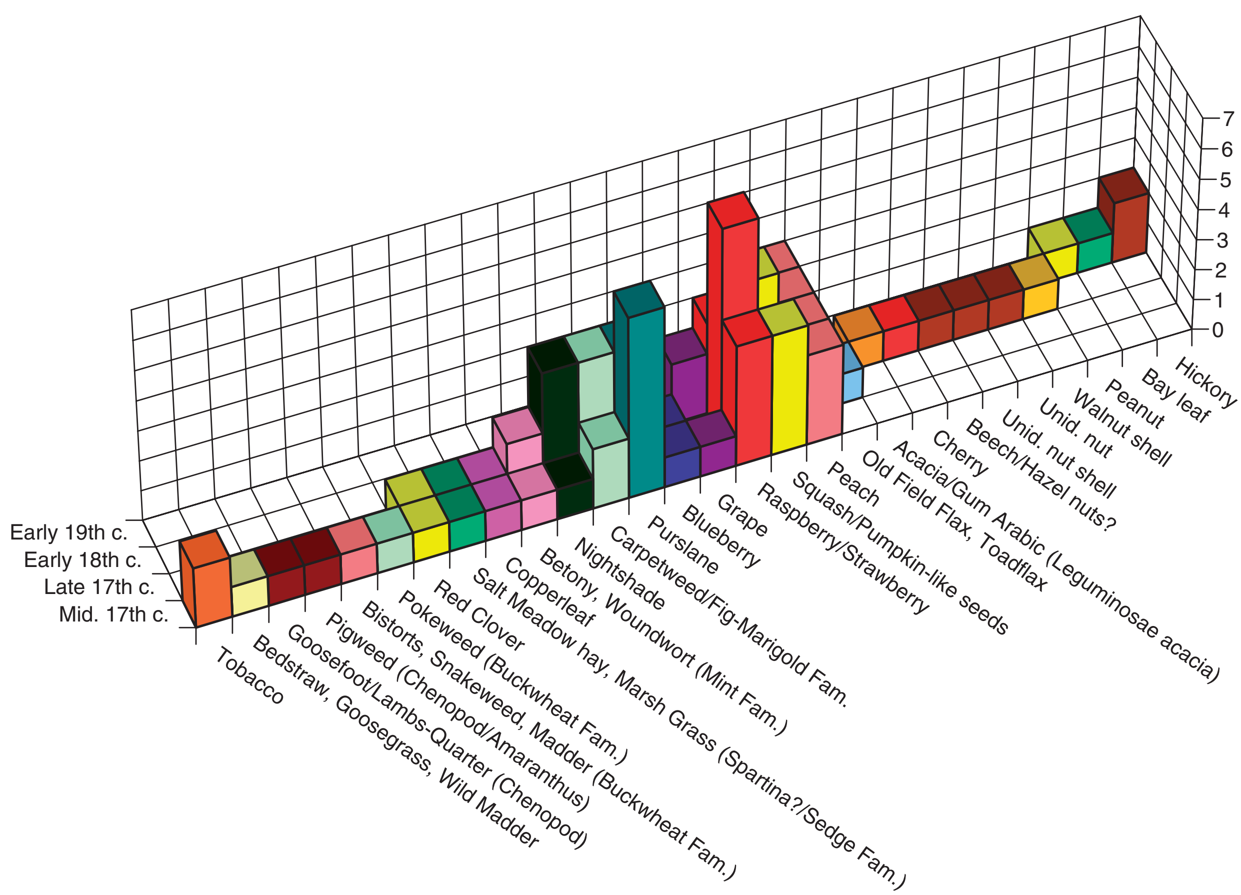

Figure 2 Three Dimensional bar graph of dated plant remains from the 17th and 18th Century features discovered in the Dutch West India Company Block at Pearl Street in Lower Manhattan, New York (Grossman *et al.* 1985). The predominance of "weed" types introduced from Europe, predominantly adopted to "Waste Ground", suggests that the environment of Dutch New York had been disturbed and traumatized at least as early as the mid-17th Century. (By Joel W Grossman, Ph.D., © Joel W. Grossman, Ph.D. 2008. Published by Elsevier Inc. All rights reserved.)

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Mayan population of some 3 million people, and that at least 8000 kilometers (out of a total of 22 700 square kilometers, or 35% of their area) had been cleared and deforested by the Classic Period Maya. Instead of being sparsely populated as many early explorers recounted, these low densities may reflect only the sudden and drastic impacts of disease on indigenous peoples. Some early diaries of the first Spanish visitors to Peru described a 90% population decline along the coast, and coastal valleys devoid of people. Current estimates put New World population levels at 40–70 million inhabitants at the time of European contact. As is the case today, the higher the density of people, the greater the environmental impact, all things being equal.

Cases of Man-Made (Anthropogenic) Environmental Change

Historical Antecedents

The awareness of man's impact on the environment is not a new concept, nor a new scientific development. In 1868 George P. Marsh published *The Earth as Modified by Human Action* with the stated goal of addressing "... the character and, approximately, the extent of the changes produced by human action in the physical conditions of the globe we inhabit...." He drew from Classical, Medieval, and historic sources to illustrate what would be described today as 'quantified geospatial' evidence and assessments of man's impacts to the landscape. Marsh suggested major landscape and climate impacts based on records of nineteenth-century coastal drainage and land reclamation projects in coastal marsh and wetland areas (100 000–400 000 acres) in England, Holland, Hungary, and California. He also made the observation that the chronological analysis of official climate records, before and after draining, documented measurable fluctuations of between a tenth and a third of a degree, in temperature. What has changed, and what is illustrated by the following case studies of anthropogenic (man-made impacts), is the time-depth and geographic diversity of these impacts. The following cases illustrate the extent and magnitude of prehistoric alternations to the landscapes of Mexico, the Andes, and Lowland South America. They also illustrate the importance of modern high-resolution palaeoenvironmental sequences, new dating techniques, the importance of aerial photography and high-altitude remote sensing for the accurate measurement and documentation of these changes.

A wide body of archaeological and ethnobotanical evidence indicates that in the New World (and presumably elsewhere) much of the environment and landscape had been heavily altered and manipulated long before European settlement and impacts. In addition to evidence of large pre-Columbian populations and dense settlement patterns in concentrated areas of Mexico, the Andes, and the Lowlands of South America, the archaeological focus on landscape and wide-area studies are documenting massive earth-moving efforts, beyond those of mound and temple construction that altered topography and drainage patterns throughout wide regions of the Americas. As the following cases and recent compilations of long-term and wide-area multidisciplinary archaeological investigations document, these pre-contact, man-made alterations of the landscape were both broad in scope and ecologically significant.

In addition to the following specific examples, a number of general changes took place independently of localized cultural and environmental conditions. These general impacts included an increase in the number and range of domesticated plants, expansion in the distribution of vermin and savaging species that lived symbiotically as by-products of human activities, a reduction in nonessential animal and plant species, and a general reduction in former distribution and habitats of animals of prey. In addition to these general cross-cultural impacts, and without belaboring the point, archaeologists (especially those working in the Americas) have begun to compile repeated cases of significant regional impacts and alterations to the environment by indigenous peoples, long before European contact. Recent archaeological treatments have revealed examples of well-documented prehistoric man-made impacts to ancient habitats in Mexico, the Andes of Peru and Bolivia, and in the lowlands of the Amazon basin.

Middle America

Comparative studies by Charles Spencer between dry uplands of Mexico and the tropical savannas of Venezuela, have documented the construction of massive water-control systems that in many cases rival the productivity and environmental conservation capabilities of modern intensive agricultural systems. One example underscores the size and capacity of a huge prehistoric dam system in the Tehuaca Valley of Mexico. Built over several centuries, the 400-meter-long (*c.* 1200-foot-long) dam impounded a volume of 2.6 million cubic meters. This reserve of water was sufficient to irrigate land to support 1000 people, with an annual surplus. Although abandoned in AD 250, the author suggested that its topographic displacement surpassed those of modern efforts. Similarly, in Oaxaca, some 20 miles to the south, several hundred inhabitants built aqueducts and canals that efficiently irrigated the majority of the valley.

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In contrast, contemporary water-control systems generally irrigate only parts of the same area for agriculture, and leave major sectors dry and unusable.

Finally, Spencer listed an extensive prehistoric system in the damp tropical plains of the Barinas region of Venezuela that drained and regulated fluctuating water levels throughout the year. Extensive networks of ditches and channels siphoned excess flood waters in the wet season and brought water to irrigate the same areas in the dry season. This seasonally adjustable, prehistoric water-control technology raised production to two crops per year, and appears to have supported populations some 20 times larger than todays.

Andean South America

The Andean regions of highland Peru and Bolivia also featured massive landscape alterations and impacts to the precontact environment. Recent work in the highlands of the Lake Titicaca Basin, such as that of Clark Erickson, have reevaluated the economic and settlement patterns of the Pre-Inca Tiahuanaco cultures living around the lake between *c*. AD 800 and 1200. These also underscored the extent of anthropic, or man-made, alterations to the environment, clearly also long before European contact. Based on surface survey and the ability to measure landscape alterations with air photos, Erickson calculated that the Lake Titicaca peoples had built over 500 000 ha (123 500 000 acres) of terracing on the surrounding foothills.

In the lower portions of the basin, extensive areas of perhaps as much as 256 ha (632 acres) had been transformed for intensive agriculture by the construction of sunken gardens or *q'ochas*. These plots provided static irrigation from groundwater for fields of potatoes, quinoa (Andean grain related to Amaranth), and feed for domesticated animals. Extensive canals irrigated fields and pastures in the dry seasons, apparently as early as 1800–2000 BC. Based on modern aerial imagery and remote sensing, it now appears that the entire landscape of the basin was managed and reconstructed – with little remaining to identify as natural or 'pristine'.

Lowland South America

Perhaps the most striking new insights and divergences from old assumptions pertain to the prehistoric ecology and environmental history of the Amazon lowlands of South America. Twenty years of diligent multidisciplinary archaeological, ethnobotanical, and chronometric work by Anna Roosevelt is producing a body of new evidence that debunks nearly a century of misconceptions concerning man–landscape interactions in the Amazon basin. Long held assumptions are beginning to fall by the wayside in the face of this new, multidisciplinary evidence. These include (1) the notion that the Amazon was a pristine habitat, only recently impacted by modern deforestation; (2) the idea that the indigenous inhabitants lived in harmony with the lowland environment; and (3) the belief that early farmers could not subsist in the tropical rain forest.

Work at three large prehistoric settlement areas in the delta flood plain, near the Amazon's outlet into the Atlantic, in the Tapajos confluence region of Monte Alegre, have revealed well-dated stratigraphic sequences, a host of well-preserved botanical and food plant remains. and clear evidence that these inhabitants were not living in small scattered settlements, but instead in large raised platform mounds above the flood plain. Roosevelt surmised that these centers covered core settlement areas of 4 km^2, each with population levels of 10 000 people, and that they developed long before European contact. These early Monte Alegre inhabitants practiced shifting 'slash and burn' agriculture that resulted in cleared regions around their settlements. The dense populations and clearing practices also appear to have created what Dr. Roosevelt suggested were degraded landscapes of localized treeless savannas, distinguished only by dense secondary stands of palms or other single-type stands of trees. In addition to these patterns of localized forest clearing, Roosevelt also identified what appear to be raised fields distinguished by layers of dark fertilized soils from the waste and domestic by-products of the local residents. The new sequence of dated pollen cores, archaeological plant remains, and the isotopic analysis of human remains suggest that the appearance of the dry interior open savannahs was not a 'natural' event with ancient roots, but instead the relatively recent prehistoric by-products of 'anthropogenic,' or man-made, land clearing. What one sees today is not the result of only modern deforestation and land clearing, but also the ancient products of prehistoric agricultural practices and localized alterations to the landscape by peoples living in relatively large and dense centers of population. This thesis recently gained support from an innovative nonarchaeological source.

Recent work by a team of geochemists from the University of South Carolina has used deep-sea core samples from the Amazon discharge fan to argue that the savannahs were not ancient, but modern and that the Amazon basin had been covered by dense, high-canopy forests little changed for 70 000 years. The researchers used dated sediment samples to measure the relative ratios of carbon-13 to carbon-12, based

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on the fact that samples eroded from arid grasslands are significantly different from that of sediments from forested regions. The Amazon samples show consistently 'high' negative values indicative of runoff from forested areas versus open savannahs.

The new core evidence also counters a widely held theory, first promulgated by an ornithologist in 1969, that explained the biodiversity of the Amazonian bird populations as the result of being isolated by stands of primeval forrest, each separated by vast expanses of open interior savannah. Known as the Refuge (or Refugio) Hypothesis, this model presumed that the savannahs were ancient and served to create 'refuges' of isolated forest stands that fostered species distinctions within and between animal and bird populations. The theory was also adopted by some lowland archaeologists to explain settlement patterns and cultural differences among modern indigenous peoples today.

These new archaeological and deep-sea core data are the first concrete and testable evidence that refutes the popular Refuge Theory. They also suggest that clearing encountered by European colonists was, as Dr. Roosevelt suggests, the result of actions by prehistoric peoples, not natural forces.

Historic Old and New World Environmental Impacts

As Marsh argued over a century ago, historical archaeology and a focus on environmental indices (pollen, seeds) is providing comparable material evidence of environmental trauma in the medieval and colonial periods in the Americas and Europe as well. In England, the analysis of pollen and metal trace-element fractions from three cores taken from peat bogs in the Northern Pennines have provided new evidence of long-term environmental impacts from the regional mining industry. The identification of shifting tree and plant communities from dated pollen cores indicate that small short-term forest clearings had begun in the Neolithic and Bronze Ages. These early impacts were followed by substantial wide-scale clearing and deforestation in the subsequent Iron Age and Romano-British Periods. Landscape changes from local mining, however, were clearly evident by the Medieval Period. However, the measurement of lead and zinc levels in pollen core samples correlated with a permanent drop off of tree pollen, together with an increase in lead trace-element readings beginning in the eleventh century AD. It is noteworthy that a modern travel description on the Web treats the area as pristine, with idyllic terms as "one of England's most special places – a peaceful, unspoilt landscape...." The archaeological evidence and the archical record instead point to a long history of environmental degradation.

Comparable indicators of man-made environmental trauma to the colonial United States environment have also been documented for later seventeenth-eighteenth and eighteenth-century sites as well. Excavations by the author along the original colonial shoreline at Pearl Street and Broadway in Lower Manhattan led to the discovery of well-preserved seventeenth-century remains of the first warehouse of the Dutch West India Company, as well as the house foundations and artifacts of some of its principal residents and officials from the 1650s. Well-preserved and tightly dated plant remains excavated from privies and cisterns were found buried and preserved 8–12 feet below the modern grade of Lower Manhattan. Instead of varieties suggestive of well-tended rear yard gardens, nurtured soils, and neatly kept yards, the earliest 1650s plants from the Dutch West India block showed little evidence of ornamentals. When the colonial seeds were compared to ornately illustrated contemporary sixteenth- and seventeenth-century European *Herbals* (e.g., Leonart's Fuchs' (German) *The New Herbal of 1543,* or Culpeper's (English) *The Complete Herbal of 1649*), they proved to be both predominantly of European origin and used as 'medicines, dyes, and industrial products' (Figure 2).

Instead of indicating well-tended household gardens, the majority of the mid-seventeenth-century plants were adapted to acidic, heavily compacted, and disturbed soils, or waste ground similar to what one might find along heavily traveled dirt roads, open yards, or paths today. With the exception of the widely dispersed peach being present from the 1650s onward, the archaeological evidence for ethnobotanical indicators of potentially landscaped or intentionally planted specimens did not become evident until the first quarter of the eighteenth century. This unique archaeological evidence implies that Colonial Dutch New Amsterdam urban landscape had been traumatized and disturbed by the introduction of foreign, often genetically dominant, invasive 'weeds' as early as 1650 (purslane, bedstraw, Pigweed (amaranth), goosefoot/lambs quarter, copperleaf, carpetweed, carpetweed and indigenous berries, and squash and tobacco seeds).

It also suggests that archaeologists, historians, and ecologists must proceed with caution in accepting accounts by later, eighteenth- and nineteenth-century 'naturalists' of supposedly pristine environmental conditions in colonial America and elsewhere.

Cultural Responses to Climate Change

The previous case studies have illustrated the range and severity of man-made impacts to the environment and landscapes of different culture areas in prehistory. Over the last 10 years, intriguing new theories

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have been presented by scientists from several disciplines about how climate change has influenced the rise and fall of ancient civilizations in both the Old and New Worlds. In particular, these theories have focused on droughts and, in one well-publicized case, floods, and most recently, the role of sea-level rise. The availability of high-resolution and well-dated paleoclimatic and archaeological sequences are providing new insights and alternate interpretations about how and why complex urban societies formed and collapsed.

Most of the following cases involve debates over the identification and cultural significance of long-term (300–500 year) mega-droughts on several well known but unexplained prehistoric economic and demographic collapses and disappearances. Peter deMenocal of the Lamont-Doherty Earth Observatory at Columbia University notes the independent record of significant episodes of climate changes over the last 3000years of the postglacial Holocene period. Instead of being uniform and climatically stable, as once thought, it was punctuated by a series of widespread, continent-wide, periods of cooling and desiccation and droughts, throughout North America, that lasted for approximately 1500 years over the last 10 000 years. He also noted that where identified, these long-term droughts emerged suddenly, often in less than a decade. And as we well see below, he also argues that these episodes of long-term climatic change had devastating consequences for prehistoric and historic peoples of the Americas. These arguments fall into two subcategories: (1) studies that point to the negative effects of severe droughts; and (2) those that point to the onset of drought conditions as catalysts for major population movements and/or adaptations to changing landscape and environmental conditions. Only recently, high-resolution environmental sequences of climatic and botanical changes, often now resolved down to 20–50-year intervals, have become available with sufficient chronological precision to be matched to comparable archaeological sequences of cultural growth, decline, or disappearance. Readers must be cautious of 'single source' explanations of culture change. Brian Fagan has warned that the 'correlation' of high-resolution data on environmental change (from sediment, lake, or ice cores) does not demonstrate a 'causal relationship'. And as he underscores, these traumatic episodes of culture change are complex and difficult to ascribe to a single guiding force.

Ancient Egyptian Droughts

Archaeologists have long been aware that significant population migrations played a role in the development of early sedentary agricultural settlements in both the Nile valley and Mesopotamia, as well as in the formerly sparsely populated and dryer southern region of the Tigris and Euphrates river drainages. Additionally, a number of scientists have argued that climate change and a shift to dryer, more arid conditions played a significant role in bringing about the demise or collapse of early urban centers in both Egypt and Mesopotamia. Recently, alternative arguments are now being put forth that the onset of more arid conditions may have served as an important 'trigger' or causal factor for the emergence of early civilizations in both regions. All of these arguments are based on the chronological correlation of recently available high-resolution sequences of environmental and climate data, generally from marine and terrestrial cores, with longstanding archaeological sequences from different culture areas.

For ancient Egypt, the 1000-year period between *c.* 5800 and 4800 BC saw the emergence of first goat and sheep herding, and then early mixed herding and farming communities in the Nile Delta. Beginning around 3300 BC, a period referred to as the Old Kingdom emerged as a period of prosperity and growth distinguished by the first urban centers, centralized state rule, large-scale construction of government and religious complexes, and the first pyramids. It was also was a period of continual and reliable Nile floods. However, sometime around 2200 BC, the Old Kingdom appears to have suddenly suffered social and economic anarchy and collapse. Scholars have spent their entire careers promulgating theories as to why, but generally without much evidence.

Work by Fekri Hassan initially suggested that drought may have been a factor in the collapse of early Egyptian civilization. Hassan based this possible explanation on the simple stratigraphic observation that an important basin fed by the Nile River, the Fayum Depression, lacked any lake-bottom sediments dating to the period of the Old Kingdom. This suggested to him that, instead of the traditional 18–20 m of water, the depression had dried out and, that where once present, the sediments from this period had blown away.

Multiple lines of recent geological and sedimentological evidence are substantiating Hassan's thesis that drought may have brought about the demise and collapse of the Old Kingdom. The recovery of high-resolution sediment cores from the Nile Delta by Jean-Daniel Stanley, has recorded a band of red wind-blown sand, suggestive of severe drought, dating to *c.* 2150 BC, or at the same time as the collapse of these earliest Egyptian urban and religious centers. Other sediment cores from elsewhere in Egypt and North Africa have recorded the chemical and mineralogical fingerprints of similar layers of wind-blown sand of the same age. Scientists of

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the French National Center for Scientific Research (CNRS) have also reported that high-resolution pollen and diatom sequences have identified parallel periods of drying and drought dating to around 2100 BC from Ethiopia, Rwanda, Uganda, and equatorial Africa. These multiple lines of evidence now appear to have world-wide implications, with comparable effects on the settlement and culture histories of other regions, including the Near East and the New World.

Hassan also argued that just as drought appears to have brought an end to the Old Kingdom, the beginning of the subsequent Middle Kingdom between *c*. 1900 and 1800 BC was distinguished by centralized efforts to control the short-term effects of drought. He points to the initial building of canals, a large dam and reservoir, and the dredging of the channel of the Nile linking the river to the Fayum Depression. These constructions both buffered against periods of drought and served to regulate the water level within the Fayum Depression in support of extensive irrigation agriculture surrounding it. He theorized that subsequent Nile floods breached the dam, inundated the depression, and rendered it unusable for agriculture until the third-century BC, or a period of abandonment lasting at least 1500 years.

Mesopotamian Droughts

Similar work on sudden climate change by Dr. deMenocal has used deep-sea sediment cores taken from the Mediterranean to argue that abrupt climate change to cooler and dryer conditions brought about the sudden collapse of the Akkadian civilization in northern Mesopotamia around 4200 BP. Detailed chemical and particle analysis identified a thick lens of air-borne sand in the column beginning (dating to 4170 BP), which appears to have lasted for at least 300 years. This and other lines of archaeological and climatic evidence were combined to contend that, as was the case for the Old Kingdom of Egypt, the collapse of the Akkadian culture and the previously identified migration of its population to the south coincided with the onset of a major long-term period of drought in the region.

As was the case for the advent of irrigation and water control systems in the Middle Kingdom of Egypt, others have used paleoclimatic evidence to suggest that a regional shift to more arid conditions also helped trigger the onset of both irrigation agriculture and urbanism in southern Mesopotamia. In 2004, two scientists – Nick Brooks and Harvey Weiss – independently used similar evidence to theorize that increased desiccation was not only responsible for the collapse and migration southward of the Akkadian peoples. In addition, they both argued that drought may have played a role in the subsequent population increases, urbanism, social stratification and onset of irrigation agriculture in southern Mesopotamia, as well.

North American Droughts

In a synthesis of both archaeological and climatic evidence from both New World and Old World archaeological chronologies Dr. deMenocal has highlighted both Old and New World examples of long-term drought relative to a number of archaeological culture sequences. His examples illustrate prehistoric shifts in settlement patterns, the abandonment of urban centers, and in the case of the Pueblo and Mayan cultures of North and Central America, their complete disappearance. He used evidence from sediment cores and tree ring dating to explain the long-debated decline of both the first European colonies in North America and, quite clearly, provided credence to the arguments by several archaeologists that drought was also the culprit behind the abandonment of the great Pueblo centers.

Archaeological evidence and tree ring dates have also provided convincing evidence that the 1587 settlement of the Lost Colony on North Carolina's Roanoke Island had disappeared during the most severe drought in 800 years. Similarly, the high mortality and near loss of the 1607 settlement of Jamestown, the first permanent English settlement of North America, coincided with the driest period of drought in the prior 770 years of the local tree ring record.

Finally, the correlation of sequences of climatic change with the pivotal benchmark dates of prehistoric culture change has provided convincing evidence to explain the thirteenth-century abandonment of the Anasazi 'cliff house' settlements in the American Southwest. Although often without much evidence to go on, earlier archaeological theories had suggested their demise through droughts, war, internecine conflict, or religious chaos. Recently, the availability of high-resolution sequences of climate change now presents a tightly dated record indicating that drought was indeed the primary cause of decline. Regional tree ring chronologies and drought distribution maps document that the thirteenth-century abandonment of Anasazi settlements coincided with the advent, around 1280 AD, of a significant, generation-long drought lasting at least 26 years.

Central American Droughts

Similar lines of evidence from dated sediment cores help to explain the sudden decline of the Maya as well. Two came from land-locked lakes in the Yucatan peninsula. A third was recovered from a

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segment of a 500-foot-deep core drilled off the coast of Venezuela, to the south of the Maya heartland in the Caribbean. Using different lines of evidence, the core sequences together provided redundant records that drought played a key, if not a primary, role in the collapse of Maya urban centers and the depopulation of the peninsula between AD 800 and 1000. Radioisotope analysis of minute fresh water shells from the inland lake cores indicated that the onset of an extended, but ill-defined (*c.* 200 year) period of dryer conditions and reduced rainfall had occurred sometime around AD 900.

More recently, based on radiocarbon determinations from the Venezuelan sediment column, Dr. Larry Peterson of the University of Miami was able to define a 200-year series of climate 'signals' – or indices of sudden climate fluctuations – dating from AD 750 to 950. Work by Gerard Haug used X-ray fluorescence to measure the relative amounts of trace titanium in a series of dated sediment samples. Titanium was tested for because it accumulated in the basin sediments as a small but measurable by-product ('trace element') of stream run-off from the Yucatan peninsula; the lower the titanium levels, the lower the rainfall. Four periods of reduced titanium measurements dated to AD 760, 810, 860, and 910. Each was interpreted to be an indicator of episodes of apparent drought, which correlated suggestively with the collapse of the Maya centers sometime after AD 800. These independent core-derived findings support the earlier thesis of an independent Texas archaeologist, Richard Gill, that drought was responsible for the abandonment of the Maya cities sometime after AD 800. Gill based his suggestion on a survey of the latest dates carved into monuments before different centers were abandoned. Despite a fudge factor of ±30 years in the core-derived radiocarbon determinations, his archaeological chronology of calendar dates for the demise of the Maya matched the dates of the titanium 'proxies' of climate change with uncanny precision.

Andean Droughts

A similar sudden climatic event in around the thirteenth-century AD has also been presented to explain the decline of the Middle Horizon urban centers in the Bolivian Andes (and by extension in highland Peru). Although somewhat less convincing than the wealth of tree ring data for the American Southwest, samples from a single ice core have been used by some to argue that the collapse of the pre-Inca urban center of Tiahuanaco on the Bolivian altiplano (11 000 feet elevation), surrounding Lake Titicaca, may also have occurred as the result of drought.

Counted and measured like tree rings, the availability of a finely dated ice core from the Quelccaya area of the southern Andes, 200 km to the north, provided a tightly dated 1500-year sequence of annual ice accumulation. The dated ice sequence indicated that a lessening of ice accumulations and a shift to significantly drier conditions began around AD 1040 and lasted for at least 200 years, or until the thirteenth century. This suggested change to dryer conditions also corresponded with a 30 foot drop in the level of Lake Titicaca. Archaeologists and climatologists have used this single line of dated climatic evidence to argue that the sudden and long-term climate shift to dryer conditions would have been of sufficient magnitude and duration to destroy or radically diminish the productivity of the traditional raised field system.

In addition, new research on the Quelccaya ice cap used radiocarbon dating of ancient plants recently exposed by the retreating glacier to argue that the onset of the Late Holocene around 5000 BP was marked by a measurable shift to cooler conditions. This evidence of dated climatic change is also identical in age to comparable climactic events in the Old World. As discussed above, the climatic transition at 5200 BP is also coincident with parallel shifts and the emergence of urbanism in Egypt, Mesopotamia, and elsewhere. This independent ice core data indicated that a climate shift also occurred in the Americas at the same time as the wind-borne sand was recorded in sediment cores from the Mediterranean. These temporal parallels suggest that the shift may have been a world-wide event, with world-wide cultural consequences.

The Black Sea and 'Noah's Flood'

In 1997, two Columbia University oceanographers and geophysicists (and again not archaeologists), Walter Pitman and Bill Ryan, presented a widely heralded theory that the breaching of a shallow ridge around 7200 years before the present, literally 'opened the flood gates' from the Mediterranean and 'deluged' the lower elevations of a landlocked basin to create the Black Sea. The two researchers also upped the scientific ante by suggesting that the event correlated in time, and was one and the same as the Biblical tale of Noah's flood. The well-publicized theory received much attention, and given the institutional affiliations of the proponents, was broadly accepted as . . . gospel. In his important 2004 synthesis, *The Long Summer: How Climate Changed Civilization*, Brian Fagan captured the enthusiasm of the moment in vivid terms of prehistoric loss and angst:

> The rising lake . . . killed carefully tended gardens . . . Helpless villages watched as their thatched houses and storage bins vanished under the brackish tide. At some points, the shoreline advanced up the river valleys as fast as a young man could walk. (p. 113).

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Alternate Data and Interpretations

Though popular in the West, the thesis apparently was developed with little consultation or reference to over 30 years of archaeological, environmental, and geological research on the Black Sea by Russian scientists. At the forefront of this research tradition was the work of a Ukrainian climatologist, Valentina Yanko-Hombach, whose investigations (like parallel studies in the West), used thousands of sediment cores and high-resolution seismic profiles to study the geological and environmental history of the Black Sea. Aside from the radiocarbon evidence that local agriculture did not flourish for another thousand years (suggesting the lack of any farming communities that would have been available to be drowned), her work on 'foraminifera' (microscopic marine shells that varied by species depending on the water being fresh or saline) suggested instead that the Black Sea basin had experienced not one major deluge, but in fact a series of many smaller 'floods' over many thousands of years. Her sediment cores identified salt-tolerant foraminifera varieties around 9500 years ago, and concluded that if there was a deluge, "Noah's flood legend has nothing to do with the Black Sea."

In 2002 the *Journal of Marine Geology* published a special volume of papers dedicated to presenting alternate data and interpretations of the Black Sea issue. One Canadian-led study indicated that the salinity of the Black Sea was never as low as that of a freshwater lake, and that gradual processes were sufficient to account for reported changes in the water chemistry of the Black Sea. In addition, pollen data suggest that environmental conditions were not amenable to either pastoral or agricultural settlements along the shores of the Back Sea until 4600 BP, or 3000 years later than the postulated flood.

The deluge hypothesis – and the international debate it precipitated – was promulgated long after the collapse of the Soviet Union and thus could not be attributed to political or Cold War barriers, only linguistic and cultural ones. What the debate does underscore is the critical need to evaluate different interpretations of cultural and environmental history with both a strong multidisciplinary and 'cross-cultural' perspective. Sometimes in science it takes a small voice to muster the courage to say "the Emperor has no clothes" – hopefully in the same language as the audience.

Stopping the Flood: The Trigger of Gradual Sea-Level Rise

As recently highlighted this year for its significance by a National Academy of Science review, two scientists, an archaeologist and paleoclimatologist, Douglas Kennett and James Kennett presented a radical new interpretation of the role of Holocene climate change on the origins of civilization. Instead of prolonged droughts, they argue that a slow-down in the rate of marine transgression, or 'sea-level rise' – and the associated formation of high water tables, coastal estuaries, and marshes – may have played an even more critical role in the formation of city-states in Mesopotamian culture history.

They summarized available climatic data for the Persian Gulf region and concluded that climate change between 10 000 and 5000 BP, but not drought alone, was responsible for the prehistoric demographic shifts and cultural changes documented in the archaeological record. They argued that between 9000 and 8000 BP the region experienced a period of high humidity and frequent monsoons that resulted in dispersed lakes, the availability of rich aquatic resources. High rates of sea-level rise also created inshoreline incursion rates of 110 m (*c.* 330 feet) per year, a rate equal to the loss of six miles of shoreline per century. This rapid shoreline incursion would, they postulate, have led to dispersed settlements that needed to periodically move inland.

Then, after 8000 BP, the slowdown or demise of melting ice brought a slowdown in the rate of sea-level rise and marine encroachment. This change in turn led to the formation of stable wetlands and marsh habitats, which depend upon low rates of 'marine transgression' to maintain sediments deposition at pace with the rising waters. These ecological changes created important new subsistence sources including access to fresh water, a diverse set of new habitats for hunting and fishing of birds, fish, and land animals. This period also corresponded with the initial formulation, between 8000 and 6300 BP, of centralized settlements – the Ubaid Period – in southern Mesopotamia.

They also make the point, overlooked by others, that irrigation agriculture can only be practiced in areas of high water table and that canal systems could have 'only been successfully constructed after' the wetlands and high water tables had formed and stabilized. Unlike earlier theories stemming from the original 1981 suggestion by Dr. Adams, that the early Mesopotamia centers developed as a 'result' of irrigation agriculture, the authors reverse the case and argue instead that irrigation agriculture came about 'after' the city-state had formed and only after the water table had stabilized near the surface. After 6300 BP – the Uruk Period – they point to an expanding population, the advent of canal systems, and the realignment of settlement patterns. Instead of being oriented to the irregular topography and shorelines

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of the marshes and estuaries, these growing urban centers followed lineal patterns paralleling the extensive network of the new canal and irrigation systems. In essence, while increasing aridity may have added to the process after 6200 BP, they argue the primary impetus was due to "a deceleration in marine transgression that stimulated the expansion of floodplains in southern Mesopotamia and formation of high water table necessary for large-scale, flood plain irrigation agriculture."

Not only does this new model present a convincing alternative to attributing demographic, settlement and economic shifts in culture history to catastrophic causes, but they also suggest, as did others 2 years before, that the source of several myths of biblical floods derived more likely from the area of southern Mesopotamia, not the Black Sea. They also conclude that both the Sumerian and the Christian flood sagas (myths) more likely reflected a period of rapid sea-level rise forming a rapidly expanding inland sea several thousand years before the advent of the Mesopotamian Urban centers.

Buried and Submerged Landscapes

This important argument has put the process of marine transgression into a whole new light. In the context of landscape archaeology, it has now emerged as a central mechanism, if not a primary trigger, for the early concentration of settlements in littoral regions – as well as for the formation of the first urban centers in the near East. This new evidence has unequivocally raised the issue of environmental change in general, and the role of sea-level rise in the formation of estuary, wetlands, and marsh habitats, in particular, to be the central causal factor or impetus for the formation of sedentary settlements. In tandem with the release of Kennett's and Kennett's paper on the role of seal-level rise in the development of early Near Eastern civilizations, two archaeologists, Erlandson and Fitzpatrick released a paper in 2006 (see additional reading) calling for a recognition of the archaeological potential of submerged archaeological sites and called for regional studies that deal with local variation.

> ....careful reconstructions of coastal paleography and predictive modeling ....to help determine the most likely locations of ancient coastal settlements as well as the places where settlements are most likely to be preserved...

This call to arms dovetails nicely with new insights into late Holocene sea-level rise and the ability of 3D geospatial techniques (3D GIS and terrain modeling) to capture the topographic subtlety and changing configuration of formally exposed cultural habitats (Figure 3).

Holocene Fluctuations and Exposure

Recently, the availability of tightly dated and micro-sampled pollen cores have revealed far-reaching new insights into the Late Holocene trends in sea-level rise that appear to contradict widely held assumptions about climate change over the past 3000 years. Just as these new high-resolution palaeoenvironmental sequences are showing correlations with archaeological events over the past 6000 years in the Near East, new high-resolution sediment and pollen cores from coastal marshes in both Europe and the Americas are now documenting equally significant fluctuations in sea-level rise and sedimentation rates over the last 2000 years as well.

Instead of static marsh habitats at the same water level over the last several millennia, it now appears that many of these sediment-filled drainages were exposed throughout the late prehistoric and early historic periods. The recorded high rates – orders of magnitude above the 'official' IPCC estimates of *c*. 11–21 cm per century – and extreme fluctuations in the rates of marine transgression over the past two millennia, are also strongly suggesting that much more of the late prehistoric landscape of now inundated drainages were exposed than we had previously suspected, when prehistoric settlements began to abound along the coastal drainages of North America and elsewhere.

For example, recent high-resolution core sample fractions by Dorothy Peteet and her team at the Lamont-Doherty Earth Observatory and the NASA/Goddard Institute for Space Studies, taken at *c*. 4 cm (20–50 year) intervals from a Hudson River estuary (Piedmont marsh), upriver from New York City, documented extreme fluctuation is sedimentation rates – and by extension as a proxy for pollen-based indices of past disturbance – over the last 1500 years. The earliest and deepest core segment, dating from *c*. AD 500–1000, showed a rate of 18 cm per century, consistent with the nineteenth-century tide gage records for the region. However, it dropped to 3 cm per century between *c*. AD 800 and 1250, but jumped to from *c*. a 30–60 cm between AD 1250 and 1300. It then dropped down to 30 cm per century in the Colonial period, half the rate of the previous century, but nearly two to three times the currently generalized estimate of 11–21 cm per century.

Several similar core sequences from the coasts of Nova Scotia and Maine have used the relative composition of foraminifera (microscopic shell species variously adapted to either fresh or saline habitats) to extend the earliest nineteenth-century tide gage

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Figure 3 Historic geospatial composite illustrating the process of 3D palaeo-environmental reconstruction of buried cultural landscapes, in this case the original topography and ground cover seventeenth century Colonial Manhattan. Relative topographic variability is extruded from historic map coverage, the actual elevations and depths from archaeological excavation records, or 'ground truth'. The historic plant and tree cover is derived from excavated and dated archaeological plant remains and ethnobotanical records. Modern digital air photo coverage is used with computer-based GIS (Geographic Information Systems) software to georeference, or 'rubber-sheet', the historic landscape projection to real-world coordinates (By Joel W. Grossman, Ph.D., © Joel W. Grossman, Ph.D. 2008, Published by Elsevier Inc. All rights reserved.)

records, back a century, to AD 1750. And like the new Hudson River core data, they also recorded historic period rates of 30–50 cm per century in Maine and 60 cm per century from Nova Scotia, with most of increases occurring in the eighteenth century.

The dated column or core samples identified evidence of significant large climate signal, or fluctuation, in the region's wetness, indicating the sudden onset of drought in the northeast, during what had been called the Medieval Warm Period in both Europe and the Americas, between approximately AD 800–1350. This *c*. 500-year warm spell was followed by what climatologists have called the 'Little Ice Age,' between fourteenth and nineteenth centuries. Similar palaeoclimatic records of drought at this time from the Chesapeake estuary, and from the Jamestown Colony to the south, suggest that the entire northeastern US region experienced the sudden onset of a 4–5-century-long period of drought, parallel with the shift to warmer conditions.

These shifts are thus beginning to document 'order of magnitude' variances in contrast to the 'straight-line'

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mean regression plots of the commonly ascribed to the multimillennium time span between the post-1850 tide gage data and the *c*. 3000-year-old chronometric dates for basal estuary or marsh sedimentation in the northeast. The new data instead suggests that rates of marine transgression appear to have (1) left significantly more dry land exposed than thought (the higher the rate of sea-level rise, the more land was formally exposed in the historic and late prehistoric periods), and (2) subject to sudden and significant shifts in regional climate trends. If these episodes of sudden climate change in the late prehistoric and historic (Medieval-Colonial) era patterns can be documented for other regions, then current discussions of 'global warming' may need to add, or factor in, the variable of 'widely fluctuating' Late-Holocene rates if sea-level rise and sudden climate change to the widely held straight-line 'handle' of the modern 'Hockey Stick' of contemporary climate modeling.

In terms of archaeological associations with the landscape, these episodes of higher late-prehistoric rates of sea-level rise also suggest that what were presumed to be low-lying or submerged landscapes within coastal drainages, may in fact have been significantly higher, dryer, ecologically diverse, and more available for human exploitation and settlement than previously presumed. These findings also strongly suggest that future palaeoclimatic and palaeoenvironmental studies must now come to grips with the need to sample and analyse equivalent high-resolution (decade level) samples in order to 'see' comparable short-term climate shifts and changes in sea-level rates in other coastal regions.

Submerged Archaeological Survivals

Recently, some astounding off-shore discoveries in the British North Sea, and off the coasts of Denmark and Sweden, have documented the unexpected survival of well-preserved archaeological sites in now submerged off-shore ocean settings. These discoveries show high levels of stratigraphic integrity, the survival of a broad-range of prehistoric food and ecological data, as well as a wide assortment of diagnostic chipped stone, wood, and bone artifacts.

In 2003, British archaeologists and divers working in the North Sea discovered two prehistoric settlements, one tentatively dated to the Early Mesolithic (8500–10 000 BP) and another to the Late Mesolithic (5000–8500 BP). While a prehistoric antler harpoon had been earlier recovered in North Sea fishing net, and a deep-sea core sample yielded a chance find of a Stone Age chipped stone artifact, these submerged sites are the first to be confirmed to have survived the often severe wave action of the North and Baltic seas. Marine archaeologists from the Estonian Maritime Museum also recorded a 1720 Russian or Swedish fort on the bottom of the Bay of Tallinn. The stone and timber fort was found at a depth of 8–11.5 m (24–35 ft), 900 m (2700 ft) off shore.

In 1999, similar cases of submerged archaeological sites, that had clearly survived the forces of tidal action and sea-level rise, were discovered by Harold Lubke along the Baltic coast in the Bay of Wismar. Fifteen sites, belonging to at least two and possibly three prehistoric culture groups were recorded along now inundated shore areas, one group at *c*. 0–5 m and oldest at −7 to −8 meters (21–24 ft) below mean sea level (msl). These seafloor sites revealed rich assemblages of stone and bone implements, most prismatic blades consistent with late Neolithic types, preserved plant remains, small-boned vertebrates, as well as numerous wooden artifacts including prongs and fishing equipment, an elm wood bow, parts of log boats, bone and antler points, a bone knife, harpoon fragments, antler strikers (to make fires), and an antler pendent and boar tusk knives. The zoo-archaeological remains included deer, boar, and large amounts of minute fish bone, including a predominance of eel and cod. The best preserved of these delicate artifacts were recovered from a band of submerged 'peat' reflecting its transition from a dry land site, to a temporary matrix of a tidal marsh before being buried under off shore sands of the rising sea.

An internally consistent series of 32 radiocarbon determinations returned dates between 4100 and 6200 BP, which together with the artifacts distinctions suggested three phases of prehistoric occupation within this 2000-year time span. In 2002 Lubke published an important paper entitled 'Submarine Stone Age Settlements as Indicators of Sea-Level Changes and the Coastal Evolution of the Wismar Bay Area'. Lubke combined his depth and bathymetric data with the radiocarbon age determinations to recompute earlier widely accepted estimates of sea-level rise that had been based on standardized morphological and analytical procedures from dated sediment cores. The archaeologically anchored calculations showed that the sea had reached the elevation of the prehistoric sites 1000–2000 years earlier than thought, reaching the −7 m mark of the earliest and deepest site around 5100 BC instead of 4000 BC, and the higher −3 meter mark of the more recent site by 4100 BC instead of 2000 BC.

In addition, like air-borne radar, a series of side-band-sonar scans of the bottom captured a broad range of topographic variability and defined specific landscape features that were found in association

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with the submerged prehistoric sites and could be used, in the future, to target the topographic characteristics of other similar underwater archaeological survivals. These included low beach gradients, original deposits imbedded in and protected by peat, wherethe local topography contains indentations, 'fossil' estuaries and river valleys, submerged gullies, depressions with former wetland deposits, on the flanks of submerged islands, bays, estuaries, near-shore lagoons, and other forms of partial shelter.

Similarly from the Pacific Coast of North America Fedje and Jasenhans from Parks Canada and the Geological Survey of Canada documented well-preserved shell-fish-rich beaches and stands of submerged treestumps from drowned forests at a depth of 150 m (*c.* 450 ft) in Werner Bay of British Columbia. In addition, the recovery of a barnacle-encrusted chipped stone tool from a depth of 55 m (*c.* 150 ft) suggests human occupation predating 10 200 BP. As was the case for the Baltic, this unique find suggested rates of marine transgression that were significantly higher than prior estimates derived from traditional geomorphological coring and dating procedures.

Like the European studies, high-resolution marine side-band sonar and remote sensing surveys reveled that the Holocene artifact was found in association with drowned landscape features (palaeobeaches, former stream confluences, lakes, terraces, bogs, and estuaries) that suggested the potential for the discovery of other drowned sites in zones of now buried and submerged drainages and coastal formations. In addition, this evidence suggests that now submerged landscape of the Pacific Coast continental shelf was both exposed and occupied by humans in the Holocene. This new marine archaeological evidence, in conjunction with new palaeoclimatic evidence that the long-adhered- to 'Ice-free corridor' route for Early Man migrations into the Americas may not have been either open, or available, for some 2000 years after the earliest evidence of human occupations in south America – at Mont Verde in southern Chile – has added credence to the alternative theory in support of a coastal migration route.

These important new insights and alternate estimates for marine transgression suggest strongly that the discovery of future buried and submerged archeological sites will depend on the availability of high-resolution 3D control of the original preinundation and prelandfill topography (Figures 3 and 4). These deep-sea survivals also suggest that if fragile

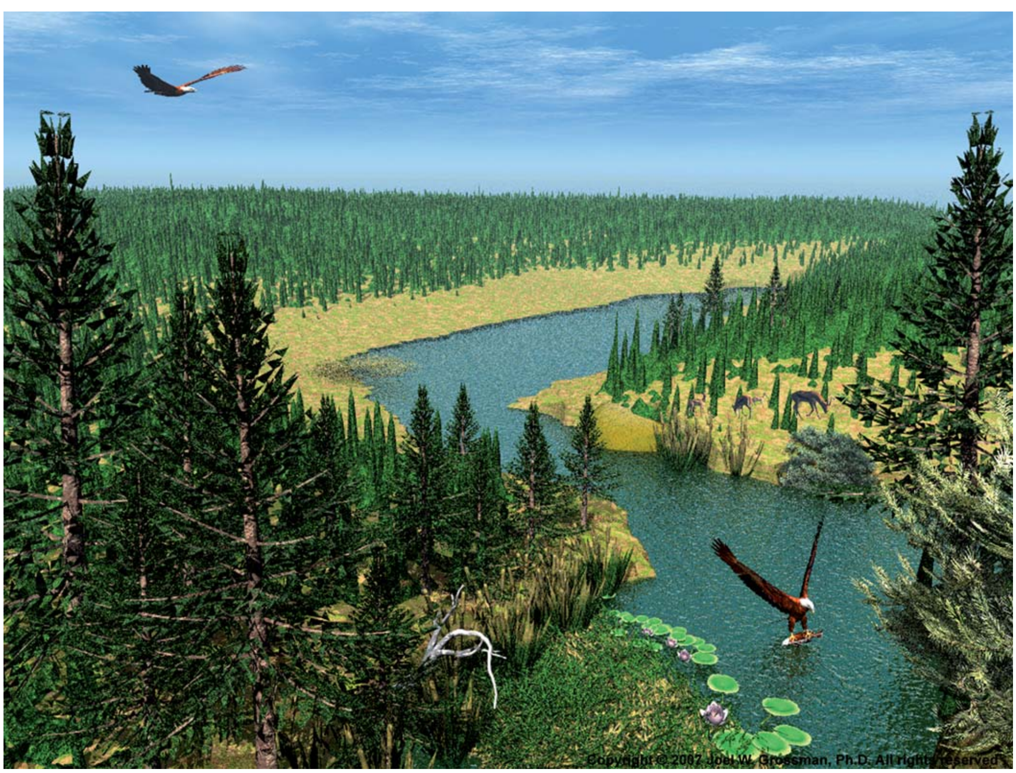

Figure 4 A 3D paleo-environmental reconstruction of prehistoric topography and habitat of the formally exposed New Jersey Meadowlands as it was before being inundated by rising sea levels ca. 2000–3000 BP. The digital terrain model, or 3D surface-mesh model, is derived from georeferenced 1865 US Army survey of bathymetry and mud-depth readings in the Hackensack Basin. The environmentally accurate 3D prehistoric tree and plant cover is identified from radiocarbon-dated pollen cores. (By Joel W Grossman Ph.D. © Joel W Grossman 2008. Published by Elsevier Inc. All rights reserved.)

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archaeological remains (with preserved organic artifacts and intact deposits) can withstand the rigors of coastal tides and wave action, they would have survived in Holocene tidal marshes as well.... and that we have to be prepared to look for them.

The Third Dimension: Modern Geospatial Strategies

Both in England and the United States, several government-sponsored programs are using historic bathymetry, GIS, and 3D terrain modeling to reconstruct the topography and archaeological sensitivity of now both buried and submerged shore areas as they appeared prior to being covered by landfill or inundated by rising seas.

For example, in England, Dr. Spikins of the University of Newcastle upon Tyne is directing a futuristic project entitled: *A Search for Submerged Early Postglacial Sites: Prospection Based on GIS Based Predictive Model*. High-resolution topographic reconstructions will be used to identify subtle underwater landscape features similar to those found in association with known sites. Also in England, scientists, working with a government-funded Estuarine Research Programme, are using GIS and 3D terrain to model and compare historic British Admiralty Charts dating back to 1847. Work directed by Dr. Daphne van der Wal is using these georeferenced correlations of historic naval charts to track changes in the estuary morphology and sedimentation rates over the last 150 years.

In the eastern seaboard of the US, historic bathymetry from US Army Civil War-era mud depth surveys is being used by the author to develop 3D georeferenced reconstructions of the premarsh topography of the now inundated wetlands of the New Jersey Hackensack Meadowlands. Three-dimension terrain modeling is being used to define what the preinundation landscape looked like, and where people may have lived on it over the last 3000 years, and when the water level was 20–30 m lower than today. Historic GIS comparisons are defining which of the sensitive archaelogical areas may have survive modern impacts (Figure 4).

As has been shown for earlier prehistoric submarine landscapes in Europe and the Pacific Coast of North America, these 3D terrain models of the Civil War-era bathymetry have documented a diverse 'preinundation landscape' of fresh water drainages, terraces, plateaus, ridges, tidal, and estuary zones beneath the modern water level. High-resolution sediment core sample sequences – taken at 4 cm or at 20–50-year intervals – will be used to create a detailed record of changing climatic, habitat, and sea-level rise. This record of localized environmental changed will be used to 'skin' the digital premarsh landscape model with period-specific plant and tree cover (Figure 4). Scaled digital GIS overlays of all identified past impacts (canals, roads, infrastructure, land fills, toxic dumps, etc.) will be subtracted from areas of projected sensitivity to provide environmental review agencies with a target-specific strategy to focus resources on only undisturbed areas of surviving potential archaeological sensitivity (see Figure 5).

Future Directions

This summary has highlighted current research issues and directions in landscape archaeology within the last decade. Instead of the traditional rationalization of archaeology and antiquity – war, population increases, trade, religion, irrigation agriculture – most without evidence to support them, the advent of high-resolution palaeoenvironmental chronologies of climate change have spawned a new generation of models which tie sequences of culture change to detailed records of climate change. Recent archaeological and ecological studies have also stressed the magnitude of human and cultural impacts to the environment in prehistoric and early historic times.

These multiple lines of new evidence and explanations indicate that (1) archaeology must address 'culture change' with the assumption that 'environmental change' has been ongoing over the last 3000 years, (2) these changes have not been uniform, but have shown major fluctuations in the Holocene, (3) that these Holocene fluctuations in climate and sea-level rise are in addition to any modern 'Green House'-ascribed postindustrial climate shifts, (4) fluctuations in the rate of sea-level rise suggest that now inundated coastal bays, estuaries, and drainages, may have been more exposed and more available to human occupation that previously assumed, (5) palaeoenvironmental reconstructions will have to address ancient landscapes from the perspective of what they looked like in the 'past', versus the present, and finally (6) archaeological evidence may represent an important source of data to fill existing Late Holocene gaps in record of sea level rise and environmental change.

Over the last 10 years, most of the major new insights have derived from refinements in the resolution and dating of regional sequences. Recent breakthroughs are beginning to highlight the 'interplay' between sequences 'of environmental change, sea level rise, and ancient topography'. Instead of only 'diachronic' or chronological treatments – as in 'point samples of 'straws' punched through a prehistoric layer cake' – we will have to use the modern geospatial tools of GIS, 3D terrain modeling, and palaeoecological reconstruction to 'geospatially correlate' these

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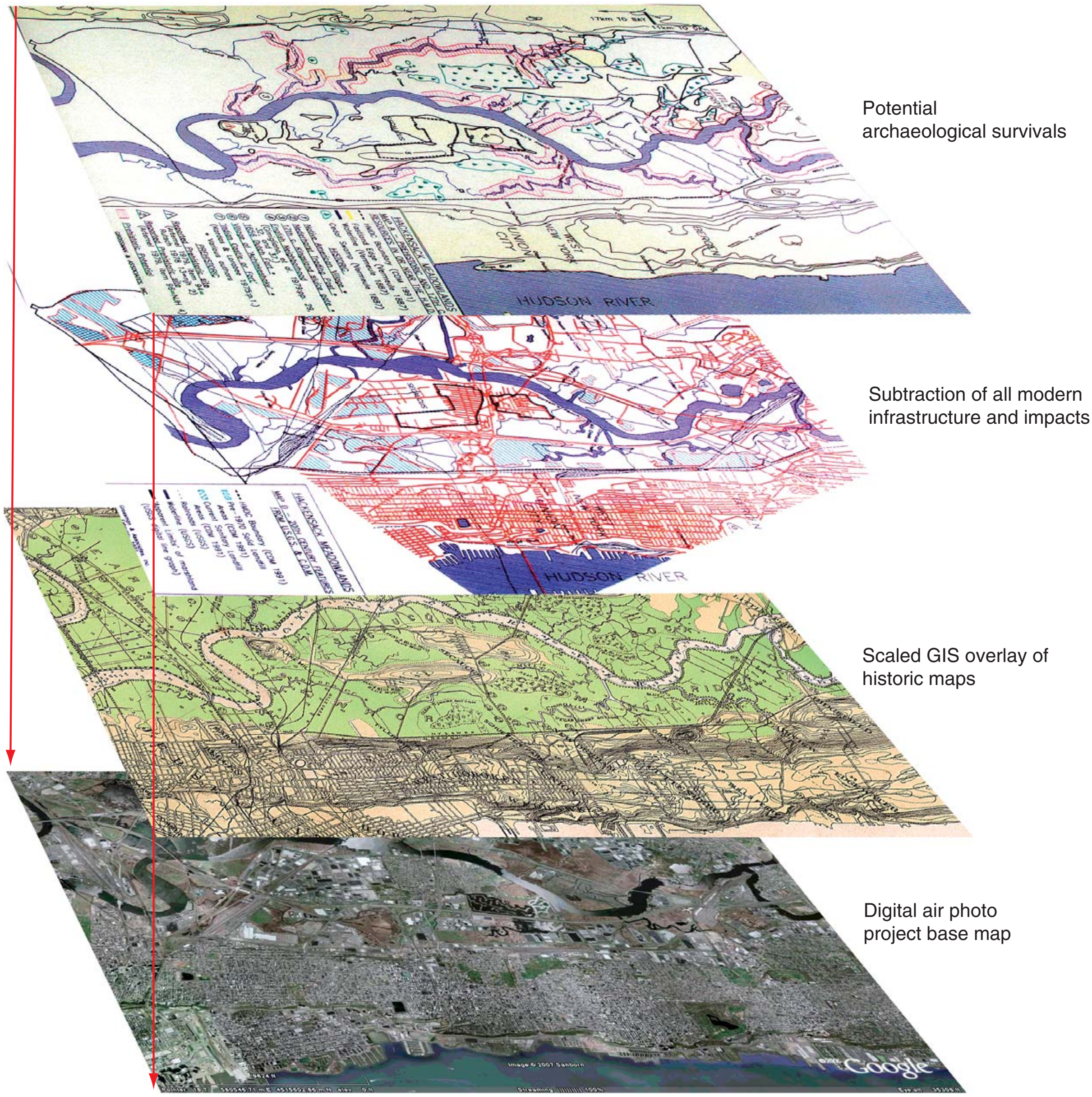

Figure 5 Historic Impact Analysis using GIS to define un-impacted areas that could contain potentially surviving prehistoric and historic cultural resources after "subtracting" modern impacts from modern construction and landfills within the New Jersey Hackensack Meadowlands. (By Joel W Grossman Ph.D., © Joel W Grossman Ph.D. 2008. Published by Elsevier Inc. All rights reserved.)

high-resolution chronologies of environmental change, with the subtle topographic variables and contexts of past archaeological landscapes, some exposed, some buried, and some submerged (Figure 3). From a treatment of archaeological landscapes as 2D and predominantly static, we must now see them as 3D, geospatial and dynamic.

See also: **Archaeometry**; **Carbon-14 Dating**; **Chemical Analysis Techniques**; **Civilization and Urbanism, Rise of**; **Cultural Ecology**; **Cultural Resource Management**; **Dendrochronology**; **Ecofacts, Overview**; **Electron Spin Resonance Dating**; **Geoarchaeology**; **Landscape Archaeology**; **Luminescence Dating**; **Maritime Archaeology**; **Neutron Activation Analysis**; **Obsidian Hydration Dating**; **Paleoenvironmental Reconstruction, Methods**; **Paleoenvironmental Reconstruction in the Lowland Neotropics**; **Paleodemography**; **Paleoethnobotany**; **Pedestrian Survey Techniques**; **Pollen Analysis**; **Remote Sensing Approaches**: Aerial; Geophysical; **Settlement Pattern Analysis**; **Settlement System Analysis**; **Spatial Analysis Within Households and Sites**; **Toxic and Hazardous Environments**.

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HUNTER-GATHERERS, ANCIENT

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Glossary

ethnoarchaeology Ethnographic study of peoples for archaeological reasons, usually focusing on the material remains of a society, rather than its culture.
sedentarization Process where tribes cease seasonal or nomadic lifestyle and settle down in all-year habitats.
Selk'nam Also known as the **Ona** lived in the Tierra del Fuego island, in southern Chile and Argentina. They were one of the last aboriginal groups in South America to be reached by Westerners, in the late nineteenth century.
Nunamiut Inuit people of Alaska's Northwest Arctic and North Slope boroughs and the Bering Straits region.

Introduction

When speaking of foragers and collectors we are referring to people living off the land by hunting wild animals, gathering wild plants, and fishing, people who are not exercising any control over the reproduction of exploited animals and plants. This remains true even in the present times when some contemporary hunters and gatherers, like the Ache of Paraguay who cut down trees and visit them later in the season to collect worms, or the Nukak of Colombia whose movements are organized depending on the wild orchards resulting from the seeds of the fruits that remained on the ground of abandoned camps.

Today, only a few scattered groups pursue a hunting and gathering way of life, and often they do so either by engaging in mutualistic associations with agriculturalists or pastoralists, or by practicing some horticulture or tending of animals. Often these economic arrangements are very close to slavery. Moreover, these hunters and gatherers are spatially restricted to economically and geographically marginal places in different parts of the world. This variety of situations prompted a debate around the definition of hunters and gatherers, which was centered in the forager populations of Southern Africa, the so-called Bushmen. At stake was their status as pure hunters and gatherers or as the result of contemporary pressing forces. Whatever the merits of both positions – and there is indeed value on both fronts – one basic result of the debate is a richer and more complex image of the many ways in which foragers can organize themselves, ranging from economically and socially complex to simple and highly mobile groups. This is important because foraging was in the distant past the basic way of life around the world, and as it is often emphasized, that was the case for at least 99% of human history.

Another conclusion derived from this debate is that modern hunters and gatherers are not very good analogs for the interpretation of the archaeological past. This observation puts a limit on the value of ethnoarchaeological results, which many times were used to produce direct analogies for the interpretation of the archaeological record. Then, one result of the debate was to confirm that methodology is the field where ethno-archaeology can best contribute to the advancement of our interpretative skills as archaeologists. For example, ethno-archaeological studies can