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This article, which is part of a larger project, examines cases in which high-resolution archaeological, textual, and environmental data can be integrated with longer-term, low-resolution data to afford greater precision in identifying some of the causal relationships underlying societal change. The issue of how

John Haldon is Shelby Cullom Davis '30 Professor of European History; Professor of Byzantine History, Princeton University; and Director of the Avkat Archaeological Project. He is the author, with Leslie Brubaker, of *Byzantium in the Iconoclast Period, ca. 680–850: A History* (New York, 2011).

Neil Roberts is Professor of Physical Geography, Plymouth University. He is the author of *The Holocene: An Environmental History* (Malden, Mass., 2014; orig. pub. 1989).

Adam Izdebski is Assistant Professor and Postdoctoral Fellow, Institute of History, Jagiellonian University. He is the author of *A Rural Economy in Transition: Asia Minor from Late Antiquity into the Early Middle Ages* (Warsaw, 2013).

Dominik Fleitmann is Professor of Palaeoclimatology and Archaeology and Director of the Scientific Archaeology Research Group, School of Archaeology, University of Reading. He is a co-author of "Vegetation and Environmental Dynamics in the Southern Black Sea Region since 18 kyr BP Derived from the Marine Core 22-GC3," *Palaeogeography, Palaeoclimatology, Palaeoecology,* CCCXXXVII/VIII (2012), 177–193 (doi: 10.1016/j.palaeo.2012.04.015).

Michael McCormick is Francis Goelet Professor of Medieval History and Chair of the Initiative for the Science of the Human Past, Harvard University. He is the author of *Origins of the European Economy: Communications and Commerce, A.D. 300–900* (New York, 2002).

Marica Cassis is Professor of History, Memorial University of Newfoundland. She is Assistant Director of the Çadır Höyük Excavation Project and Director of the Byzantine Project. She is the author of "Çadır Höyük: A Rural Settlement in Byzantine Anatolia," in Tasha Vorderstrasse and Jacob Roodenberg (eds.), *Archaeology of the Countryside in Medieval Anatolia* (Leiden, 2009), 1–24.

Owen Doonan is Professor of Art History, California State University, Northridge. He is the author of *Sinop Landscapes: Exploring Connections in the Hinterland of a Black Sea Port* (Philadelphia, 2004).

Warren Eastwood is Lecturer in Physical Geography, School of Geography, University of Birmingham. He is a co-author of "Integrating Palaeoecological and Archaeo-Historical Records: Land Use and Landscape Change in Cappadocia (Central Turkey) since Late Antiquity," in Tasha Vorderstrasse and Jacob Roodenberg (eds.), *Archaeology of the Countryside in Medieval Anatolia* (Leiden, 2009), 45–69.

Hugh Elton is Dean of Humanities and Professor of Ancient History and Classics, Trent University, and Field Director, Avkat Archaeological Project. He is the author of *Warfare in the Roman Empire: A.D. 350–425* (New York, 1996).

Sabine Ladstätter is Director of the Austrian Archaeological Institute and of the

environmental, especially climatic, disruptions affect human societies and political systems has begun to attract a great deal of attention from the scientific community and the general public. Recent studies suggest that one possible result of certain climatic events is an increase in violence over contested resources—a conclusion that has significant consequences for, at least, policymakers, investment bankers, insurance companies, and the military.[1]

The series of important articles about the climate and environment of the Roman Empire and early medieval Europe that this journal has recently published makes a significant, and accessible, contribution to the debate about the influence of environmental factors on human society. This article focuses on the Byzantine world—in particular, Anatolia, which for several centuries was the heart of that world—through regional and microregional case studies, addresses some of the challenges raised in those earlier

Ephesus Archaeological Excavations. She is the author, with Falko Daim, of *Ephesos in byzantinischer Zeit* (Mainz, 2011).

Sturt Manning is Goldwin Smith Professor of Classical Archaeology and Director, Malcolm and Carolyn Wiener Laboratory of Aegean and Near Eastern Dendrochronology, Department of Classics, Cornell University. He is the author of *A Test of Time and a Test of Time Revisited: The Volcano of Thera and the Chronology and History of the Aegean and East Mediterranean in the Mid-Second Millennium BC* (Oxford, 2014).

James Newhard is Director of Archaeology and Associate Professor of Classics, College of Charleston, and Survey Director, Avkat Archaeological Project. He is a co-author of "A Geoinformatic Approach to the Collection of Archaeological Survey Data," *Cartography and Geographic Information Science,* XL (2013), 3–17.

Kathleen Nicoll is Associate Professor of Geography, University of Utah. She is a co-editor of *Climates, Landscapes, and Civilizations* (Malden, Mass., 2013) (doi: 10.1029/GM0198).

Ioannes Telelis is Assistant Researcher, Research Center for Greek and Latin Literature, Academy of Athens, Greece. He is the author of *Georgios Pachymeres, Philosophia, Book 5. Commentary in Aristotle's Meteorologica. Editio princeps. Prolegomena, Text, Indices. Corpus Philosophorum Medii Aevi.* Commentaria in Aristotelem Byzantina. 6 (Athens, 2012); "Climatic Fluctuations in the Eastern Mediterranean and the Middle East AD 300–1500 from Byzantine Documentary and Proxy Physical Palaeoclimatic Evidence—a Comparison," *Jahrbuch der Österreichischen Byzantinistik,* LVIII (2008), 167–207

Elena Xoplaki is Assistant Professor of Geography, Justus-Liebig-University of Giessen. She is the author, with M. H. Clarvis, of "Governing and Managing Water Resources under Changing Hydro-Climatic Contexts: The Case of the Upper Rhone Basin," *Environmental Science Policy* (2014) (doi: 10.1016/j.envsci.2013.11.005).

The authors thank the Plymouth University GeoMapping Unit for graphics and the anonymous reviewers for helpful and constructive comments.

1 S. M. Hsiang, M. Burke, and E. Miguel, "Quantifying the Influence of Climate on Human Conflict," *Science,* 341 (Sept. 13, 2013), *doi:* 10.1126/science.1235367.

discussions, and promotes further collaboration between historians, archaeologists, and climate scientists.[2]

HISTORIOGRAPHY, METHOD, AND INTERDISCIPLINARITY More and more historians are trying to integrate environmental explanations into the established explanatory models, sometimes with considerable differences in interpretive outcomes. Witness, for example, Ellenblum's account of the collapse of certain eastern Mediterranean political systems in the eleventh through twelfth centuries, and Raphael's discussion of extreme weather events in the later medieval and early modern periods. Bulliet's discussion of the decline of Iranian cotton production during the eleventh century draws a causal association between the rise of cotton production and the spread of Islam and a declining Iranian agriculture triggered by a significant cooling of the climate that lasted for over a century. This development was associated with the arrival of Turkish nomadic groups in Iran, establishing a political dominance that lasted for centuries, as well as with the lucrative, but temperature-sensitive, cross-breeding of different types of camel. White's work on climate and crisis in the Ottoman Empire also goes beyond the traditional textual sources of most historians. He observes that historians pay far too little attention to the ways in which social and economic structures respond to climatic change and state systems deal with short-term crises.[3]

The problematical relationship between environmental and social history has been noted before in critiques of reductionist models. Rosen is particularly clear on this matter, pointing to the many different strategies that societies might use to overcome significant environmental challenges or shifts in their circumstances.

2 McCormick, "History's Changing Climate: Climate Science, Genomics, and the Emerging Consilient Approach to Interdisciplinary History," *Journal of Interdisciplinary History,* XLII (2011), 251–273; *idem* et al., "Climate Change during and after the Roman Empire: Reconstructing the Past from Scientific and Historical Evidence," *ibid.,* XLIII (2012), 169–220, esp. 206.

3 Geoffrey Parker, *Global Crisis: War, Climate Change and Catastrophe in the Seventeenth Century* (New Haven, 2013). Ronnie Ellenblum, *The Collapse of the Eastern Mediterranean: Climate Change and the Decline of the East, 950–1072* (New York, 2013); S. K. Raphael, *Climate and Political Climate: Environmental Disasters in the Medieval Levant* (Leiden, 2013); Richard Bulliet, *Cotton, Climate and Camels in Early Islamic Iran: A Moment in World History* (New York, 2009). See also Fernando Dominguez-Castro et al., "How Useful Could Arab Documentary Sources Be for Reconstructing Past Climate?" *Weather,* LXVII (2012), 76–82. Sam White, *The Climate of Rebellion in the Early Modern Ottoman Empire* (New York, 2011); *idem,* Review of Ellenblum, *Collapse of the Eastern Mediterranean, Mediterranean Historical Review,* XXVIII (2013), 70–72; Peter Frankopan, review of White, *Climate of Rebellion,* in *History Today,* 22 Jan. 2013.

Historians understand causal relationships from the point of view of multiple interrelated social, economic, and political factors, whereas climate scientists think in terms of environmental impacts on agriculture, warfare, demographics, and long-term stability. Those who study ancient climates have a range of tools at their disposal—proxy data deriving from such biological and geological climate archives as tree rings, stalagmites, and marine and continental sediment sequences. Historians can misconstrue or misuse these environmental data, generalizing from limited datasets or misappropriating low-resolution data: Insensitivity to both limitations in data and limitations in interpretation are pitfalls for everyone.[4]

By contrast, the higher-resolution evidence deployed by historians and archaeologists, though sometimes facilitating detailed narrative accounts of events or indirectly reflecting adjustments in economic activity, the nature of warfare, or the quality and quantity of harvests and crops, can nevertheless suffer from a considerable degree of uncertainty and subjectivity. In some cases, scholars have only recently begun to study the data sources—such as the archaeobotanical evidence and the stable-isotope records from archaeological materials—that are relevant to a particular climate. Apart from the methodological issues involved and the difficulties associated with reconciling qualitative with quantitative data, the best way around these problems is for the different specialists to work together with a common project in mind.[5]

Until recently, archaeologists who investigate the earliest human societies have tended to be far more familiar with these matters than have those who study historical periods with written records. Current debates about a major period of aridity in the

4 Arlene M. Rosen, *Civilizing Climate: Social Response to Climate Change in the Ancient Near East* (Lanham, 2007); *eadem* and S. A. Rosen, "Determinist or Not Determinist? Climate, Environment and Archaeological Explanation in the Levant," in S. R. Wolfe (ed.), *Studies in the Archaeology of Israel and Neighbouring Lands in Memory of Douglas L. Essel* (Chicago, 2001), 535–549.

5 For prehistoric examples, see S. Riehl, "Archaeobotanical Evidence for the Interrelationship of Agricultural Decision-Making and Climate Change in the Ancient Near East," *Quaternary International,* CXCVII (2009), 93–114; *idem,* E. Bryson, and K. Pustovoytov, "Changing Growing Conditions for Crops during the Near Eastern Bronze Age (3000–1200 BC): The Stable Carbon Isotope Evidence," *Journal of Archaeological Science,* XXXV (2008), 1011–1022. For useful comments regarding approaches to climate history as well as the range of data that can be employed, see Nicoll and Ceren Küçükuysal, "Emerging Multi-Proxy Records of Late Quaternary Palaeoclimate Dynamics in Turkey and the Surrounding Region," *Turkish Journal of Earth Sciences,* XXI (2012), 1–19.

Mediterranean between c. 2300 and 2000 B.C.E. (the so-called 4.2 ka event), for example, depend largely upon archaeological data to infer societal adaptations to drought (although the phenomenon appears also to be evident in a range of palaeoclimatic records). They are usually based on a different approach to the subject than historians normally adopt. Questions of chronological resolution and scale remain a major challenge for prehistoric studies (though increasingly refined, as shown by the 4.2 ka event), but the techniques developed in fields outside the traditional scope of historians can offer new insights about the Roman and medieval worlds.[6]

Historians of more recent periods, especially those who focus on cultural or socio-economic history, are often resistant to thinking about climate as a causal element. This reluctance frequently carries the (not always unreasonable) excuse that such explanations

6 See M. W. Salzer et al., "Five Millennia of Paleotemperature from Tree-Rings in the Great Basin, USA," *Climate Dynamics* (2013) doi: 10.1007/s00382-013-1911-9. See also M. Staubwasser and H. Weiss, "Holocene Climate and Cultural Evolution in Late Prehistoric-Early Historic West Asia," *Quaternary Research,* LXVI (2006), 380–383. For the different approach, see, for example, Harvey Weiss et al., "The Genesis and Collapse of Third Millennium North Mesopotamian Civilization," *Science,* CCLXI (1993), 995–1004; K.W. Butzer, "Collapse, Environment and Society": *Proceedings of the National Academy of Science,* CIX (2012), 3632–3639; G. D. Middleton, "Nothing Lasts Forever: Environmental Discourses on the Collapse of Past Societies," *Journal of Archaeological Science,* XX (2012), 257–307; survey in Arie S. Issar and M. Zohar, *Climate Change: Environment and History of the Near East* (Heidelberg, 2010). For chronological resolution and scale, see, for example, Weiss et al., "Genesis and Collapse"; Manning, "Cyprus at 2200 BC: Rethinking the Chronology of the Cypriot Early Bronze Age," in A. B. Knapp, J. M. Webb, and A. McCarthy (eds.), *J. R. B. Stewart—An Archaeological Legacy* (Uppsala, 2013), 1–21; Manning et al., "High-Precision Dendro-^{14}C Dating of Two Cedar Wood Sequences from First Intermediate Period and Middle Kingdom Egypt and a Small Regional Climate-Related ^{14}C Divergence," *Journal of Archaeological Science* (2014), http://dx.doi.org/10.1016/j.jas.2014.03.003.

M. H. Wiener, "Minding the Gap: Gaps, Destructions, and Migrations in the Early Bronze age Aegean: Causes and Consequences," *American Journal of Archaeology,* CXVII (2013), 581–592; Weiss et al., "Genesis and Collapse"; *idem* (ed.), *Seven Generations since the Fall of Akkad* (Wiesbaden, 2012); A. Wossink, "Challenging Climate Change," in *Competition and Cooperation among Pastoralists and Agriculturalists in Northern Mesopotamia (c. 3000–1600 BC)* (Leiden, 2009); M. Finné et al., "Climate in the Eastern Mediterranean, and Adjacent Regions, during the Past 6000 Years—a Review," *Journal of Archaelogical Science,* XXXVIII (2011), 3153–3173; David Kaniewski et al., "Late Second-Early First Millennium BC Abrupt Climate Changes in Coastal Syria and Their Possible Significance for the History of the Eastern Mediterranean," *Quaternary Research,* LXXIV (2010), 207–215; Kaniewski et al., "The Medieval Climate Anomaly and the Little Ice Age in Coastal Syria and Pollen-Derived Palaeoclimatic Patterns," *Global and Planetary Change,* LXXVIII (2011), 178–187; the contributions to C. Kuzucuoğlu and C. Marro (eds.), *Sociétés humaines et changement climatique à la fin du troisième millénaire: un crise a-t-elle eu lieu en haute Mésopotamie? Actes du colloque de Lyon, 5–8 décembre 2005* (Istanbul, 2007); S. E. van der Leeuw, "What Is an "Environmental Crisis" to an Archaeologist? The Archaeology of Environmental Change," in C. Fisher, B. Hill, and G. Feinman (eds.), *Socio-Natural Legacies of Degradation and Resilience* (Tucson, 2009), 40–61.

reduce human history to climate history, thus ignoring both social complexity and multi-causality, but it just as frequently reflects a disinclination to deal with the bewildering complexity of scientific evidence and methodologies. What is more, due to differences in the quantity and scope of the available evidence, climate study of the late-antique and medieval Middle East is considerably different from that of early modern Europe. Although valuable written evidence is available, in many cases it is insufficient to infer specific reactions to the extreme weather events associated with climate fluctuations. Wherever there is also a lack of high-quality palaeoclimatic data, attempts to establish firm links between climate and society become complicated.[7]

The interest of historians and archaeologists in merging palaeoclimatic data with traditional historical sources has been growing since the 1980s, when the now-classic volume edited by Rotberg and Rabb appeared. Virtually every period and region has been drawn into the discussion, and a number of individual studies, as well as larger projects, have brought specialists from different fields and disciplines together with a view toward analyzing particular pre-modern historical periods in specific regions of the world.[8]

During the last few years, historians and archaeologists of the Roman world have begun to focus on the relationship between

7 For examples of early modern studies of climate and society, see Christian Pfister, "Climatic Extremes, Recurrent Crises and Witch Hunts: Strategies of European Societies in Coping with Exogenous Shocks in the Late Sixteenth and Early Seventeenth Centuries," *Medieval History Journal,* X (2007), 1–41; *idem* et al., "The Meteorological Framework and the Cultural Memory of Three Severe Winter-Storms in Early Eighteenth-Century Europe," *Climatic Change,* CI (2010), 281–310; for an example of the medieval–early modern contrast, compare McCormick et al., "Volcanoes and the Climate Forcing of Carolingian Europe, A.D. 750–950," *Speculum,* LXXXII (2007), 865–895, with R. Brázdil et al., "European Floods during the Winter 1783/1784: Scenarios of an Extreme Event during the 'Little Ice Age,'" *Theoretical and Applied Climatology,* C (2010), 163–189.

8 Robert I. Rotberg and Theodore K. Rabb (eds.), *Climate and History: Studies in Interdisciplinary History* (Princeton, 1981); Hubert H. Lamb, *Climate: Present, Past, Future,* 2: *Climatic History and the Future* (London, 1977); *idem,* "Climatic Changes during the Course of Early Greek History," *Antiquity,* XLII (1968), 231–232. See also the bibliographies in Telelis, *Meteorologika phainomena sto Vizantio* (Athens, 2004), I, xxiv–xxxvi, for an indication of the breadth of coverage. For examples of the rapidly expanding literature on specific premodern regions, see H. N. Dalfes, G. Kukla, and Weiss (eds.), *Third Millennium BC Climate Change and the Old World Collapse* (Berlin, 1997); Rosen, *Civilizing Climate;* Butzer, "Sociopolitical Discontinuity in the Near East c. 2200 B.C.E.: Scenarios from Palestine and Egypt," in Dalfes, Kukla and Weiss (eds.), *Third Millennium BC Climate Change,* 245–296; H. M. Cullen et al., "Climate Change and the Collapse of the Akkadian Empire: Evidence from the Deep Sea," *Geology,* XXVIII (2000), 379–382; R. L. Zettler, "Reconstructing the World of Ancient Mesopotamia: Divided Beginnings and Holistic History," *Journal of the Economic and Social History of the Orient,* XLVI (2003), 3–45.

climate/environment and the Empire's ascendance, thereby raising a series of broader questions about the causal connections between political and social-cultural evolution and climate. In Rome's case, they have demonstrated a distinct parallel between a period of stable climatic conditions and the Empire's rise and consolidation, and between a subsequent period of climatic instability—the prevalence of highly variable climatic conditions on a decadal scale—and the breakdown of the imperial economy and the state that it supported. Although the climatic effects are distinct regionally—between the eastern and western parts of the Empire and among sub-regions—the precise nature of the causal relationships between environmental, political, social-economic, and cultural developments remains to be elucidated. Historians of the Byzantine world have followed suit, although they have a great deal more work to do.[9]

Historians of eastern Roman (Byzantine) Anatolia must grapple with a limited written record and rely on as wide a range of sources as possible; archaeology and environmental sciences are

9 For a range of recent literature relevant to the Roman period, see McCormick et al., "Climate Change," 170–172; for detailed study, Ulf Büntgen et al., "2500 Years of European Climate Variability and Human Susceptibility," *Science,* CCCXXXI (2011), 578–582; Manning, "The Roman World and Climate: Context, Relevance of Climate Change, and Some Issues," in William V. Harris (ed.), *The Ancient Mediterranean: Environment between Science and History* (Leiden, 2013), 103–170; Harris, "What Kind of Environmental History for Antiquity?," *ibid.,* 1–10; McCormick, "What Climate Science, Ausonius, Nile Floods, Rye and Thatch Tell Us about the Environmental History of the Roman Empire," *ibid.,* 61–88. See also Joseph A. Tainter and C. L. Crumley, "Climate, Complexity, and Problem Solving in the Roman Empire: Sustainability or Collapse?," in R. Costanza, L. J. Graumlich, and W. Steffen (eds.), *An Integrated History and Future of People on Earth* (Boston, 2007), 61–75. For a hypothetical causal association between climate (tree-ring evidence for droughts related to long-term ENSO climate forcing) and the migratory movements of Huns and Avars during the fourth to sixth centuries C.E., see Edward R. Cook, "Megadroughts, ENSO, and the Invasion by the Huns and Avars," in Harris (ed.), *Ancient Mediterranean,* 89–102.

For the Byzantine world, see, for example, Johannes Koder, "Climatic Change in the Fifth and Sixth Centuries?" in P. Allen and E. Jeffreys (eds.), *The Sixth Century—End or Beginning?* (Brisbane, 1996), 270–285; *idem,* "Historical Aspects of a Recession of Cultivated Land at the End of the Late Antiquity in the East Mediterranean," in Burkhard Frenzel (ed.), *Evaluation of Land Surfaces Cleared from Forests in the Mediterranean Region during the Time of the Roman Empire* (Frankfurt am Main, 1994), 157–167; Haldon, "'Cappadocia Will Be Given over to Ruin and Become a Desert': Environmental Evidence for Historically-Attested Events in the 7th–10th Centuries," in *Mediterranea: Festschrift Johannes Koder* (Vienna, 2007), 215–230; Telelis, "Climatic Fluctuations in the Eastern Mediterranean and the Middle East AD 300–1500 from Byzantine Documentary and Proxy Physical Palaeoclimatic Evidence—a Comparison," *Jahrbuch der Österreichischen Byzantinistik,* LVIII (2008), 167–207; *idem, Meteorologika phainomena;* Dionysios Stathakopoulos, "Reconstructing the Climate of the Byzantine World: State of the Problem and Case Studies," in J. Laszlovsky and P. Szabó (eds.), *People and Nature in Historical Perspective* (Budapest, 2003), 247–261.

key. The integration of three types of archive offers significant advantages. The subject invites interdisciplinary cooperation, as well as the construction of relatively general models of climate/environment/society interaction. It is precisely the bringing of climate and environment into the existing models of social, economic, and political change in Byzantine Anatolia that promises to expand our understanding of this historical society.

Historians are just as likely to reject arguments based on climate and environment on reductionist grounds as they are to misunderstand them and misuse their underlying data. They also need to be careful with, and critical about, temporal resolution—for example, high-resolution data capable of annual to decadal association versus centennial data, which is much less causally specific. Issues of scale can easily confuse or lead to misunderstandings. What a climate scientist might see as a "crisis" lasting a *mere* century, a historian might regard as a long period of change and social, political, and economic transformation. Different disciplines have different styles: Scientists seek to reduce causality to simple terms, such as temporal coincidence or statistical correlation, whereas historians deal with complex processes and are wary of oversimplification.

Neither climate scientists, historians, nor archaeologists are in a position by themselves fully to integrate the vast range of data necessary for a multicausal analysis that explains rather than simply describes. More local and regional studies are needed to test methodologies, collect multidisciplinary data, and ultimately derive holistic interpretations. This article can be understood in the context of Past Global Changes (PAGES) FOCUS 4 project (http://www.pages-igbp.org/science/foci/focus-4), "Past Human—Climate—Ecosystem Interactions," rightly arguing that this interrelationship becomes clear through a comparison of regional-scale reconstructions of environmental and climatic processes with evidence of past human activity. Our study also links to IHOPE (The Integrated History and Future of People on Earth).[10]

CLIMATE AND THE WIDER PERSPECTIVE Human activity has arguably had a greater imprint on the landscape than any other single factor, particularly with respect to the way in which deforestation and over-grazing have led to soil exhaustion, erosion, alluviation,

10 The IHOPE project can be found at http://ihopenet.org/. The PAGES (Past Global Changes) project is an international effort to coordinate and promote research about global change in history (http://www.pages-igbp.org/).

and land abandonment. But outside factors have also affected human exploitation of the landscape. Because relatively minor shifts in climate can have significant effects at a local to regional level, it will be worth reviewing what we know of the climate history of the region from late antiquity into the medieval period before looking at the possible significance of such factors for some important changes in social, economic, and political history.[11]

Palaeoclimatic records indicate that the conditions prevailing across western Eurasia from the third to the second century B.C.E. into the late second century C.E. remained relatively warm and humid, conducive to intensive agriculture. Often referred to as the "Roman Warm Period" (RWP), it was typified by conditions that minimized much of the usual risk and decadal variability associated with Mediterranean climate, coinciding with the growth and consolidation of Roman military and political power and economic expansion. By the same token, such conditions were also particularly favorable to the advance of agriculture and the increase in population across central and northern Europe. A detailed examination, however, shows significant climatic variations both in time and in space during this period; the RWP was not warm and wet everywhere all the time. Just as the Medieval Warm Period is now more commonly referred to as the Medieval Climate Anomaly (MCA), it is likely that the RWP should similarly be re-evaluated.

A correlation has been postulated between climate and changing solar activity, with periods of low solar activity—solar minima—commonly found in conjunction with low temperatures. Accordingly, scholars have associated climate and solar activity with historical events or developments, although this relationship is never one-to-one, and its existence is often hotly debated.[12]

11 Michael F. Hendy, *Studies in the Byzantine Monetary Economy, c.300–1450* (New York, 1985), 58–68; Bernard Geyer, "Physical Factors in the Evolution of the Landscape and Land Use," in Angeliki Laiou et al. (eds.), *The Economic History of Byzantium from the Seventh through the Fifteenth Century* (Washington D.C., 2002), 36–40.

12 McCormick et al., "Climate Change," 174–180; Manning, "Roman World and Climate," 169 (with further references and evidence). H. F. Diaz et al., "Spatial and Temporal Characteristics of Climate in Medieval Times Revisited," *Bulletin of the American Meteorological Society,* XCII (2011), 1487–1500; N. E. Graham et al., "Support for Global Climate Reorganization during the "Medieval Climate Anomaly," *Climate Dynamics,* XXXVII (2011), 1217–1245. Peter Garnsey, *Famine and Food Supply in the Graeco-Roman World: Responses to Risk and Crisis* (New York, 1988); T. W. Gallant, *Risk and Survival in Ancient Greece* (New York, 1991); Geyer, "Physical Factors," 41–42; F. L. Cheyette, "The Disappearance of the Ancient Landscape and the Climatic Anomaly of the Early Middle Ages: A Question to Be Pursued," *Early Medieval Europe,* XVI (2008), 127–165; R. S. Bradley, M. K. Hughes, and Diaz, "Climate in

Notwithstanding the absence of consensus, climate historians largely agree about the long-term (multicentennial to millennial scale) changes that have affected the earth. What is usually less clear from the historical perspective are the decadal-scale climatic fluctuations that are superimposed on long-term changes in mean climate, because they are affected by a range of factors that in many cases still need to be fully investigated and understood.[13]

The broad picture for the Roman world shows favorable and stable climatic conditions from c. 250 B.C.E. to 200 C.E., giving way thereafter to a far more variable climate, with higher-amplitude fluctuations between cold/dry and warm/wet periods. In central and western Anatolia, climatic variations appear to have been well distinguished, with some significant wet-to-dry oscillations. In the southern Levant, the climate may have become more humid after c. 400 C.E. until sometime in the sixth century, when drier weather prevailed, although the chronology of such changes remains insecure.[14]

The exact timing and duration of the subregional variations are yet to be clarified due to the imprecisely dated palaeoclimatic data, but the evidence suggests that the pattern of change may not have been the same everywhere—for example, in western Anatolia and the southern Levant. Given the paucity of proxy records for temperature in the eastern Mediterranean within this time interval, we must resort to an analysis of tree rings and speleothems (stalagmites, stalactites, and flowstones) from the Alps and central Europe. They indicate that the climate became much colder during the first

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Medieval Time," *Science,* CCCII (2003), 404–405; Büntgen et al., "2500 Years of European Climate Variability."

For review and literature, see Manning, "Roman World and Climate," 120–135; L. J. Gray et al., "Solar Influences on Climate," *Reviews of Geophysics,* XLVIII (2010), 1–53 (doi: 10.1029/2009RG000282); M. Lockwood, "What Do Cosmogenic Isotopes Tell Us about Past Solar Forcing of Climate?," *Space Science Reviews,* CXXV (2006), 95–109; G. Bond et al., "Persistent Solar Influence on North Atlantic Surface Circulation during the Holocene," *Science,* CCXCIV (2001), 2130–2136; U. Neff et al., "Strong Coherence between Solar Variability and the Monsoon in Oman between 9 and 6 kyr Ago," *Nature,* CMXI (2001), 290–293.

13 Heinz Wanner et al., "Mid- to Late Holocene Climate Change: An Overview," *Quaternary Science Reviews,* XXVII (2008), 1791–1828.

14 Büntgen et al. "2500 Years of European Climate Variability"; Jörg Luterbacher et al., "A Review of 2000 Years of Paleoclimatic Evidence in the Mediterranean," in Piero Lionello (ed.), *The Climate of the Mediterranean Region: From the Past to the Future* (Amsterdam, 2012), 87–185; McCormick et al., "Climate Change"; Manning, "Roman World and Climate." See also T. J. Crowley, "Causes of Climate Change over the Past 1000 Years," *Science,* CCLXXXIX (2000), 270–277.

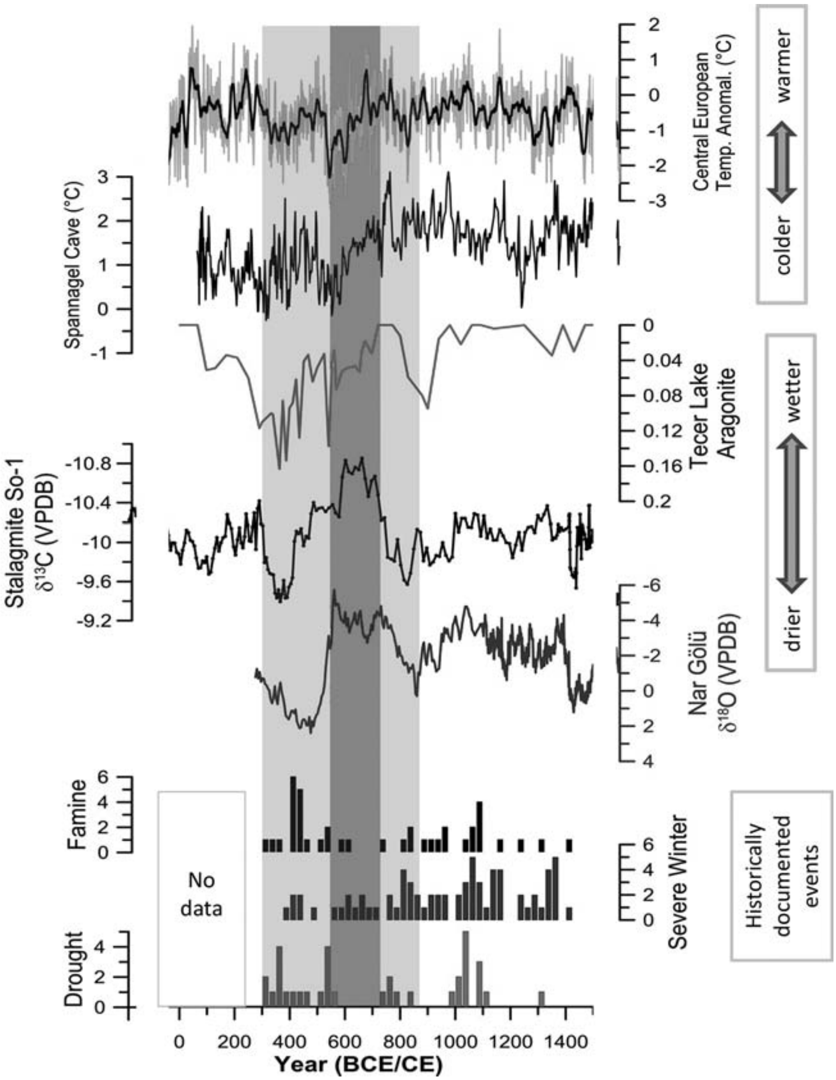
half of the sixth century (Figure 1). For the period from the 530s, conditions may have been affected by what appears to have been a large volcanic eruption dated roughly between 536 and 541, although there is no strong evidence to link it with events in the northern hemisphere. The plague of Justinian broke out in 541, but the nature of a possible connection between a changing climate and this pandemic over subsequent years remains unelucidated.[15]

During the second half of the sixth century and into the first half of the seventh, conditions were cold in central Europe, allowing glacial advance in the Alps. Alpine glacier evidence suggests warming c. 400 and some very slow glacial advance c. 430, although the fifth-century tree-ring data indicate conditions that are neither especially cool nor warm; speleothem evidence from Austria shows cooling c. 400 to 450, followed by warming again. In the Balkans and eastern Mediterranean, broadly, the period from the second to the fifth century may have become increasingly arid, although the evidence is not always easy to interpret, and opinions differ. Most observers agree, however, about a shift to a wetter (and possibly warmer) regime during the fifth and into the sixth century. In the southern Levant, this wetter phase seems to end in the course of the first half of the sixth century; in central and western Anatolia more humid conditions appear to have persisted into the eighth century. Some historians have wondered whether this weather has causal implications regarding the revival and consolidation of the Eastern Roman Empire at this time. The evidence of ceramics and other data would certainly support an intensification of economic activity at that time in that region.[16]

15 For the southern Levant, see Ian J. Orland et al., "Climate Deterioration in the Eastern Mediterranean as Revealed by Ion Microprobe Analysis of a Speleothem That Grew from 2.2 to 0.9 ka in Soreq Cave, Israel," *Quaternary Research,* LXXI (2009), 27–35; Rosen, *Civilizing Climate.* Manning, "Roman World and Climate," 139, 165; Michael G. L. Baillie, "Volcanoes, Ice-Cores and Tree-Rings: One Story or Two?" *Antiquity,* LXXXIV (2010), 202–215; L. B. Larsen et al., "New Ice Core Evidence for a Volcanic Cause of the A.D. 536 Dust Veil," *Geophysical Research Letters,* XXXV (2008), L04708, doi:10.1029/2007GL032450. Joel D. Gunn, *The Years without Summer: Tracing A.D. 536 and Its Aftermath* (New York, 2000); Lester K. Little (ed.), *Plague and the End of Antiquity: The Pandemic of 541–750* (New York, 2006); Stathakopoulos, "The Justinianic Plague Revisited," *Byzantine and Modern Greek Studies,* XXIV (2000), 256–276. For a cautionary comment on the connection between climate and plague, see McCormick et al., "Climate Change," 198–199.

16 For a discussion of the data for the northern European situation, see McCormick et al., "Climate Change," 191–195. Note again the emphasis on regional variation, a reflection of the uncertain chronology currently derived from the data. For Anatolia, see J. R. Dean et al., "Palaeo-Seasonality of the Last Two Millennia Reconstructed from the Oxygen Isotope Composition of Diatom Silica and Carbonates from Nar Gölü, Central Turkey," *Quaternary*

Fig. 1 Comparison of Proxy Records of Temperature from Central Europe, Climatic Moisture Conditions in Central and Western Anatolia, and Historically Documented Climate-Related Events in Anatolia



NOTE Shaded bars mark notable periods of dry climate.

Science Reviews, LXVI (2013), 35–44. See the review of the debate about the arid conditions in Manning, "Roman World and Climate," 164–165. For the Levant, see McCormick et al., "Climate Change,"197–198, 201–202. For a more optimistic view of the evidence for the wetter regime, see Yizhar Hirschfeld, "A Climatic Change in the Early Byzantine Period? Some Archaeological Evidence," *Palestine Exploration Quarterly,* CXXXVI (2004), 133–149; Issar, "Climate Change and History during the Holocene in the Eastern Mediterranean Re-

Fig. 1 (Continued)

SOURCES For Central Europe, see Manning, "The Roman World and Climate: Context, Relevance of Climate Change, and Some Issues," in William V. Harris (ed.), *The Ancient Mediterranean: Environment between Science and History* (Leiden, 2013), 136-158; for central and western Anatolia, M. D. Jones et al., "A High-Resolution Late Holocene Lake Isotope Record from Turkey and Links to North Atlantic and Monsoon Climate," *Geology,* XXXIV (2006), 361–364; O. M. Göktürk et al.,"Climate on the Southern Black Sea Coast during the Holocene," *Quaternary Science Reviews,* XXX (2011) 2433–2445; C. Kuzucuoğlu et al., "Mid-Holocene Climate Change in Central Turkey: The Tecer Lake Record," *The Holocene,* XXI (2011) 173–188; for climate-related events, Ioannis Telelis, *Meteorologika phainomena sto Vizantio* (Athens, 2004), II, 711–795; *idem,* "Climatic Fluctuations in the Eastern Mediterranean and the Middle East AD 300–1500 from Byzantine Documentary and Proxy Physical Palaeoclimatic Evidence—a Comparison," *Jahrbuch der Österreichischen Byzantinistik,* LVIII (2008), 169–177; Dionysios Ch. Stathakopoulos, *Famine and Pestilence in the Late Roman and Early Byzantine Empire* (Aldershot, 2004); McCormick, Kyle Harper, and A. More, "Geodatabase of Historical Evidence on Roman and Post-Roman Climate," in McCormick et al. (eds.), *Digital Atlas of Roman and Medieval Civilizations,* available at http://darmc.harvard.edu.

The key proxy climate records shown in Figure 1 pertain mainly to central and western Anatolia, which after the middle of the seventh century lay at the heart of the Byzantine Empire (see Figure 2b). The relatively well-dated stable-isotope records from Sofular Cave, reflective of the Black Sea environment, and Nar Lake, in a more continental location, both show closely aligned trends throughout the period from 270 to 1450 C.E. They indicate drier climatic conditions during the later fourth and early fifth centuries; greater humidity during the later sixth, seventh, and early eighth centuries; and a shorter-lived dry phase afterward. The same pattern is recorded in the less detailed and not so well-dated sedimentary record from Tecer Lake (See Figure 1).[17]

gion," in *idem* and N. Brown (eds.), *Water, Environment and Society in Times of Climatic Change* (Dordrecht, 1998), 113–128. But this interpretation seems no longer consonant with newer evidence. See McCormick et al., "Climate Change," 197 and n. 22.

McCormick et al., "Climate Change," 203–205; Izdebski, "Why Did Agriculture Flourish in the Late Antique East? The Role of Climate Fluctuations in the Development and Contraction of Agriculture in Asia Minor and the Middle East from the 4th till the 7th c. AD," *Millennium,* VIII (2011), 291–312.

17 M. D. Jones et al., "A High-Resolution Late Holocene Lake Isotope Record from Turkey and Links to North Atlantic and Monsoon Climate," *Geology,* XXXIV (2006), 361–364; O. M. Göktürk et al.,"Climate on the Southern Black Sea Coast during the Holocene," *Quaternary Science Reviews,* XXX (2011) 2433–2445 (note that Fleitmann, a co-author, used a more sophisticated algorithm to develop a new age model for the stalagmite from Sofular Cave, replacing the linear interpolation used in this article); Kuzucuoğlu et al., "Mid-Holocene Climate Change in Central Turkey: The Tecer Lake Record," *The Holocene,* XXI (2011) 173–188.

To what extent are these climatic trends registered in historical records of weather and crisis for the same time period? Telelis compiled systematic surveys of extreme weather conditions and their effects from Byzantine archival sources for the period from 300 to 1500 C.E., and Stathakopoulos cataloged episodes of famine and disease from 284 to 750 C.E. These conditions, covering the eastern Mediterranean as a whole, are listed in Appendix 1 and shown summarily in Figure 1. In contrast to most proxy climate records, historical observations are neither continuous nor complete; events may be missing from the documentary record. Furthermore, it may not always be possible to locate events with geographical precision, though the ones that are relatively easy to place can provide clear causal connections. For example, according to Stathakopoulos, between 451 and 454 C.E., "as a result of a drought in Phrygia, Galatia, Cappadocia, Cilicia and Palestine, a famine occurred . . . and a pestilence broke out." But causality is not always so obvious. For instance, the reasons for the lack of wheat and barley that led to the shortage of bread in Constantinople in 555 C.E. are unclear; this might have been the result of provisioning problems in Egypt.[18]

Given these potential difficulties, it is all the more striking that proxy data and historical records show such a close overall correspondence for western and central Anatolia for the period between 300 and 870 C.E. (Figure 1). During the drier climatic phase from 300 to 560 C.E., twelve droughts and eighteen famines are recorded, and during the subsequent wet phase from 560 to 730 C.E., no droughts and only two famines are noted in the historical record. After 730 C.E., droughts and famines again became more frequent, this time accompanied by severe winter weather (cold and snow), especially in the ninth and subsequent centuries.[19]

The good correspondence between the proxy and historical

18 Telelis, "Climatic Fluctuations in the Eastern Mediterranean and the Middle East"; Stathakopoulos, *Famine and Pestilence in the Late Roman and Early Byzantine Empire* (Aldershot, 2004), 238. Divine providence is reported to have alleviated this famine by raining food and by making fruit ripen by itself! For a summary of key events, see Appendix 1. For a detailed tabulation of written evidence for the period until c. 800 C.E., see McCormick, Kyle Harper, and A. More, "Geodatabase of Historical Evidence on Roman and Post-Roman Climate," in McCormick et al. (eds.), *Digital Atlas of Roman and Medieval Civilizations,* available at http://darmc.harvard.edu.

19 Several droughts are recorded for neighboring Syria during the wet spell and one for Crete: McCormick et al., "Geodatabase," nos. 545, 553, 595, 604, 625, 651, 692, 698, 718 (Syria); 678 (Crete); 642–643 (Thessaloniki).

data sets breaks down for the late tenth and eleventh centuries; no hint of documented droughts is evident in any of the proxy-climate records. The reasons for this divergence are not entirely clear, but notably only one of the historically recorded droughts (in 1037 C.E.) is located in Anatolia; many more occurred in Greece and Macedonia to the west. The absence of reports cannot be attributed to the Byzantines' loss of central and eastern Anatolia to the Turks, because this loss did not occur until the battle of Manzikert in 1071, and Anatolia provided numerous weather reports (mainly of cold winters) prior to this date. Hence, although certain parts of the eastern Mediterranean undoubtedly experienced harsh weather conditions during the tenth and eleventh centuries, drought conditions do not appear to have affected all parts of the region.[20]

After the second century C.E., a series of changes in regional climate patterns continued across the fifth and sixth centuries, and well into the seventh century, marking the end of the relative stability of the RWP; the impacts varied by north and south and by east and west, as well as by time. In central Anatolia, for example, the early fifth century was markedly dry, followed by the rapid onset of much wetter climatic conditions during the course of the sixth century (Figure 1). To what extent the different historical trajectories of east and west can be tied to these different climatic trends remains to be seen, although some distinct causal connections have been posited. The current state of our knowledge of these changes across several centuries is still sketchy, given both the absence of data from many areas and inadequate chronological control within some datasets, leaving a good deal of the dating uncertain. Despite the incompleteness of the regional pattern beneath the general trends, approximate parallels between climatic history and the evolution of states and societies suggest that climate and environment should figure prominently in an integrated interpretation of past events.[21]

THE CASE FOR ANATOLIA Byzantine Anatolia is a fitting locus for a multidisciplinary study because it is has three vital types of data in

20 See also Ellenblum, *Collapse of the Eastern Mediterranean.*

21 Roberts et al., "Palaeolimnological Evidence for an East–West Climate See-Saw in the Mediterranean since AD 900," *Global and Planetary Change,* LXXXIV/LXXXV (2012), 23–34; McCormick et al., "Volcanoes." For a detailed survey of the fifth and sixth century, see McCormick et al., "Climate Change"; see also Manning, "Roman World and Climate," 165.

abundance—written, archaeological, and palaeoenvironmental (see Table 1). Other candidates, like the ancient Maya lowlands, are weak in the written component or, like early modern and modern Europe, are already well documented in both historical and paleoclimatic records. Anatolia's historical data allows us to test such critical causal propositions as "drought causes societal collapse," which would be difficult to falsify in a setting without documentary evidence—say, the end of the Early Bronze Age in the Middle East. Nor does it hurt that Anatolia is currently a major focus of attention with regard to climate change.[22]

Following a workshop at Princeton University in May 2013, a small group of climate and environmental scientists, historians, and archaeologists established a project to examine Anatolia and adjacent lands between the second/third century and the thirteenth/fourteenth century C.E.—the period that saw the "decline and fall" of the Roman Empire in the west, the survival of the Byzantine Empire (something of a misnomer but a well-established one) in the east, the rise of the Arab-Islamic Empire in the eastern provinces of the late Roman state during the seventh century C.E., the appearance of Turkic peoples first in Iran and then the Middle East from the later tenth and eleventh centuries C.E. and their occupation of the Anatolian plateau, and the rise of Ottoman power (see Appendix 2 for a selective list of historical events). This article deals primarily with the early part of the period.[23]

Environmentally, Anatolia and the southern Balkans are subject to three large-scale circulation systems that affect the region at different times of the year—the North Atlantic system, the South Asian summer monsoonal system, and the continental winter climate system, anchored over northern Asia, western Russia, and Si-

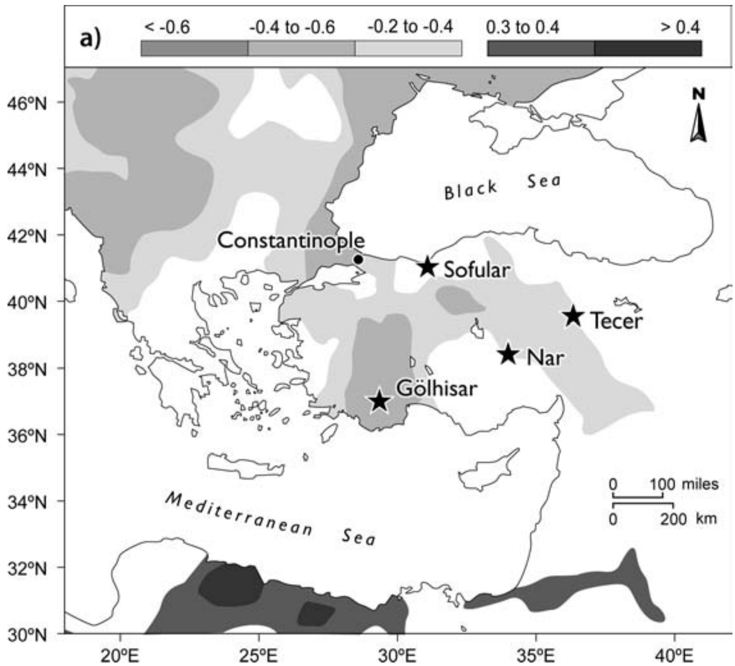
22 For early modern and modern Europe, see Parker, *Global Crisis;* Emmanuel Le Roy Ladurie, *Histoire humaine et comparée du climat* (Paris, 2004); Pfister, "Climatic Extremes, Recurrent Crises and Witch Hunts" (see also the citations in n. 8). J. Lelieveld et al., "Climate Change and Impacts in the Eastern Mediterranean and the Middle East," *Climatic Change,* CXIV (2012), 667–687. A note of caution should be introduced at this point. It is not always clear whether the abundant Egyptian literature on famines and related phenomena with respect to the First Intermediate Period reflects actual events or is political and allegorical in nature. See, for example, Nadine Moeller, "The First Intermediate Period: A Time of Famine and Climatic Change?" *Ägypten und Levant,* XV (2005), 153–157; Stephan Johannes Seidlmayer, "The First Intermediate Period (c. 2160 2000)," *Oxford History of Ancient Egypt* (New York, 2000), 118–147.

23 The workshop was organized by Haldon as part of the ongoing Avkat Archaeological Project (www.princeton.edu/avkat/news).

Table 1 Data Sources and Characteristics

TYPE OF EVIDENCE	WRITTEN	ARCHAEOLOGICAL	PALAEOENVIRONMENTAL
Origin of data	manuscripts, archived documents, inscriptions, seals	excavation, surface survey, or studies of standing monuments	coring of lakes and peats (for analysis of pollen, isotopes, etc.), tree-ring analysis, speleothems, and other natural archives,
Preparation for interpretation	editing, source criticism, translation	artefact or monument analysis, statistical processing of data	laboratory analysis and statistical calibration
Dating precision	submonthly to subannual	decadal to century (occasionally annual)	decade to century (occasionally annual, such as for trees)
Time duration and continuity	typically discontinuous or of short (<100 yr) duration	semicontinuous and normally multi-century duration	normally continuous and long duration
Customary ways of interpretation	reconstruction of events, historical model building	identifying periods with stable socio-economic and cultural-material characteristics, reconstructing changing settlement pressure	identifying periods of different environmental and climatic conditions
Subject	detailed information on specific events, phenomena, and processes—social, economic, cultural, and political	quantitative and qualitative data on socio-economic and cultural transformations in the long duration; demographic estimations inferential, normally site- or area-specific (from excavated or surface materials)	reconstructions of environmental and climatic change via proxy evidence (for example, pollen for past vegetation)
Climate-society causality	possibly detailed explanatory mechanisms		inferential, often achieved by temporal correlation

Fig. 2a Statistically Significant Spatial Correlations between the North Atlantic Oscillation Index (NAOI) and Winter Precipitation in the Eastern Mediterranean (1951–2006) (along with Palaeoclimatic Sites Discussed in the Text).



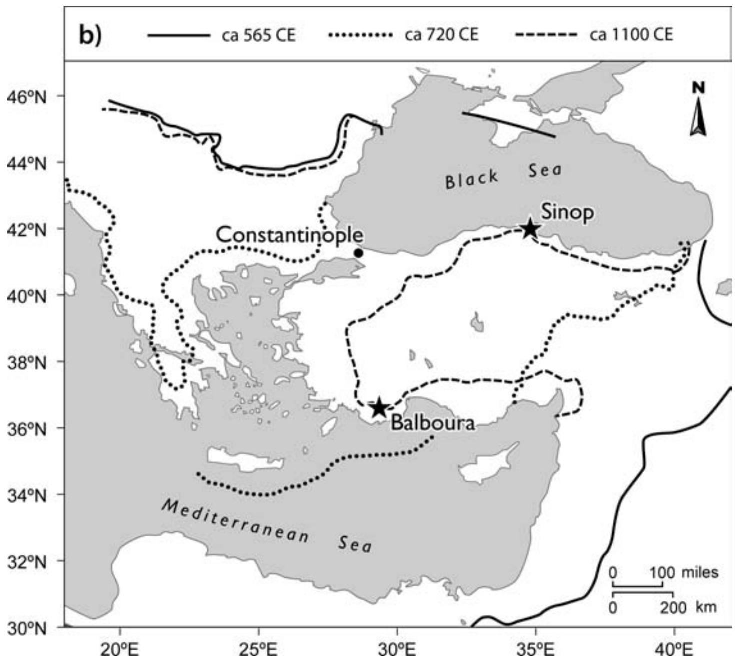
SOURCE Adapted from Roberts et al., "Palaeolimnological Evidence for an East–West Climate See-Saw in the Mediterranean since AD 900," *Global and Planetary Change,* LXXXIV/LXXXV (2012), 23–34.

beria. Anatolia also contains a wide range of geographies, from open lowlands and upland plains to mountains, forests, and steppes, as well as significant variations in climate. Some parts of the area have extremely cold winters with considerable snow, while others have mostly damp winters; summers vary from damp and hot to dry and extremely hot.[24]

As Figure 2a indicates, central and western Anatolia, along with Thrace, show a notable spatial coherence of temperature and

24 Xoplaki, "Climate Variability over the Mediterranean," unpub. Ph.D. diss. (University of Bern, 2002); *eadem* et al., "Wet Season Mediterranean Precipitation Variability: Influence of Large-Scale Dynamics and Trends," *Climate Dynamics,* XXIII (2004), 63–78. M. Türkeş, T. Koç, and F. Sarş, "Spatiotemporal Variability of Precipitation Total Series over Turkey," *International Journal of Climatology,* XXIX (2009), 1056–1074.

Fig. 2b The Changing Borders of the East Roman (Byzantine) Empire (along with Archaeological Survey Sites Discussed in the Text).



precipitation during the recent period of instrumental measurements. Such coherence is also likely to have been the case during the last two millennia (although, interestingly, the southern Levant has shown an opposite pattern). The fact that this same area broadly coincides with the extent of Byzantine Anatolia between c. 660 C.E. and 1071 C.E. permits us to map the two directly onto each other (Figure 2b).[25]

Anatolia supports a substantial microregional differentiation in climate, land use and demographic history; the relationship between historically attested extreme weather events, longer-term climate change, and socio-economic organization there presents singular opportunities and challenges. Since the Roman, early medieval European, and early and middle Byzantine era, unlike more recent historical periods, has no *continuous* written records, the uncertainties accompanying the integration of historical, archaeologi-

25 Luterbacher et al., "A Review of 2000 Years of Paleoclimatic Evidence in the Mediterranean."

cal, climatic data abound. Yet, thanks to the introduction of new approaches and new sources, the study of Anatolia promises to expand and deepen our understanding of how society functioned, particularly when environmental changes stressed that society. The whole is considerably greater in this respect than the sum of the parts in such a project: The interaction of climate scientists and palaeoenvironmentalists with historians and archaeologists promotes a much better understanding of the methodological problems that specialists encounter, as well as a more coherent and synthetically persuasive integrated interpretation of the various datasets that they deliver to each other.[26]

HUMAN ADAPTATION AND CLIMATIC CHANGE Anatolia is relatively rich in useful palaeoenvironmental data compared to other parts of the Eastern Mediterranean; we know a good deal about its vegetation and land-use history thanks to palynology. One phenomenon on which palynological data from Georgia and Iranian Azerbaijan across to the Balkans and the Levant shed light is the Beyşehir Occupation Phase (BOP), a distinctive Late Holocene period of anthropogenic activity marked by the cultivation of olive and nut trees, cereal growing, and pastoralism—the dominant form of agrarian exploitation from the Late Bronze Age to the Hellenistic-Roman and Byzantine world in the Eastern Mediterranean (c. 300 B.C.E. to c. 700/800 C.E.). Although it began and ended in different places at different times, the BOP roughly dates from the "Minoan Warm period" c. 1500 B.C.E. to the markedly cooler seventh/eighth century C.E, identified chiefly through the evidence of pollen found in such natural deposits as lake beds. Although most clearly evident in the upland valleys of southwest Anatolia, it is also recorded in pollen diagrams from sites in central and northwestern Turkey and parts of Greece. Archaeologists associate this phase with a range of material-cultural phenotypes characteristic of the classical cultures of antiquity.[27]

26 *Ibid.*

27 The Beyşehir Occupation Phase was named for the site at which it was first identified, Beyşehir Gölü, in southwestern Turkey: S. Bottema, H. Woldring, and B. Aytuğ, "Palynological Investigations on the Relations between Prehistoric Man and Vegetation in Turkey: The Beyşehir Occupation Phase," *Proceedings of the 5th Optima Congress, September 1986* (Istanbul, 1986), 315–328; Bottema and Woldring, "Anthropogenic Indicators in the Pollen Record of the Eastern Mediterranean," in Bottema, G. Entjes-Nieborg, and W. Van Zeist (eds.), *Man's Role in the Shaping of the Eastern Mediterranean Landscape* (Rotterdam, 1990), 231–264;

The debate about the end date for the BOP is explicable only partially by the imprecision of the chronologies derived from the various data sets. In certain sites with well-defined timescales, the end is dated to the middle or later seventh century C.E., whereas in others, its termination is earlier, sometimes considerably so. The pollen at the sites of Lakes Beyşehir and Hoyran suggest a date in the middle years of the sixth century (see Figure 3 and Table 2). Those at Lake Bafa on the Aegean Coast and the one at Köyceğiz

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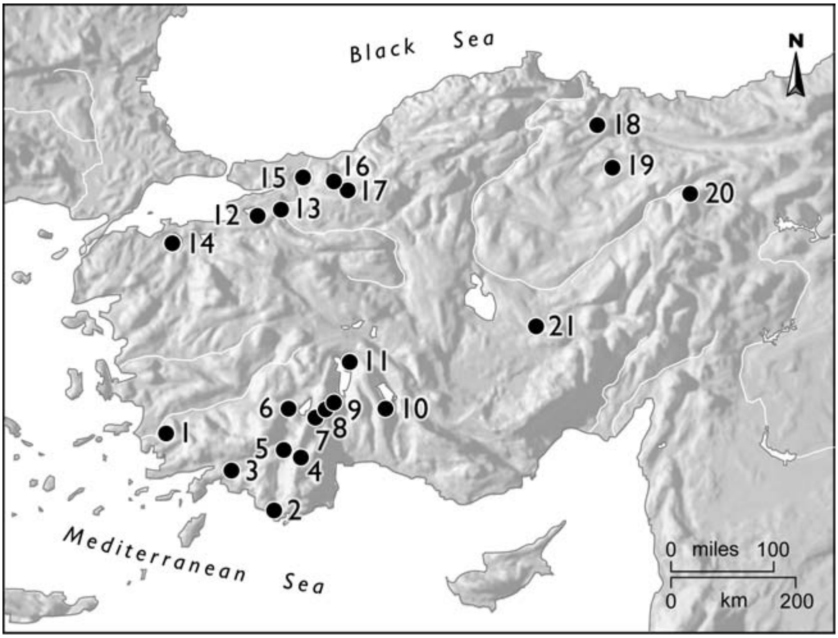
Eastwood, Roberts, and Lamb, "Palaeoecological and Archaeological Evidence for Human Occupancy in Southwest Turkey: The Beyşehir Occupation Phase," *Anatolian Studies,* XLVIII (1998), 69–86. For the Levant, see M. J. Schwab et al., "Holocene Palaeoecology of the Golan Heights (Near East): Investigation of Lacustrine Sediments from Birket Ram Crater Lake," *Quaternary Science Reviews,* XVI/XVII (2004), 1723–1732; F. Neumann et al., "Holocene Vegetation and Climate History of the Northern Golan Heights (Near East)," *Vegetation History and Archaeobotany,* XVI (2007), 329–346; Dafna Langgut, I. Finkelstein, and T. Litt, "Climate and the Late Bronze Age Collapse: New Evidence from the Southern Levant," *Tel Aviv,* XL (2013), 149–175.

Bottema et al., "Palynological Investigations"; Roberts, "Human-Induced Landscape Change in South and South-West Turkey during the Later Holocene," in Bottema, Entjes-Nieborg, and van Zeist (eds.), *Man's Role,* 53–67; Eastwood et al., "Palaeoecological and Archaeological Evidence"; *idem* et al., "Holocene Environmental Change in Southwest Turkey: A Palaeoecological Record of Lake and Catchment-Related Changes," *Quaternary Science Reviews,* XVIII (1999), 671–695; M. Vermoere, *Holocene Vegetation History in the Territory of Sagalassos (Southwest Turkey): A Palynological Approach: Studies* (Turnhout, 2004); Vermoere et al., "Modern and Ancient Olive Stands near Sagalassos (Southwest Turkey) and Reconstruction of the Ancient Agricultural Landscape in Two Valleys," *Global Ecology and Biogeography,* XII (2003), 217–235; *idem* et al., "Late Holocene Local Vegetation Dynamics in the Marsh of Gravgaz (Southwest Turkey)," *Journal of Paleolimnology,* XXVII (2002), 429–451; *idem* et al., "Late Holocene Environmental Change and the Record of Human Impact at Gravgaz near Sagalassos, Southwest Turkey," *Journal of Archaeological Science,* XXVII (2000), 571–595; Roberts, "'Living with a Moving Target': Long-Term Climatic Variability and Environmental Risk in Dryland Regions," in N. F. Miller, K. M. Moore, and K. Ryan (eds.), *Sustainable Lifeways: Cultural Persistence in an Ever-Changing Environment* (Philadelphia, 2011), 13–38.

For southwestern Turkey, see Van Zeist, Woldring, and D. Stapert, "Late Quaternary Vegetation and Climate of Southwestern Turkey," *Palaeohistoria,* XVII (1975), 53–144; Bottema and Woldring, "Late Quaternary Vegetation and Climate of Southwestern Turkey: Part II," *ibid.,* XXVI (1984), 123–149; for northern Turkey, *idem* and B. Aytuğ, "Late Quaternary Vegetation History of Northern Turkey," *ibid.,* XXXV/XXXVI (1993), 13–72; for Israel, Neumann et al., "Holocene Vegetation and Climate History of the Northern Golan Heights (Near East)," *Vegetation History and Archaeobotany,* XVI (2007), 329–346; S. Leroy, "Pollen Analysis of Core DS7–1SC (Dead Sea) Showing Intertwined Effects of Climatic Change and Human Activities in the Late Holocene," *Journal of Archaeological Science,* XXXVII (2010), 306–313; for northwestern Iran, M. Djamali et al., "A Late Holocene Pollen Record from Lake Almalou in NW Iran," *ibid.,* XXXVI (2009), 1364–1375; for Georgia, P. De Klerk et al., "Vegetation History and Environmental Development since ca 6000 cal yr BP in and around Ispani 2 (Kolkheti lowlands, Georgia)," *Quaternary Science Reviews,* XXVIII (2009), 890–910; for Greece, Bottema, "Pollen Analytical Investigations in Thessaly, Greece," *Palaeohistoria,* XXI (1979), 19–40.

Fig. 3 Sites with Pollen Data for the First Millennium C.E. in Central and Western Anatolia (See Table 2 for Site Numbers and Names)



on the southern coast indicate that BOP-type agriculture ceased during the later third or fourth century.[28]

What caused this discrepancy? Did the change occur synchronously or diachronously across different regions? Furthermore, to what extent did its end coincide with observable changes in the social, economic, and political histories of the regions in which it had been dominant? It should be borne in mind that the relatively

28 For later termination, see Eastwood et al., "Palaeoecological and Archaeological Evidence"; *idem* et al., "Holocene Environmental Change in Southwest Turkey"; for an earlier termination, for example, Kaniewski et al., "A High-Resolution Late Holocene Landscape Ecological History Inferred from an Intramontane Basin in the Western Taurus Mountains, Turkey," *Quaternary Science Reviews,* XXVI (2007), 2201–2218; for Lycia and the South Aegean, Eastwood et al., "Palaeoecological and Archaeological Evidence"; Bottema and Woldring, "Anthropogenic Indicators in the Pollen Record of the Eastern Mediterranean," 231–264 (246 for the pollen on the coasts); van Zeist et al., "Late Quaternary Vegetation and Climate of Southwestern Turkey," 113–122, 132. M. Knipping, M. Müllenhof, and H. Brückner, "Human Induced Landscape Changes around Bafa Gölü (Western Turkey)," *Vegetation History and Archaeobotany,* XVII (2007), 365–380.

Table 2 Estimated End Dates of the Beyşehir Occupation Phase in Anatolia

SITE NUMBER	SITE NAME	ESTIMATED END DATE	AGE-DEPTH MODEL (NUMBER OF RADIOCARBON DATES)	ORIGINAL PUBLICATION
	AEGEAN COAST			
1	Bafa (n/Miletus)	third century C.E.	radiocarbon-based (3)	Knipping et al. 2007
	SOUTHWESTERN ASIA MINOR			
2	Ova	second century B.C.E.?	radiocarbon-based (2)	Bottema et al. 1984
3	Köyceğiz	second to third century C.E.	radiocarbon-based (2)	van Zeist et al. 1975
4	Söğüt	fourth to fifth century C.E.	radiocarbon-based (2)	van Zeist et al. 1975
5	Gölhisar	mid-seventh–mid-eighth century C.E.	radiocarbon-based (11 for 3 cores)	Eastwood et al. 1999
6	Pinarbaşi	ninth–tenth century C.E.	radiocarbon-based (2)	Bottema et al. 1984
7	Gravgaz	Mid-seventh century C.E.	radiocarbon-based (5)	Bakker et al. 2011
8	Bereket	early fourth century C.E.	radiocarbon-based (11)	Kaniewski et al. 2007
9	Ağlasun	seventh–eighth, or early eleventh C.E.	radiocarbon-based (7)	Vermoere 2004/ Bakker et al. 2012
10	Beyşehir Gölü I	fourth–sixth century C.E.	radiocarbon-based (2)	van Zeist et al. 1975
11	Hoyran	fourth–sixth century C.E.	radiocarbon-based (1)	van Zeist et al. 1975

Table 2 *(Continued)*

SITE NUMBER	SITE NAME	ESTIMATED END DATE	AGE-DEPTH MODEL (NUMBER OF RADIOCARBON DATES)	ORIGINAL PUBLICATION
	BITHYNIA			
12	Göksü	sixth–seventh century C.E.	radiocarbon-based (2)	Argant 2003
13	Adliye (n/Iznik) (Iznik)	sixth–seventh century C.E.	radiocarbon-based (2)	Argant 2003
14	Manyas	eighth century C.E.	radiocarbon-based (2)	Leroy et al. 2002
15	Küçük Akgöl	fifth–sixth, then eleventh century C.E.	radiocarbon-based (2)	Bottema et al. 1993/1994
16	Melen	tenth–eleventh century C.E.	radiocarbon-based (1)	Bottema et al. 1993/1994
17	Abant	eleventh century C.E.	radiocarbon-based (5)	Bottema et al. 1993/1994
	PONTUS			
18	Ladik	eighth–ninth century C.E.?	radiocarbon-based (4)	Bottema et al. 1993/1994
19	Kaz	fifth–sixth century C.E.	radiocarbon-based (2)	Bottema et al. 1993/1994
20	Demiryurt	sixth–seventh century C.E.	radiocarbon-based (1)	Bottema et al. 1993/1994
	CAPPADOCIA			
21	Nar	670s C.E.	varve years	England et al. 2008

NOTE A question mark indicates that interpretation of the core remains uncertain. The table includes only those pollen sites from Anatolia in which the BOP can be identified and radiocarbon dates or varve chronologies are provided.

SOURCE Based on Adam Izdebski, *A Rural Economy in Transition: Asia Minor from the end of Antiquity into the Early Middle Ages* (Warsaw, 2013), 145–201. See text notes for full citations of works in the "Original Publication" column.

few ^{14}C dates offered by older pollen studies derived from bulk organic matter rather than AMS dating, which can be applied to much smaller samples (for example, single charred cereal grains) and achieve smaller statistical age uncertainty. Hence, dating of the BOP's end in most of these older records has a precision of no better than ±200 years. What is clear is that almost all of the records show a sharp decline in anthropogenic indicators and a rise in pine pollen at some point during the middle of the first millennium C.E., indicating a decline in rural agriculture and a re-wilding of many landscapes.

Although anthropogenic factors probably played a major role in the appearance of the BOP, a beneficial climate régime must have had something to do with it; thus, the relationship between human and climatic factors still needs to be addressed. Although the appearance of the BOP coincides with the rise of the first major state formations in several areas, the climatic "tipping points" for substantive change clearly varied. The economic and social-political developments that accompanied the end of the BOP comprise only part of the many complex changes that Byzantium—in particular, its Anatolian territories—underwent from c. 400 to 1400 C.E.

How we understand the Byzantine response to the crisis of the later seventh and early eighth centuries depends on the palaeoclimatic work discussed above. It reveals that much, but not all, of Anatolia experienced a wetter climate from the sixth to the later seventh century, possibly stretching into the early eighth century in some areas, although the end of this humid phase varies by site: at Nar Gölü in central Cappadocia (known by the tenth century as "lesser Cappadocia)" and at Çöl Gölü near Çankırı (Gaggra) to the east of Ankara—typical of the central sections of the plateau—c. 750; at Tecer Gölü in northwestern Cappadocia the later eighth century; and at Gravgaz marsh in southwestern Anatolia the middle of the seventh century.[29]

Temperature is also important in Anatolia and the Byzantine

29 See Roberts, Eastwood, and J. Carolan, "Palaeolimnological Investigations in Paphlagonia," in C. Glatz and R. Matthews (eds.), *At Empires Edge: Project Paphlagonia: Regional Survey in North-Central Turkey* (London, 2009), 64–73; Jones et al., "A High-Resolution Late Holocene Lake Isotope Record from Turkey"; Kuzucuoğlu et al., "Mid-Holocene Climate Change in Central Turkey." For the briefly summarized results of a range of analyses across Asia Minor, see Izdebski, *A Rural Economy in Transition: Asia Minor from the End of Antiquity into the Early Middle Ages* (Warsaw, 2013), 132–143, 203–215; for a shorter account, *idem,* "Why Did Agriculture Flourish in the Late Antique East? The Role of Climate Fluctua-

world. Given its raised central plateau, and marked variations in elevation, the cooling associated with reduced solar activity (major solar minimum in the seventh century C.E.) would have had varying effects. These effects would have been most pronounced in the most elevated areas with longer snow-covered winters, reduced growing seasons, and generally less favorable circumstances for certain crops and types of farming. But, notwithstanding the limited nature of the data, this general climatic pattern seems to have been replicated, with minor variations, across Anatolia. Indeed, the available textual evidence from the wider eastern Mediterranean and Levantine context hints at the instability that these climatic conditions promoted—a comparatively greater number of severe winters and apparently unusually severe frosts and snows across the later sixth and into the eighth century in the Levant and Asia Minor, as well as occasional droughts and aridity-related events. A recent analysis of Arabic written sources from Baghdad (Iraq) for the period 830 C.E. to the early eleventh century, for example, found a preponderance of cold-winter anomalies for the first part of the tenth century.[30]

GATHERING THE DATA A close look at palynological data from a series of sites across the western half of Anatolia is highly informative. Pollen from flora representing both human activities (from cereals and nut trees, for example, or the weeds and grasses favored for grazing livestock) and the natural vegetation that replaces crops or expands to occupy formerly tilled land are suggestive of particular agricultural patterns. A first conclusion is that Anatolia's arable and pastoral land, even the marginal areas, was, with regional variations according to local conditions, put to relatively intensive use during the sixth and seventh centuries. Both the palynological record and the archaeological evidence indicate that much of the region was densely inhabited and characterized by mixed farming.

Beginning in the seventh century, however, this intensive and relatively homogenous exploitation of land receded, at different

tions in the Development and Contraction of Agriculture in Asia Minor and the Middle East from the 4th till the 7th c. AD," *Millennium,* VIII (2011), 291–312.

30 Manning, "Roman World and Climate," 128–131 (Figs. 6–8). For the textual evidence summarized in tabular form, see Telelis, *Meteorologika phainomena;* Stathakopoulos, *Famine and Pestilence in the Late Roman and Early Byzantine Empire*. Dominguez-Castro, "How Useful Could Arab Documentary Sources Be for Reconstructing Past Climate?"

rates, across the southern Balkans and much of Asia Minor with the entire BOP agricultural régime. In its place, many locations underwent a sequence of progressive expansion of natural vegetation—increasingly prominent indications of post-arable growth, followed by scrub, and either wild grasses and steppic vegetation or woodland re-growth. Other locations show evidence of continued anthropogenic land use but with a much more limited range of crops that varied according to specific local conditions. Cereal production and livestock raising began to dominate, and the cultivation of vines and olives to decrease dramatically in many areas.

Palynological investigation shows considerably less pollen from fruit trees of all types for this period. Parts of inland Bithynia in northwest Anatolia, close to Constantinople, however, appear to defy this trend to some extent, showing signs that the BOP suite of cultivars continued unbroken, albeit with an overall reduction in the volume of production. By contrast, the evidence suggests that the coastal regions of Bithynia increased their reliance on pastoral farming at the expense of cereal and fruit production, possibly testifying to the frequent sea-borne attacks there during the second half of the seventh and early eighth centuries, which made such cultivation risky. The survival of traditional agriculture in inland areas, away from the threatened coastal areas, may reflect market demand from Constantinople.[31]

As a whole, Anatolia in this period evinces a much simplified agro-pastoral regime and a reduced level of activity. The wholesale retreat from many of the marginal areas that had formerly been farmed and the often dramatic reduction in farming elsewhere might be indicative of a reduced rural population in some areas as well—certainly in the Konya plain region, where a hitherto dense settlement relying on extensive seasonal irrigation vanished in the later seventh/early eighth century. A similar pattern is evident in the material remains at Çadır Höyük (in the basin of the Kanak Su, Yozgat province), where the wealthy settlement of the late antique period was replaced by a smaller habitation. Although the dates are still difficult to assess, these changes appear to have been roughly

31 J. Argant, "Données palynologiques," in B. Geyer and J. Lefort (eds.), *La Bithynie au moyen âge* (Paris, 2003), 175–200; Bottema et al., "Palynological Investigations." The material is summarized in Izdebski, "The Changing Landscapes of Byzantine Northern Anatolia," *Archaeologia Bulgarica,* XVI (2012), 47–66, and detailed in *idem, A Rural Economy in Transition,* 145–201.

contemporary with those in the broader region. Similar developments appear to have occurred in Cappadocia, Bithynia, and eastern Paphlagonia. Although the evidence for these developments is patchy, and many more sample sites are necessary to ensure comprehensive coverage (particularly in the lowland sites where many cities were located), the overall picture appears to fit well with the textual and the archaeological evidence about the collapse of established urban and agricultural customs, the downward demographic trend, and the general militarization of the Empire's provincial society.[32]

In some regions, after 100 to 250 years, a further shift is evident in the pollen, indicating greater entrenchment of this simplified regime; an expansion of large-scale pastoral farming; and a reappearance, in some contexts, of cultivars, mainly cereals, but also traces of vines, olives, and fruits. This slight return coincides with the political and economic recovery of the Empire during the later ninth and tenth centuries, as well as with the end of a drier (and cooler) period that had lasted from the eighth into the tenth century (see Figure 4).[33]

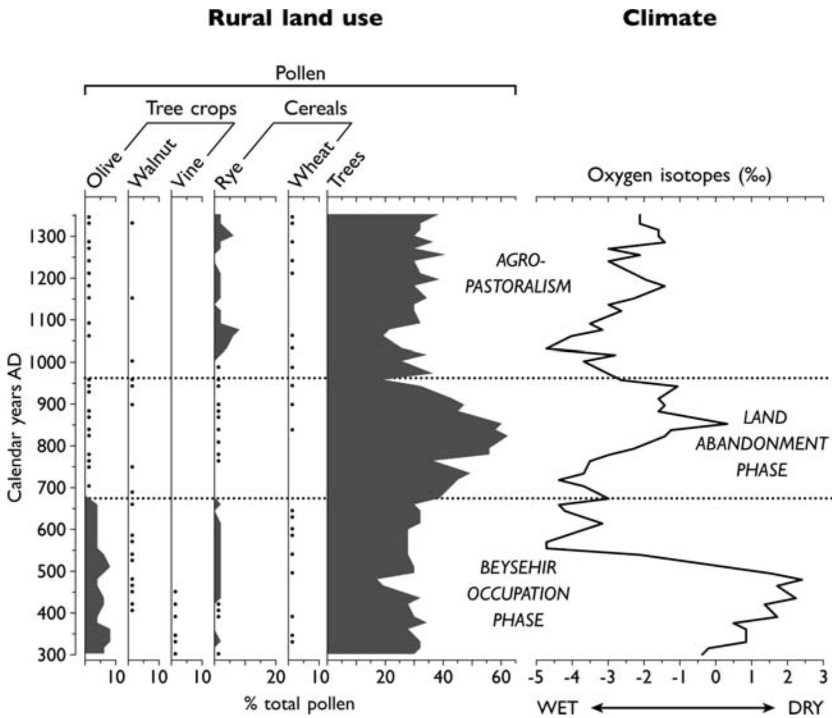
By way of illustration, the palynological data from Nar Gölü—which included the Roman and Byzantine center of Nazianzos, laying just to the north of the current Melendiz Ovası (Bishop's Meadow)—indicates a significant agrarian recovery during the second half of the tenth century C.E., presenting a new configuration in the region's rural economy. The area now placed greater emphasis on cereal production and livestock herding, as opposed to the orchards and gardens of the BOP before its abrupt termination in the region between, roughly, 670 and 690.

32 For the Konya plain region, see D. Baird, "Settlement Expansion on the Konya Plain, Anatolia: 5th–7th Centuries A.D.," in W. Bowden, L. Lavan, and C. Machado (eds.), *Recent Research on the Late Antique Countryside* (Leiden, 2004), 219–246; for Çadır Höyük—situated between Roman Tavium (modern Yozgat) and Sebasteia (Sivas), and near the boundary between Roman Galatia and Cappadocia—Cassis, "Çadır Höyük," in P. Niewöhner (ed.), *The Archaeology of Byzantine Anatolia: From Late Antiquity to the Coming of the Turks* (Leiden, forthcoming); *eadem,* "Çadir Höyük: A Rural Settlement in Byzantine Anatolia," in Tasha Vorderstrasse and Jacob Roodenberg (eds.), *Archaeology of the Countryside in Medieval Anatolia* (Leiden, 2009), 1–24.

For a detailed account of the overall picture, see Leslie Brubaker and Haldon, *Byzantium in the Iconoclast Period (Ca. 680–850): A History* (New York, 2011), 531–563; Haldon, "'Cappadocia Will Be Given Over to Ruin and Become a Desert,'" 215–230.

33 Izdebski, "Changing Landscapes of Byzantine Northern Anatolia;" *idem, A Rural Economy in Transition.* The settlements at Çadır Höyük (and Lake Nar, see below) saw an increase in visible wealth at approximately this time. See Cassis, "Çadır Höyük" (forthcoming).

Fig. 4 Synthetic Summary Diagram of Vegetation, Land Use, and Climatic Change from Nar Gölü, Cappadocia, 300–1400 C.E.



SOURCE Modified from Anne England et al., "Historical Landscape Change in Cappadocia (Central Turkey): A Paleoecological Investigation of Annually-Laminated Sediments from Nar Lake," *The Holocene,* XVIII (2008), 1234–1237.

In the 960s, just to the south of Nar Gölü, was a productive and wealthy imperial estate (called Drizion in the Byzantine sources). Contemporary sources imply that it had only recently become safe from hostile attack, after years of warfare and conflict. It may well be the activities of such imperial estates, in expanding or re-establishing cereal production, among other crops, that the pollen data for the period from 950 onward reflect. But we also know that a number of Anatolian aristocratic landlords began to invest in expanding their estates around this time, coinciding with the height of imperial political and military power and expansion and widespread growth of the agrarian economy in the Byzantine world. Was the degree of this improvement in the economic, political, and military fortunes of the Empire—more specifically, its

Table 3 Summary Interpretation of High-Resolution Pollen and Stable Isotope Data, Nar Lake, 270–1400 C.E.

CLIMATE		RURAL LAND USE AND POPULATION	
950–1400 C.E.	moderately wet	950–1400 C.E.	population increase, agro-pastoral economy
750–950 C.E.	moderately dry	680–950 C.E.	rural abandonment, greatly reduced farming, forest recovery
540–750 C.E.	very wet	pre-680 C.E.	dense settlement, agriculture of cereals and tree crops
270–540 C.E.	dry		

social elite in Asia Minor—aided by an amelioration in the climate regime?[34]

A persuasive universal explanation for these developments is still elusive. Most, but not all, of the shifts inferred from the palaeoecological record can be demonstrated to coincide neatly with known political events, such as the Arab-Islamic invasions from the late seventh century. Moreover, not all of the "climate change" events fit perfectly with other types of events. The substantial regional variation across Anatolia (as indicated by the palaeoclimatic data), which we have already discussed, is rarely given sufficient at-

34 For more information about this region, see Friedrich Hild and Marcel Restle, *Tabula Imperii Byzantini 2: Kappadokien (Kappadokia, Charsianon, Sebasteia und Lykandos)* (Vienna, 1981), 261–262, 258–259, 298–299, 243–244, 142, 172–173; for the history of the region(s) of Kappadokia between the seventh and ninth centuries, *ibid.,* 70–84; for the arrangements along the frontier, Haldon and H. Kennedy, "The Byzantine-Arab Frontier in the Eighth and Ninth Centuries: Military Organisation and Society in the Borderlands," *Zbornik Radova Vizantološkog Instituta,* XIX (1980), 79–116; Sophie Métivier, "L'organisation de la frontière arabo-byzantine en Cappadoce (VIIIe–IXe siècle)," in E. Cuozzo et al. (eds.), *Puer Apuliae: Mélanges offerts à Jean-Marie Martin* (Paris, 2008), 433–454.

Johannes Thurn, *Ioannis Scylitzae Synopsis Historiarum* (New York, 1973), 268.90–96; 311, 95–96; Carl Benedict Hase (trans. Alice-Mary Talbot and D. Sullivan), *The History of Leo the Deacon: Byzantine Military Expansion in the Tenth Century* (Washington D.C., 2005; orig. pub. Bonn, 1828), 218–219. For comments, see William M. Ramsay, *The Historical Geography of Asia Minor* (London, 1890; repr. Amsterdam, 1962), 347–348; Hendy, *Studies,* 104–106.

Michel Kaplan, *Les hommes et la terre à Byzance du VIe au XIe siècles* (Paris, 1992), 448–449; *idem,* "Les grands propriétaires de Cappadoce (VIe–XIe siècles)," in *Le aree omogenee della Civiltà rupestre nell'ambito dell'Impero bizantino: la Cappadocia* (Galatina, 1981), 125–158; esp. Alan Harvey, *Economic Expansion in the Byzantine Empire 900–1200* (New York, 1989). On the nature of the middle Byzantine social elite, see Haldon, "Social Élites, Wealth and Power," in *idem* (ed.), *The Blackwell Social History of Byzantium* (Malden, 2009), 168–211; Frankopan, "Land and Power in the Middle and Later Period," *ibid.,* 112–142.

tention. It is particularly relevant in this context, especially with respect to the contrast between central Anatolia and the western areas and their very different climate regimes and sometimes trajectories (see, for example, Figure 2a). Anatolia's apparent climatic instability suggests that environmental shifts may have contributed significantly to changes in the vegetation reflected in the pollen data from the fifth and sixth centuries into the seventh and eighth centuries. But because many pollen deposits, as well as climatic changes, are amenable to only approximate dating, their exact relationship remains obscure at most sites.[35]

As already noted, in some areas, such as around Lake Beyşehir on the western edge of the plateau, or around Sagalassos in Pisidia, the change in vegetation patterns occurred across the period from the first half of the sixth century into the mid-seventh century, but with a high level of local variation within a small area. At the coastal sites in Lycia, in the Bereket Valley south of Sagalassos, and on the southern Aegean littoral, the end of the BOP appears even earlier; in Bithynia, Paphlagonia, and Pontus, the seventh century marks the key transition, although the traditional suite of cultivars may have survived into the eighth century in certain localities. In parts of Cappadocia, however, the 670s certainly denote an end to BOP-type agriculture but not any clearly identifiable shift in climate. At Lake Nar, some 30 km south-west of Derinkuyu, the BOP ended precipitously within the period 664 to 678 C.E., dateable by annually laminated high-resolution sediments from the lake. Here a decided increase in tree pollen and a decrease in anthropogenic indicators (for example, *Olea,* cereal pollen types) is noticeable, and analysis of the pollen concentrations indicates a substantial, and abrupt, increase in tree cover and/or density.[36]

35 For a detailed analysis of methodologies and results, see Eastwood, "Palaeoecology and Landscape Reconstruction in the Eastern Mediterranean: Theory and Practice," in Haldon (ed.), *General Issues in the Study of Medieval Logistics: Sources, Problems and Methodologies* (Leiden, 2006), 119–158; Izdebski, *Rural Economy in Transition,* 109–143, with literature.

36 For Beyşehir, see Bottema et al., "Palynological Investigations"; Eastwood et al., "Palaeoecological and Archaeological Evidence"; Van Zeist et al., "Late Quaternary Vegetation and Climate of Southwestern Turkey"; for Sagalassos, J. Bakker et al., "Climate, People, Fire and Vegetation"; Eva Kaptijn et al., "Societal Changes in the Hellenistic, Roman and Early Byzantine Periods: Results from the Sagalassos Territorial Archaeological Survey 2008 (Southwest Turkey)," *Anatolian Studies,* LXIII (2013), 75–95; for Lycia and the South Aegean coast, Eastwood et al., "Palaeoecological and Archaeological Evidence"; Bottema and Woldring, "Anthropogenic Indicators"; Van Zeist et al., "Late Quaternary Vegetation and Climate of Southwestern Turkey"; Knipping et al., "Human Induced Landscape Changes around Bafa

A sustained increase in pine-pollen percentages is typical of many other western Anatolian pollen diagrams that record the end of the BOP, by all accounts signifying an expansion of pine forests across the Taurus and Pontic mountain chains, though probably at some distance from Nar. The sustained increase in deciduous oak pollen, however, most likely reflects expanding oak woodland areas and/or an increase in tree density more locally within Cappadocia.[37]

Significantly, pollen percentages for grasses associated with steppe vegetation also declined in this period, possibly implying that woody vegetation began to cover some of the areas previously dedicated to livestock grazing. At Nar Lake highly resolved palaeoclimatic data show a distinct change in conditions—from humid to more arid—but only from c. 750. Importantly, the pollen and the independent climate proxies, such as oxygen isotopes, come from the same sediment cores, thus precluding the possibility of miscorrelation. In this particular example, it has been possible to demonstrate a reasonably persuasive association between anthropogenic activity—intensive Arab raiding that devastated the landscape during the years in question—and the picture derived from the environmental data. No simple correlation exists between societal collapse and any adverse climatic changes in the Nar Lake record during the seventh and eighth centuries. The re-occupation of Cappadocia between 850 and 950 C.E., however, coincided with an amelioration of the climate toward wetter conditions, suggesting that an increasingly propitious agro-climatic environment may

Gölü"; for Bithynia, Argant, "Données palynologiques"; Leroy et al., "Abrupt Environmental Changes within a Late Holocene Lacustrine Sequence South of the Marmara Sea (Lake Manyas, N-W Turkey): Possible Links with Seismic Events," *Marine Geology,* CXC (2002), 531–552; for Paphlagonia/Pontus, Roberts, Eastwood, and Carolan, "Palaeolimnological Investigations in Paphlagonia," 64–73; Bottema et al., "Late Quaternary Vegetation History of Northern Turkey"; Izdebski, "Changing Landscapes of Byzantine Northern Anatolia"; for Cappadocia, Anne England et al., "Historical Landscape Change in Cappadocia (Central Turkey): A Paleoecological Investigation of Annually-Laminated Sediments from Nar Lake," *The Holocene,* XVIII (2008), 1229–1245; Eastwood et al., "Integrating Palaeoecological and Archaeo-Historical Records: Land Use and Landscape Change in Cappadocia (Central Turkey) since Late Antiquity," in Vorderstrasse and Roodenberg (eds.), *Archaeology of the Countryside in Medieval Anatolia,* 45–69. Haldon, "'Cappadocia Will Be Given over to Ruin and Become a Desert.'"

37 A study of modern pollen deposition in Cappadocia found that oak pollen—although produced abundantly—was not dispersed far from oak trees and woodland. See Woldring and Bottema, "The Vegetation History of East-Central Anatolia in Relation to Archaeology: The Eski Acıgöl Pollen Evidence Compared with the Near Eastern Environment," *Palaeohistoria,* XLIII/XLIV (2003), 1–31.

have encouraged the re-establishment of the middle Byzantine rural economy. So far, however, Nar Lake presents the only case study in which this degree of cross-disciplinary interpretation has been possible (see Table 3).[38]

Archaeological site surveys provide an alternative data set for changes in rural population. A number of the recent field surveys in Anatolia have begun to yield settlement data within systematic sampling programs. The majority of them are multi-period field programs, though the Sagalassos regional survey in Pisidia, for one, was initially prompted by interest in a particular archaeological period—the Hellenistic-Roman-Byzantine. Identification of site-occupation periods is primarily based on analysis of potsherds collected in the field, the typology of which allows attribution to broad archaeological phases lasting several centuries (for instance, the late Roman). Periods of site abandonment, which are represented by the absence of evidence, are, by definition, harder to define and identify.[39]

Despite the unavoidably broad dating for many archaeological periods, some of the Anatolian site surveys manage to shed light on changing rural settlement patterns between c. 200 and c. 1000 C.E., as we can illustrate with results from the Sinop and Balboura Re-

38 Jones et al., "A High-Resolution Late Holocene Lake Isotope Record," 361–364; *idem* et al., "A Coupled Calibration and Modelling Approach to the Understanding of Dry-Land Lake Oxygen Isotope Records," *Journal of Paleolimnology,* XXXIV (2005), 391–411. High-resolution stable isotope analyses were completed on the core sequence retrieved from the lake. Individual $\delta^{18}O$ and $\delta^{13}C$ analyses on precipitated authigenic carbonate were undertaken for each of the upper 900 varves; the following 825 varves were analyzed from contiguous bulk samples at a five-year resolution. The Nar $\delta^{18}O$ record was interpreted as reflecting variability in precipitation and evaporation, showing marked shifts in isotope values. A major change to more negative isotope values is dated c. 530 C.E. Major shifts to more positive isotope values occur at c. 800 C.E. and c. 1400 C.E. These findings are supported by mineralogical data, since aragonite deposition (characteristic of more evaporated systems) occurs during periods with more positive isotope values (prior to c. 530 C.E. and c. 1400–1960 C.E.), whereas calcite is deposited during periods with more negative isotope values. See M. J. Leng and J. D. Marshall, "Palaeoclimate Interpretation of Stable Isotope Data from Lake Sediment Archives," *Quaternary Science Reviews,* XXIII (2004), 811–831. The stable-isotope data therefore show drier periods (300–500 and 1400–1960 C.E.) and wetter intervals (560–750, 1000–1400, and post-1960 C.E.) related to the intensity in summer drought and changes in the amount of spring and winter precipitation. See also Haldon, "'Cappadocia Will Be Given over to Ruin and Become a Desert'"; England et al., "Historical Landscape Change in Cappadocia; Eastwood et al., "Integrating Palaeoecological and Archaeo-Historical Records."

39 For a review of recent field surveys, see Doonan, "Surveying Landscapes: Some Thoughts on the State of Survey Archaeology in Anatolia," *Backdirt: Annual Review of the Cotsen Institute of Archaeology* (2013), 118–23; Izdebski, *Rural Economy in Transition,* 13–46; H. Vanhaverbeke, *The Chora of Sagalassos: The Evolution of the Settlement Pattern from Prehistoric until Recent Times* (Turnhout, 2003).

gional Archaeological Surveys. The Sinop survey demonstrates a remarkable rise in settlement density from the fourth century along the east-facing coast to the south of the main port. This coast was known in antiquity as the most favorable along the Black Sea for the production of olives. Strabo, the first-century B.C.E. geographer, who was a native of the region and almost certainly an eyewitness, described it as thickly planted with olive groves. Furthermore, olive pits have been recovered from locally produced late Roman amphorae raised from the Sinop harbor area. Environmental evidence is still under analysis, but there is a dramatic drop in settlement density in the Demirci valley, 15 km south of Sinop, from forty-five recorded archaeological sites to a mere eight Middle-Late Byzantine sites; and in the Kirkgeçitcayı valley, from forty-six Late Roman sites to just four Middle-Late Byzantine sites. Based on the datable material finds, this decrease in the number of identifiable settlements appears to correspond with the seventh century, consistent with the cool/wet climatic conditions associated with the end of the BOP.[40]

A crop like olives, always marginal in the Black Sea, would be highly sensitive to this climatic shift. The radical reduction in rural settlement in the Sinop hinterland could be explained by the collapse of a near-monopoly on olive exports in the Black Sea linked to climate "deterioration." Olive cultivation would also have been sensitive to temperature conditions, especially in spring, and the severe winters that became increasingly common from the sixth century onward (see Appendix 1) made olive trees at or above 1,000 masl (meters above sea level) increasingly vulnerable to frost damage. A postclassical decline in olive cultivation is evident both

40 Doonan, *Sinop Landscapes: Exploring Connection in the Hinterland of a Black Sea Port* (Philadelphia, 2004). Strabo—II.i.15; XII.iii.12—implies that this coast of Sinope held a monopoly on Black Sea olive production because of its unique micro-climate. For discussion, see Doonan, "Production in a Pontic Landscape: The Hinterland of Greek and Roman Sinope," in M. Faudot et al. (eds.), *Pont-Euxin et commerce: la genèse de la "Route de soie"* (Besançon, 2003), 185–198. D. Kassab Tezgör, I. Tatlıcan, and H. Özdaş, "Prospection sous-marine près de la côte sinopéenne: transport d'amphores depuis l'atelier et navigation en Mer Noire," *Anatolia Antiqua,* VI (1998), 443–449. Olive pollen was also present in samples from the Demirci plaj excavations, directed by Tezgör in collaboration with the Sinop Museum. See A. Emery-Barbier, "Végétation actuelle et passée de la région de Sinope: Apports des analyses palynologiques et anthropologiques du site de Demirci à la couverture végétal au 1er millénaire AD," in Tezgör (ed.), *Les fouilles et le matériel de l'atelier amphorique de Demirci près de Sinope* (Istanbul, 2010), 27–40. Doonan et al., "Sinop Bölgesel Arkeoloji Projesi 2012 Saha Çalışmaları," *Araştırma Sonuçları Toplantısı,* XXXI (2014).

archaeologically and in pollen diagrams (see Figure 5), at least in part due to climatic adversity.[41]

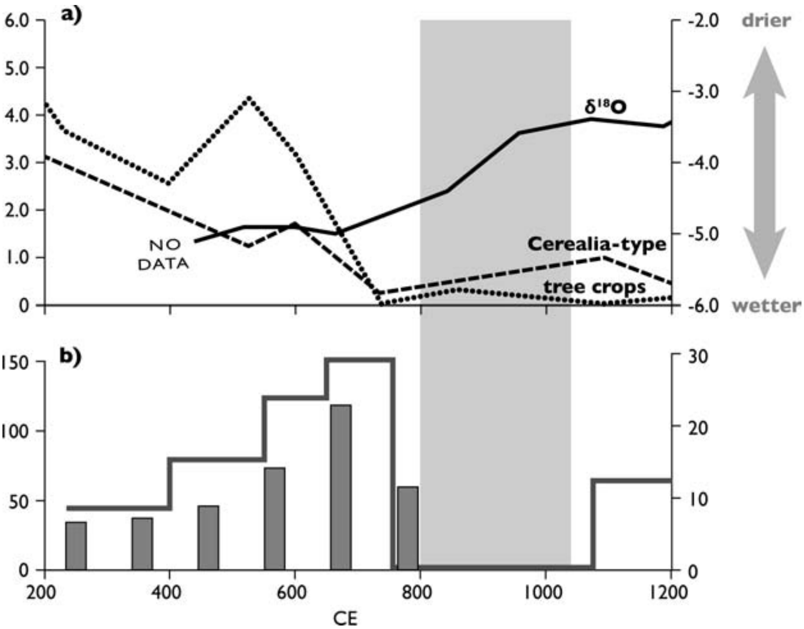
A similar case involving the potential influence of climate on the economic history of the countryside is manifest in the results of the archaeological survey around the classical city of Balboura in northern Lycia (southwestern Anatolia), almost all of its territory above 1,200 masl. As in the Sinop region, the rural settlement of the main Roman period continued into late antiquity. The total number of potsherds from this remote highland area rose in the fifth century, reaching a peak two centuries later, just when the economic system of the Eastern Roman Empire was failing. Yet after another 100 years, the entire area seems to have been abandoned; no substantial ceramic finds date later than the eighth century C.E. (see Figure 5). Interestingly, even for this final century, there is enough evidence to suggest that the city of Balboura had continuous access to the wider networks of commercial exchange, creating no impression of gradual economic decline.

Although the depopulation of the area cannot be easily linked to any specifically identifiable political or military factor, location, with respect to both climatic and strategic circumstances, appears to have been the key to its eighth-century abandonment. As the micro-climate of this highland became drier and colder during the course of the eighth century, agriculture in such a relatively marginal area became impractical and cost-ineffective, especially with such crops as olive trees and vines, which are sensitive to spring frost. Such a marginal agrarian economy was also highly vulnerable to the sort of disruption that hostile military activity caused, even if only occasionally. Given the many other more attractive territories in southwestern Anatolia that had become underpopulated by this time as a result of warfare and other calamities, researchers surmise, plausibly enough, that the population simply migrated to more favorable districts.[42]

41 For further discussion of past changes to olive cultivation in Anatolia, see England et al., "Historical Landscape Change in Cappadocia"; Roberts, "Human-Induced Landscape Change in South and South-West Turkey."

42 J. J. Coulton, "Late Roman and Byzantine Balboura," in *idem* (ed.), *The Balboura Survey and Settlement in Highland Southwest Anatolia. I. Balboura and the History of Highland Settlement* (London, 2012), 163–184. For a general historical-archaeological context for the period, see Brubaker and Haldon, *Byzantium in the Iconoclast Period,* 453–572; Izdebski, *Rural Economy in Transition;* for Gölhisar, Eastwood et al., "Holocene Environmental Change in Southwest Turkey"; *idem* et al., "Holocene Climate Change in the Eastern Mediterranean Region: A Comparison of Stable Isotope and Pollen Data from Lake Gölhisar, Southwest Turkey," *Journal of Quaternary Science,* XXII (2007), 327–341.

Fig. 5 (a) Changes in Climate (Inferred from Oxygen Isotopes) and Pollen-Inferred Land Use at Gölhisar (core GHA-92) Compared with (b) Byzantine Rural Potsherd (Bars) and General Site Numbers (Solid Line) in the Countryside per Century from the Balboura Archaeological Survey



NOTE The abandonment phase from the eighth to the eleventh century is highlighted. Early Islamic Avlan-ware potsherd counts (mainly from the eleventh through the thirteenth century) are not shown.

SOURCE Archaeological site and sherd numbers from J. J. Coulton (ed.), *The Balboura Survey and Settlement in Highland Southwest Anatolia. I. Balboura and the History of Highland Settlement. II. The Balboura Survey: Detailed Studies and Catalogues* (London, 2012), Tables 19.7 (II, 239) and 7.2 (I, 183, for the Avlan ware). For discussion, see I, 169–181. For pollen and isotopes, see Eastwood et al., "Holocene Environmental Change in Southwest Turkey: A Palaeoecological Record of Lake and Catchment-Related Changes," *Quaternary Science Reviews,* XVIII (1999), 671–695; Eastwood et al., "Integrating Palaeoecological and Archaeo-Historical Records: Land Use and Landscape Change in Cappadocia (Central Turkey) since Late Antiquity," in Tasha Vorderstrasse and Jacob Roodenberg (eds.), *Archaeology of the Countryside in Medieval Anatolia* (Leiden, 2009), 45–69.

The combined pollen and stable-isotope record from Gölhisar Gölü—near the classical city of Kibyra, which lies adjacent to Balboura, but at a slightly lower elevation (930 masl)—lacks the detailed sampling resolution and precise dating control of the Nar Lake record; only long-term (multicentennial) trends can be recognized in it (see Figure 5). It is a perfect example of the limitations inherent in low-resolution data regarding the kind of shorter-term events or extremes that the Nar data are able to capture. Nevertheless, by using a multi-proxy approach from the same core sequence, it can be demonstrated that because the onset of drier and probably colder climatic conditions did not begin before the end of the BOP (dated in this case to sometime between 600 and 735 C.E.), it cannot have caused the end of the BOP.

The trend toward a drier climate between c. 660 and c. 960 C.E. is likely, however, to have deterred Balboura's population from continuing its commitment to a place with an increasingly marginal agrarian economy, and although location was a key factor, the additional threat of Arab invasion may have been an added disincentive. The local community might have persisted if faced with only one of these dangers, but the resilience of Balboura and other upland cities would have been severely tested with both of them in place. The pollen evidence in Balboura, unlike that in Cappadocia, shows that this area of southwest Anatolia did not see a return to crop production in medieval times, in spite of archaeological evidence for re-occupation. The new economy was likely based on nomadic pastoralism rather than year-round settlement; crops such as olive trees played no part in it.

All of the pollen and archaeological data collected thus far indicate a degree of interregional variation, suggesting that the end of the established patterns of land use depended on specific local factors. When placed in the broader context of the eastern Mediterranean basin, we might suspect that the plague of Justinian also played a demographic role, however randomly differential its impact was according to area, population, and settlement density or such natural environmental factors as the dust-veil event of the late 530s. The cooler and less stable climatic conditions in Anatolia after the sixth century C.E. must have rendered some agricultural activities more marginal than before, possibly accounting for the development of a less vulnerable, simpler, and safer mode of agrarian economy.[43]

43 Larsen et al, "New Ice Core Evidence for a Volcanic Cause of the A.D. 536 Dust Veil"; Gunn, *Years without Summer.* For the effects of plague and pandemics in the eastern Mediterranean during the late ancient and early medieval period, see Stathakopoulos, *Famine and Pestilence in the Late Roman and Early Byzantine Empire;* more specifically for the plague of Justinian, *idem,* "The Justinianic Plague Revisited," 256–276, with a review of literature; for the Levant,

The regionally specific suite of cultivars and agrarian activities characteristic of the period until the sixth and early seventh centuries managed to survive in some areas—parts of Bithynia, Paphlagonia, and the central plateau—into the eighth century, notwithstanding changes in climatic conditions. In other areas, changes that are evident in the palynological data appear to have occurred at times when no evidence for a shift in the prevailing climate is available; we may make the hardly remarkable assumption that human agency was responsible. The intervention of human agents on the environment in response to a range of social and economic pressures or stimuli—market demand, political conditions, fiscal demands, and so forth—is commonplace.

In the case of the seventh-century eastern Roman world, important and largely overlooked historical data suggest that farmers reacted to perceived environmental changes by introducing new crops and that the state reacted to the loss of the eastern provinces and the serious threat posed by the Arab-Islamic attacks by instituting a new tax policy, by organizing the military, and by controlling resources. We surmise that the adverse environmental conditions of this period contributed, at least in part, to the persistence, rather than the demise, of a political system—a point deserving of its own detailed argument elsewhere.

This article compares and synthesizes evidence from multiple disciplinary traditions—the documentary sources of historians, the material culture of archaeologists, the pollen of palynologists, and the stalagmite chemistry of earth scientists. We have focused on western and central Anatolia during the millennium-long transition from the classical to the medieval world. Maintaining spatial congruence ensures a working scale on which climatic and societal changes were broadly homogenous, permitting analysis of the complex causal relationships between human activity, environmental change, and the transformation of social, economic, and political structures. Any attempt to examine the Eastern Roman Empire as a whole would amalgamate regions with distinct environmental histories (for instance, Egypt vs. Anatolia). Wider geo-

Lawrence Conrad, "Epidemic Disease in Central Syria in the Late Sixth Century: Some New Insights from the Verse of Hassan ibn Thabit," *ibid.,* XVIII (1994), 12–58; Stathakopoulos, "Reconstructing the Climate of the Byzantine World."

graphical linkages certainly exist, both societal and environmental, but they are less likely to map onto each other.

Late classical to medieval Anatolia offers a particularly interesting regional "laboratory" for studying the effect of climate on society, as well as the effect of human activity on the environment. At the very least, the Anatolian case challenges a number of longstanding assumptions about such causal connections, particularly with regard to how environmental conditions during the later seventh and eighth centuries C.E. affected the Byzantine Empire's ability to weather the storm of Arab-Islamic incursion c. 650 to 740. After the rupture of the eighth and ninth centuries, the subsequent recovery of the Byzantine Empire in the tenth century was followed c.1100 C.E. by a sudden downturn in rural agrarian activities, especially on the central Anatolian plateau and around its fringes. This dynamic, observable in the palaeoenvironmental as well as in the archaeological and historical data, reflects a complex interaction of natural factors with anthropogenic ones, including the arrival of the Selçuk Turks and of Türkmen nomads and their flocks and herds in central and eastern Anatolia, concomitant with the abandonment of cereal production in much of these area.[44]

Regarding the following period, pollen evidence from some locations indicates a recovery during the later twelfth and early thirteenth century, a phenomenon that may well be associated with the gradual re-instatement of cereal production on a large scale as central Anatolia returned to political and economic stability. But the various categories of data do not always suggest the same conclusions, and the dating of climate change is generally imprecise. Moreover, the pollen record does not yet cover all of Anatolia, and many of the pollen datasets currently available can offer only a broad range of timing for changes in vegetation and land use. Such contradictions, inconsistencies, and inadequacies confirm the importance of focusing on a specific region-scale analysis.

This is not to suggest, however, that we can completely ignore the wider geographical perspective, either that of the Eastern Roman Empire or of the extensive area from the Middle East to the Atlantic. Indeed, we must always bear in mind the dialectic be-

44 For some preliminary approaches to this issue and related ones during the period, see Ellenblum, *Collapse of the Eastern Mediterranean*; for an assessment of how the Turks figured into the environmental history of Anatolia, see Izdebski, "Byzantine Ecologies," in M. Decker (ed.), *Cambridge Companion to Byzantine Archaeology* (New York, 2014).

tween events and circumstances throughout the duration of the Empire and transformations in the treatment and condition of the local environment. A comparison between how Byzantine society and the societies that preceded and followed it responded to climatic and environmental challenges can bring significant insight, provided that reliable proxy data are available. For example, recent archaeological work on the the 4.2 ka BP Early Bronze Age "collapse" suggests that communities did not handle the same drought in the same way. The settlement at Tell Leilan appears to have been abandoned, whereas that at Tell Mozan continued. The crucial question in this case, as in the case of Anatolia from the seventh to the ninth-century C.E., is precisely why some communities were more resilient—or less "brittle," to use Wilkinson's term—than others.[45]

The upshot is that integrated regional and chronological synthesis, in the context of a broader picture, is an excellent platform on which historians, archaeologists, and environmental scientists can work together to interrogate evidence of causal and explanatory relationships for long-term socio-environmental change.

45 Note that one site is at the marginal edge of dry farming and another one is less exposed. Hence, increased aridity left one below the cereal production level (on a sustained basis) and the other not. For differing views regarding these settlements, see Wossink, "Challenging Climate Change"; Weiss et al., "Genesis and Collapse," 995–1004; R. Koliński, "The Upper Khabur Region in the Second Part of the Third Millennium BC," *Altorientalische Forschungen,* XXXIV (2007), 342–369; Wiener, "Minding the Gap," 581–592. T. J. Wilkinson, "The Structure and Dynamics of Dry-Farming States in Upper Mesopotamia," *Current Anthropology,* XXV (1994), 483–520.

APPENDIX 1: SUMMARY OF HISTORICALLY RECORDED EXTREME CLIMATE-RELATED EVENTS IN ANATOLIA AND ADJACENT REGIONS FROM BYZANTINE SOURCES (300–1453 C.E.)

The table that follows presents a summary of the catalogue of climatic events from textual sources to be found in the works of Telelis and Stathakopoulos, recently updated in McCormick et al. (eds.), *Digital Atlas of Roman and Medieval Civilizations*. References to any environmental or climate-related event in a historical or archival document, however, represent an initial stage of interpretation in light of the observer's/reporter's experience, or the assumptions of the informant(s). Since an observer's geographical location may reflect uncorroborated generalizations, such reports may offer only a tentative guide to actual climate conditions or events.

Historical scholarship is constantly developing a deeper understanding of the historical sources, addressing such issues as their ideological outlook; the literary and theological traditions that informed them; the geographical location of their composition; and, most importantly for the purpose of this article, their dating methods and chronological frameworks. Written sources often report events within a broad time frame that gives an (approximate) date of composition, for example. Such events are included in the table as a single entry to prevent distortion of the overall pattern, unless they were clearly repeated across a number of years (the catalogue in Telelis' 2004 work takes this distinction into account in its tabulation).

The availability of the various reports testifies not only to whether they were able to survive through the ages but also to the extent to which texts were produced during their era; written evidence from the period before the sixth century and from the period after the tenth century far outnumbers that from the intervening centuries. For a detailed methodological discussion, see Telelis, "Climatic Fluctuations in the Eastern Mediterranean and the Middle East AD 300–1500 from Byzantine Documentary and Proxy Physical Palaeoclimatic Evidence—a Comparison," *Jahrbuch der Österreichischen Byzantinistik,* LVIII (2008), 169–177, as well as his analysis by source category in *Meteorologika phainomena sto Vizantio* (Athens, 2004), II, 711–795, and the tabulation of results from that analysis (796–829).

Two concluding points: First, because many of the witnesses are from Constantinople—which in an eastern Roman context is only to be expected, especially after the seventh century—the locational bias is particularly strong. It does not preclude careful generalization, however, if we acknowledge the methodological considerations outlined in Telelis, *Meteorologika phainomena sto Vizantio,* mentioned above. Second, the causal relationship between events and their context is not always clear. The overall picture must take into account that several of the "famine" events were caused by political circumstances (such as a siege, for example, or wartime devastation).

● Drought events ■ Severe winter ◆ Winter-related? ▲ Flood/heavy rains

	DATE C.E.	EVENT	LOCATION	REFERENCE
●	300–301	Drought	Thrace	T3 S2
▲	300–311	Floods	N Anatolia	T2, T4
●	ca. 304–330	Droughts	Eastern Empire	T5
●	305–41	36 yr drought	Cyprus	T6
●	311–312	Drought and famine	E Anatolia, Caria	T8 S4
◆	319	Hail	NE Anatolia	T10
●	333	Drought, famine	Anatolia, Syria	T 14 S5
●	360	Drought	Anatolia	T27 S13
●	361–363	Drought	Anatolia	T29
■	364	Severe cold	Ankara	T39
◆	367	Hail	Constantinople	T41
	ca. 362–403	Famine	Cyprus	T32 S19
●	368–369	Drought	Anatolia (Phrygia, Cappadocia	T43 S21, S22
▲	370	Floods	NW Anatolia	T44
●	377–378	Drought	Anatolia	T51
▲	399	Floods	W Anatolia	T64
■	400–402	Heavy snows	Cilicia, SE Anatolia	T66
■	401	Heavy snows, extreme cold	Thrace and Black Sea area	T68 S38
◆	404	Large hailstones	Constantinople	T70
	ca. 400–420	Famine	Anatolia (Ankara)	T67 S39
	ca. 406–435	Famine	Constantinople area	T71 S56
	406–407	Famine	Cappadocia	S41
	409	Famine	Constantinople	T75 S43
▲	413	Floods	SE Anatolia	T76
●	418	Drought	Constantinople	T77 S47
	422	Famine	Pontus, Paphlagonia	T78 S48

■	423	Severe winter, heavy snows	Constantinople	T80
	423	Famine	Constantinople	T81
●	ca. 429–440	Drought, crop failure, famine	Anatolia (Cilicia), Syria,	T82
	431	Famine	Constantinople	T83 S51
▲	435–446	Floods	Bithynia	T89
■	437	Severe winter	Cappadocia, Galatia	T87
■	443	Severe winter, extreme cold	Constantinople	T88 S58
	446	Famine	Constantinople	T90 S60
◆	447	Hail	Constantinople	T91
	447	Famine	Constantinople	S61
	448–450	Grain shortage	Amaseia/Pontus	S62
●	ca. 453–457	Drought, famine	Phrygia, Galatia, Cappadocia, Cilicia	T94 S64 + S62, S65, S66
◆	461	Heavy rain, hail	Constantinople	T95
▲	467	Floods	NW Anatolia	T100
■	500	Extreme cold	SE Anatolia	T109
●	524	Drought, famine	Constantinople	T127 S87
▲	525	Floods	SE Anatolia	T128
●	527–528	Drought	Trebizond, Ankara	T132
▲	527–562	Floods	(W) Anatolia	T134–136, T139
●	ca. 527–613	Drought hailstorms	Ankara/Pessinous/Pergamon	T126, T138, T140
●	530	Drought	Constantinople	T142
	535	Grain shortage	Thrace	S91
▲	535	Floods	SE Anatolia	T128
	545	Grain shortage	Constantinople	S132
▲	547	Heavy rains, flooding	Constantinople	T159
●	ca. 552–559	Drought	Constantinople	T170, T174 S132
■	571	40 day freeze, Feb–March	Constantinople	T183
	581–582	Grain shortages	Western provinces of Eastern Empire	T190 S148
■	ca. 582–602	Floods after heavy snows	Galatia	T192
	602	Grain shortage	Constantinople	T193–194 S149

● Drought events ■ Severe winter ◆ Winter-related? ▲ Flood/heavy rains

	DATE C.E.	EVENT	LOCATION	REFERENCE
■	609–610	Heavy snow and bitter cold	everywhere	T211
■	623	Cold, harsh winter	Caucasus (not unusual)	T218
■	628	Harsh winter	E Anatolia	T220
■	667–668	Heavy snows	Amorium	T231
■	ca. 668–670	Severe winter, heavy snows	Anatolia, Constantinople	T232
■	698	Severe winter	L Van region	T240
■	717	Very harsh winter	Thrace, Constantinople, NW Anatolia	T249
	735	Famine	Affecting Arab army in Anatolia	S215
●	742–743	Drought	SE Anatolia/Syria	T257
■	763–764	Very severe winter, hail	Constantinople area	T271, 273
●	764	Drought	Constantinople	T272
●	766–767	Drought	Constantinople	T275
■	773	Severe winter	Armenia	T276
●	ca. 784–806	Drought	North-west Anatolia	T281
■	793	Severe winter	Pontus	T282
▲	794	Floods	NW/central Anatolia	T285
■	802	Cold, cloudy spring	Constantinople	T287
■	ca. 803–811	Rain, snow, floods	W. Anatolia	T289
▲	813	Floods	Thrace	T298
■	820	Heavy frosts	Constantinople	T302
	821–823	Famine (due to siege)	Constantinople	T304
■	822	Severe winter	Thrace	T308
■	ca. 829–842	Severe winter, famine	Constantinople	T312
■	833–836	Severe cold	Thrace	T317
■	835–836	Floods	Anatolia	T319
●	839	Drought, shortage of grain	Macedonia	T324

▲	841	Floods	SE Anatolia	T325
■	ca.842–868	Heavy snows	Macedonia	T328
◆	843	Hailstorms	E. Anatolia	T329
	843	Famine	Aegean	T331
■	851–852	Severe winter, extreme cold	Armenia	T334
■	852–853	Severe winter	Macedonia	T335
▲	867–886	Floods	S and NW Anatolia	T341, T346
▲	873	Floods	E Anatolia	T349
	ca. 879	Famine	Peloponnese	T351
■	880	Severe winter, extreme cold	Central/s. Anatolia	T352
	893	Unusually high winter temps	Constantinople	T355
	903	Famine	Anatolia	T362
■	921	Severe winter and cold	Peloponnese	T368
■	921–922	Extreme cold	Aegean/Crete	T369
■	927–928	Long severe winter	Constantinople	T373
	928–933/34	Famine	Thrace, Anatolia	T373
■	931	Very heavy snows	E. Anatolia	T376
■	952–953	Heavy winter snows	Greece	T389
■	956	Floods after heavy winter snows	NW Anatolia	T391
	952–959	7-year famine	Armenia	T388
■	960–961	Extreme cold, heavy rains	Aegean, Crete	T395
	963–964	Famine	SE Anatolia, Cilicia	T398
▲	967	Flooding	Constantinople	T402
■	969–04	Severe winter	Macedonia	T407
	976–992	Flooding and other events	Anatolia and Constantinople	T411
	996	Floods	Thessaly	T418
●	997	Drought	Greece, Peloponnese	T419
●	1005–19	Drought	Macedonia	T423
■	1010–11	Severe winter, ice, snow	Constantinople	T432
■	1021	Severe winter, snows	Armenia	T433

● Drought events ■ Severe winter ◆ Winter-related? ▲ Flood/heavy rains

	DATE C.E.	EVENT	LOCATION	REFERENCE
●	1025–28	4-year drought	Constantinople	T437
■	1031–32	Dry/wet winter, very cold	Cappadocia, Paphlagonia	T443
◆	1034	Hailstorms	Constantinople	T448
■	1035	Long, severe winter, v. cold	Black Sea area, E. Anatolia	T451
	1035–51	Famine	Thrace	T453
●	1037	Drought	Constantinople, Anatolia	T454
◆	1037	Hailstorms	Constantinople	T455
●	1040	Drought	Constantinople	T459
■	1046–47	Extreme cold	Armenia	T465
▲	1051	Flooding, torrential rain	W Anatolia	T468
	1053	Famine	W. Anatolia	T470
◆	1054	Hailstorms	Constantinople	T472
■	1054–55	Extreme cold	Armenia	T471, T474
■	1058–59	Long severe winter	Anatolia	T478
■	1068	V. severe cold	S. Anatolia, Cilicia	T485
■	1068–69	Heavy snows	Armenia	T486
	ca. 1070–1105	Famine	Thrace	T488
■	1071, 1072	Heavy snows	Macedonia	T489, T490
●	1081	Drought	Epiros	T493
■	1081	Snow and high winds	Ionian Sea area	T494
▲	1081	Flooding	Constantinople	T495
●	ca. 1085	Drought	Greece	T498
■	1091	Severe winter	Constantinople	T502
	ca. 1091–94	Famine	Armenia	T503
	ca. 1091–96	Famine	Thrace	T504
■	ca. 1091–1105	Severe winter	Greece	T505
	1096	Famine	Armenia	T511

●	1099–1100	Drought	SE Anatolia	T514
◆	1103	Hailstorms + flooding	SE Anatolia	T516
▲	1115–1116	Floods	SE Anatolia	T522
●	1116	Drought	W. Anatolia	T526
■	1134	Heavy snows	Constantinople	T534
◆	1134	Hail	Edessa	T535
■	1134–35	Heavy snows	E. Anatolia	T537
	1135	Mild winter	E. Anatolia	T539
■	1135–36	Severe winter	SE Anatolia	T540
■	1139	Severe winter	Cappadocia	T545
▲	1143	Floods	Cilicia/S. Anatolia	T551
▲	1147	Floods	E. Thrace	T552
◆	1148	Hail	Aegean	T554
■	1149–50	Severe winter	Thrace	T559
■	1150–51	Severe winter	SE Anatolia	T563
■	1158	Heavy snows	Central Anatolia	T569
	1164–65	Famine	S. Anatolia, Cilicia	T571
■	1167	Extreme cold	NE Anatolia	T572
■	1172–73	Severe winter	E. Med. Area, Anatolia, Armenia	T574
▲	1179	Floods	NW Anatolia	T585
▲	1205	Floods	Thrace	T599
■	1235–36	Severe winter	E. Anatolia	T601
■	1242	Severe winter	W Anatolia	T603
	1243	Famine	W Anatolia	T604
■	1256	Heavy snows, extreme cold	Thrace, Macedonia	T606 –T609
◆	1265	Hail	Constantinople	T611
■	ca. 1277–88	Severe cold	Thrace	T615
▲	1297	Floods	Constantinople	T622
	1298–99	Severe winter	Constantinople	T624
●	1301	Drought	Anatolia	T625
▲	1302	Floods	NW Anatolia	T626

● Drought events ■ Severe winter ◆ Winter-related? ▲ Flood/heavy rains

	DATE C.E.	EVENT	LOCATION	REFERENCE
	1303–09	Famine	Constantinople	T627
■	1321	Severe cold	Thrace	T631
■	1325–28	Severe winter	Constantinople	T633–634
■	1330	Floods	Cyprus	T635
■	1341	Heavy snows, severe winter, floods	Constantinople, Thrace	T639-T644
■	1342–43	Severe winter	Thrace	T646
▲	1342	Floods	Macedonia	T647
◆	1343	Hail	Constantinople	T648
◆	1344	Hail	Constantinople	T649
■	1346–47	Severe winter	Constantinople	T650
■	ca. 1346–53	Heavy snows	Macedonia	T651
■	1350	Extreme cold	Macedonia	T656–657
■	1352	Extreme cold	NW Anatolia	T659
■	1354	Extreme cold	Thrace	T663
■	1358–59	Severe winter, heavy snows	W Anatolia	T664
■	1373	Very severe winter	NE Anatolia	T667
■	1370s	Severe winters	Macedonia	T670
■	1403	Severe winter	W Anatolia	T682
	1403	Famine	W Anatolia	T683
●	1419	Drought	Macedonia	T686
■	1435–36	Heavy winter	S. Balkan region	T687–688
▲	1440	Torrential rain	Constantinople	T692
●	1445	Harsh summer heatwave	Constantinople	T694
▲	1453	Flooding	Constantinople	T697

NOTES In the reference column, "S" is Dionysios Ch. Stathakopoulos, *Famine and Pestilence in the Late Roman and Early Byzantine Empire* (Aldershot, 2004), plus the catalogue number; "T" is Ioannes G. Telelis, *Meteorologika phainomena sto Vizantio* (Athens, 2004), 2 v., plus the catalogue number.

APPENDIX 2: KEY DATES IN BYZANTINE HISTORY (300–1453 C.E.)

284–305	Diocletian and the tetrarchy; division of the Roman Empire
330	Constantinople established as capital of the Eastern Roman Empire
378	Defeat and death of Valens by Goths in battle of Adrianople
406–407	Germanic groups cross Rhine and enter the western Roman Empire in numbers
410	Visigoths sack Rome
527+	Justinian re-conquers most of Italy and North Africa
541+	Plague of Justinian
565–591	Wars with Persia
566+	Slavs begin to infiltrate across Danube frontier
611–620s	Central and northern Balkans fall from imperial control
614–619	Persians occupy Syria, Palestine, and Egypt
626–628	Heraclius defeats Persian forces in the east
634–646	Arab conquest leading to loss of Syria, Palestine, Mesopotamia, and Egypt
644+	Long-term Arab raiding in Byzantine Anatolia begins
668–669	First Arab blockade and siege of Constantinople
698	Carthage falls to Arabs and North Africa
717–718	Second siege of Constantinople
746+	Last major plague in Constantinople (prior to Black Death)
824+	Beginning of Arab conquest of Sicily and of Crete
860	Rus' (Viking) attack on Constantinople; mission to Chazars of St. Cyril
900+	Final loss of Sicily
958	Samosata on R. Euphrates captured, ending Arab invasions of Anatolia
1054	Selçuks take Baghdad; Norman power in southern Italy expanding
1071	Romanos IV defeated and captured at Mantzikert by Selçuks; beginning of Turkish occupation of central Anatolia, ending the Byzantine "golden age"; Normans take Bari
1097+	First Crusade; Selçuks defeated
1146–1148	Second Crusade
1203–1204	Constantinople sacked by Fourth Crusade; establishment of Latin empire 1204–1205; successor states in Nicaea, Epirus, and Trebizond established
1280–1337	Ottomans take most remaining Byzantine possessions in Anatolia
1347	Black Death reaches Constantinople
1365	Ottomans take Adrianople, which becomes their capital
1397–1402	Bayezit I besieges Constantinople but withdraws after Timur defeats Ottomans at battle of Ankara (1402)
1422	Murat II lays siege to Constantinople
1453	Final Ottoman siege of Constantinople; city falls on May 29th