The Role of Climate Change in the Decline of the Roman Empire

Capstone Paper

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Every historian has a vested interest. "The Decline and Fall of the Roman Empire" was not about the Roman but the British Empire. What price the truth?[1]

The causes for the decline and collapse of the Roman Empire have long preoccupied historians, but until very recently, few Roman historians have paid any attention to the role of the most devastating and definitive cause: adverse climate change.[2] Tacitus blamed corruption and moral decadence; Christian historians attributed the decline to the wrath of God; Edward Gibbon pointed to barbarian invasions and Christianity; and modern historians have identified over 200 possible causes.[3] More startlingly, historians rarely mention one of the most significant environmental disasters in human history: the climate catastrophe of 536 CE. This event—triggered by massive volcanic eruptions that filled the sky with ash and reduced solar energy around the world—caused the Dark Age Cold Period, crop failures, famine, and plague. This incident, more than any other, ended any chance the Roman Empire had to reconstitute itself after the barbarian invasions of the fourth and fifth centuries.

While decadence and invasion certainly played a part in Rome's decline, solar cycles, violent volcanic activity, and cooler climate-loving bacteria also played significant roles. Because both ancient and many modern historians rarely knew and barely understood these silent killers, they continued to blame the usual suspects. Who could fault them? Nearly five centuries after the dawn of the Age of Science, however, scholars have no excuse for not re-examining

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[1] Peter Greenaway, interview by Gary M. Kramer, February 4, 2016, www.salon.com.
[2] Julia Adeney Thomas, "Comment: Not Yet Far Enough," *American Historical Review* 117 (2012): 794-803.
[3] Demandt famously listed 210 causes for the fall of Rome, and the vast majority are entirely plausible. Among them, he lists "climatic deterioration." See A. Demandt, *Der Fall Roms. Die Auflösung des römischen Reiches im Urteil der Nachwelt* (Munich: C. H. Beck, 1984), 695.

mounting evidence. It is time to consider the data that scientific studies produce about the role of climate change in history and to revise the narrative that many historians continue to ignore.[4]

Evidence derived from new scientific methods—unavailable to previous historians—now reveals that environmental issues played a significant role in the rise and decline of the Roman Empire in both the West and the East. Adverse climatic change in Europe, North Africa, and even Southwest and Central Asia contributed not only to Rome's inability to feed its population (and the Western army by 444 CE), but also to the westward migrations of the Huns, the Goths, other Germanic peoples, and later the Arabs.[5] Finally, bacteria-carrying fleas on vermin that thrived under ideal climate conditions set off a time bomb that wiped out as much as half of the Mediterranean's estimated 75 million population in the early sixth century.[6]

In an age of rapid climate change and states in collapse or decline because of it, it is more important than ever to understand the mechanisms of environmental catastrophe on human society and its ability to adapt to it. Modern failed states like Syria, Afghanistan, and Yemen offer bitter lessons of what happens when states are unable to understand the relationship between human societies and their natural environments. The Roman Empire offers one of the best examples of how environmental catastrophe served as a catalyst for disease and how these two forces together were catalysts for a failing state. To better comprehend the tragedy of the current situation, it is useful to start by reviewing what historians have said over the centuries about the causes of the decline of Rome and climate change.

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[4] Harper's *Fate of Rome* is the only scholarly Roman history to consider climate change at any length. There is nary a word from the others. That said, there are many books on climate that address Roman history as well as many that address the role of climate in the decline of other civilizations such as John L. Brooke's *Climate Change and the Course of Global History*.

[5] Peter Heather, "The Huns and the End of the Roman Empire in Western Europe," *The English Historical Review* 110, no. 435 (February 1995): 28-29.

[6] Kyle Harper, *The Fate of Rome: Climate, Disease, and the End of an Empire.* (Princeton: Princeton University Press, 2017), 115.

The Historiography of Rome's Decline

The historiography of the decline of the Western and Eastern Roman Empire breaks down into three major approaches. The first trend was one of denial: many of the original authors who witnessed Rome's decline first-hand had little sense that the empire approached its doom. The second approach, offered by apocalyptic Christians, saw historians more resigned to Rome's justified fate and took a providential view of the whole event since Rome's fall might accelerate the second coming of Christ. After the Renaissance, scholars revived the first approach, tracked the lives of the great men of the age through the primary sources, and recounted how their lack of moral courage as well as barbarian invasions contributed to decline. The third approach is an interdisciplinary one that first gained prominence in the mid-twentieth century when scientists, archaeologists, and historians who studied the natural environment looked for how it might have influenced the Rome's destiny.

The first historiographic approach was a secular one that found its inspiration in the Attic tradition of Herodotus and prevailed from the decline of the Republic (ca. 27 BCE) to the ascension of Emperor Constantine (306 CE). Post-Renaissance scholars revived this methodology when the Christian apocalyptic approach fell out of favor. These primary sources offered a balanced query that explored why the ship of state (a favorite metaphor of Ammianus Marcellinus and other Romans) seemed rotten while on perilous seas.[7] The conclusions varied but boiled down to a combination of moral corruption, political unrest, and barbarian invasions.

Tacitus (d.120 CE), arguably Rome's best historian, documented the climate and agriculture of various regions in his *Annales* but lacked historical data to understand the significance of climate change. He focused his attention on the corruption of the governing

[7] Gavin Kelly, "Ammianus and the Great Tsunami," *Journal of Roman Studies* 94 (2004): 155, 160-164.

classes as senators increasingly put personal interests above those of the common good. He expressed trepidation over the Senate's propensity to give up its freedom of speech to tyrants who bought them off. The Senate's obsequiousness upset the balance of power and often put decision-making into the hands of the worst elements of society.[8] His most celebrated quote summed up his concern: "They plunder, slaughter, and steal in the name of the Empire; where they make a wasteland, they call it peace."[9] Tacitus vividly illustrated the environmental destruction of Roman warfare and had more respect for Germanic harmony with nature.

Roman scholars Cato the Elder (d. 149 BCE), Varro (d. 27 BCE), and Columella (d. 70 CE) adhered to that same methodology but also wrote about the relationship between climate and agriculture. Greek botanist Theophrastus (287 BCE) and Roman natural historian Pliny the Elder (d. 79 CE) offered some of the first anecdotal evidence of the Roman Warm Period or Roman Climate Optimum (ca. 200 BCE to 150 CE) in the form of cold-loving beech trees that had retreated from Rome into the cooler Apennine Mountains to escape the heat. Pliny and Roman historian Livy (d. 17 CE) both commented on the now-vanished forests and elephants in barren northwestern Africa.[10] The Roman geographer Ptolemy (d. 170 CE) corroborated Pliny's descriptions of a more verdant North Africa and noted regular thunderstorms eleven months of the year in the now bone-dry summers of his hometown Alexandria.[11] The Greek historian

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[8] Adrian Goldsworthy, *How Rome Fell: Death of a Superpower* (Cornwall, UK: Yale University Press, 2010), 83. Goldsworthy shares the belief of Tacitus that the decline of the senatorial governing class contributed enormously to the fall of Rome.
[9] Publius Cornelius Tacitus, *De Vita et Moribus Iulii Agricola*, 30.
[10] Titus Livius Patavinus, *Ab Urbe Condita* 7-10. trans. G.P. Goold and B.O. Foster, Loeb Classical Library (Cambridge, MA: Harvard University Press, 1975).
[11] Claudius Ptolemaeus, *Ptolemy's Geography: A Brief Account of all the Printed Editions Down to 1730, With Notes on Some Important Variations Observed in That of Ulm 1482, Including the Recent Discovery of the Earliest Printed Map of the World yet Known* (Laverngne, TN: Andesite Press, 2009).

Strabo (d. 23 CE) listed the widespread locations of vineyards and olive trees in areas all over the Mediterranean that saw almost none by the seventh century.[12]

There are many testimonies that suggest Rome's climate and agricultural output declined before its politics did. For example, ancient historians have documented plentiful precipitation in Italy between 200 BCE and 174 CE when there were 22 floods of the Tiber, but only two during the next three centuries.[13] After ca. 175 CE, primary sources increasingly report drought, failed crops and food crises—all problems not seen for generations previously. Still, anecdotal record-keeping prevented the early authors from noticing that climate change was a viable threat to society. In fact, they rarely recorded the correlation between rainfall, agricultural productivity, and subsequent economic and cultural development.

Imperial overreach also troubled the classical writers. For example, Cassius Dio (d. 235 CE) traced the decline to Marcus Aurelius' decision to inaugurate a tradition of filial succession rather than a choice of the most capable.[14] For Dio, the ascension of Commodus marked the beginning of a long line of corrupt and incapable emperors that lasted for much of the third century.[15] Commodus' reign probably marks the end of Rome's Golden Age, but the Empire's final days were still far off.

Other historians of this approach, like Byzantine scholar Zosimus (d. 520 CE), blamed Christianity for the decline of the Roman Empire. Specifically, they often targeted Constantine's ascension as the beginning of the end.[16] The alleged lack of esteem for the martial virtues among

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[12] Strabo, *Rerum Geographicarum Libri XVII, 5: Graeca Ad Optimos Codices Manuscriptos Recensuit, Varietate Lectionis Adnotationibusque Illustravit,* (London: Classic Reprints, 2018).
[13] H. H. Lamb, *Climate History and the Modern World, 2nd Edition* (New York: Routledge, 1997), 156-170.
[14] Cassius Dio, *Historia Romana,* 71.33.1. trans. Earnest Cary, Loeb Classical Library (Cambridge, MA: Harvard University Press, 2001).
[15] Alfody, "The Crisis of the Third Century as Seen by Contemporaries," 94-111.
[16] Zosimus, *Historia Nova,* 57 (London: Classic Reprints, 2018).

Christians in favor of so-called effeminate virtues was a popular theme.[17] The Roman Goth historian Jordanes (d. 575 CE) blamed the terrible Huns who forced the poor Goths out of their ancient homeland to seek refuge in the Roman Empire, but he knew nothing of the climatic changes that drove the Hunnic westward migration.[18] Procopius of Caesarea (d. 554 CE), an aide to General Belisarius, blamed the decline of Rome on the costly wars against the Goths in Italy, the Vandals in North Africa, and the Persians in the East. He is the last of the secular historians, and the historiography after him gradually moved towards a teleological history that saw the hand of God in the decline.[19]

Christian historians in late Antiquity made up the majority of the second methodology: the Christian apocalyptic approach. They agreed that the ship was rotten and interpreted various political and cosmic events as providential signs that the ship was destined to smash itself on the rocks and sink. Since Christians believed that their kingdom was "not of this world," its demise might herald the ultimate triumph of the Church.[20] The believers viewed the famines and plagues as signs of divine wrath and imminent judgment rather than indicators of poor agro-planning or deficient hygiene.

This Christian approach had a strong providential and occasionally apocalyptic tone. It found its first, most articulate voices in St. Augustine (d. 430 CE), Ammianus Marcellinus (d. 400 CE), John of Ephesus (D. 588 CE), and even Boethius (d. 524). Of course, St. Augustine was no secular historian as he suffused a supernatural meaning onto the eventual collapse that influenced almost a millennium of writers after him. In Augustine's *City of God*, pride ruled the

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[17] Arthur E.R. Boak, "Manpower Shortage and the Fall of the Roman Empire in the West," *The Jerome Lectures: Third Series* (2005) (Ann Arbor: The University of Michigan Press, 1955), 117, 129.
[18] Jordanes, *Historia Gestae.* Trans. Charles Mierow (Middletown, DE: Forge Books, 2018).
[19] J.A.S. Evans, "The Attitudes of the Secular Historians of the Age of Justinian towards the Classical Past," *Traditio* 32, (1976): 353-358.
[20] Jn 18:36.

temporal "city of man" (Rome), whereas love governed the eternal city (the Church), and believers should pin their hopes on the latter. While Augustine, whose later days witnessed the Vandal invasion and sacking of North Africa, lamented the decline of the temporal empire he loved, he viewed it as part of the divine plan to bring about the heavenly kingdom.[21] Similarly, the Neoplatonist philosopher Boethius, in *The Consolation of Philosophy,* saw earthly affliction as an aid to direct oneself properly to the next life without the chain of earthly fortune: "Good fortune seduces weak men away from the true good through flattery, but misfortune often turns them around and forcibly leads them back to the true good."[22] Many Christians adopted this worldview.

Ammianus Marcellinus blamed the decline on the invasions by the Huns and Goths.[23] While slightly sympathetic to the Goths whom he viewed as victims of the advancing Huns, Ammianus too allowed for no consideration of what might have prompted the fierce Huns to abandon their ancestral homeland.[24] His chronology of the Gothic War described the manpower shortage in the army and noted how it compelled the legal settlement of more barbarians on Roman soil.[25] In addition to the decline of the army, Ammianus pointed to the excessive taxation and the subsequent disintegration of the mercantile class as primary causes for Rome's decline.[26] Ammianus' work reflected a common worldview held in Late Antiquity that natural and political

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[21] Augustine, *De Civitate Dei contra Paganos.* 1-5. trans. R.S. Pine-Coffin, Penguin Classics (New York: Viking Penguin Inc., 1984).
[22] Boethius, *The Consolation of Philosophy,* 2.8. trans. Richard Green (New York: The Bobbs-Merrill Company, Inc., 2006).
[23] Otto Maenchen-Helfen, *The World of the Huns*. ed. Max Knight (Berkeley: University of California Press, 1973).
[24] Bryan Ward-Perkins, *The Fall of Rome and the End of Civilization*. New York: Oxford University Press, 2005. Such an insight might have been useful to posterity when drought-ravaged Avars, Arabs, and Turks repeated this westward migration, but climate change had not worked its way into the mainstream narrative yet. See Etienne De La Vaissiere, "Central Asia and the Silk Road," in *Oxford Handbook of Late Antiquity,* ed. S.F. Johnson (New York: Oxford University Press, 2012), 142-169.
[25] Walter Scheidel, "Measuring Sex, Age, and Death in the Roman Empire: Explorations in Ancient Demography," *Journal of Roman Archaeology* 21 (1996): 93-112.
[26] Ammianus Marcellinus, *Res Gestae,* 31. Latin Edition first published 353-378, Reprinted (Denham Springs, LA: Cavalier Classics, 2016).

disasters served as warnings of divine displeasure with human activities, as when the earthquake and tsunami of 365 portended the disastrous Battle of Adrianople in 378.[27]

The historian Evagrius Scholasticus (d. 594 CE) defended Christianity against accusations by pagans (like Zosimus) that its ascendancy had contributed to decline. He pinned the decline primarily on the long wars with Persia that further bled the manpower and drained the treasury.[28] St. Gregory of Tours (d. 593 CE), who wrote on behalf of the Merovingian Court, became one of the first to interpret all these climatic downturns, Haley's comet, and falling empires as signs.[29] Many Christians could find no meaning in these events other than to conclude that all the violence and sin that characterized the onset of the Dark Ages had *caused* God's wrath to come down upon Earth.[30]

Pope St. Gregory the Great's (d. 604 CE) sermons called for acts of public penance, fasting, and processions of litany to avoid the plague.[31] When the Christian Carolingians overthrew the Church-deposed Merovingian dynasty in 751 (the year after the last wave of Justinianic Plague), they appeared to establish a serendipitous link between orthodoxy and plague-avoidance.[32] The next several hundred years of medieval thought continued this hermeneutic. It only began to wane with the dawn of the Renaissance and a philosophical rejection of a default to supernatural causes and interpretations of such events. This revived approach believed it was the task of the theologian—not the historian—to give supernatural meaning to these events.

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[27] Kelly, "Ammianus and the Great Tsunami," 141-167.
[28] Evagrius Scholasticus, *Εκκλησιαστικησ 'ιστοριασ*, Reprint edition (Charleston, SC: BiblioLife, LLC, 1935).
[29] Joel D. Gunn, ed. *The Years without Summer: Tracing A.D. 536 and its Aftermath* (Oxford: BAR International Series, 2000), 13.
[30] Gregory of Tours, *Historiæ Ecclesiasticæ Francorum Libri Decem*, I. Latin Edition (Charleston, SC: Nabu Press, 2012).
[31] Lester K. Little, ed. *Plague and the End of Antiquity: The Pandemic of 541-750* (New York: Cambridge University Press, 2007), 11-12.
[32] Ibid., 25.

After the fall of Constantinople to the Turks in 1453 and with the benefit of hindsight, scholars saw that the Christians were premature in the assumption of a doomed ship and drowned crew and revived the secular approach. Their methodology offered a more detached reflection of the original theories. It is ironic, however, that although this approach emerged out of the Renaissance and the Age of Science, it incorporated little scientific data into its historical method. While much of climatology is over a century old, it only entered the mainstream historical narrative in the last few decades and remains a bit of an outlier.

Edward Gibbon, Barthold Georg Niebuhr, and Henri Pirenne best personify the historians of the Age of Reason. Contemporary scholars, however, often fault their preoccupation with the lives of the "great men" and the neglect of much else.[33] While Gibbon's *Decline and Fall of the Roman Empire* (published between 1776 and 1789) mentioned the cold weather in Germania and famished Goths, he did not explore climate change as a contributing cause to decline. For Gibbon, who echoed many of the primary sources upon whom he heavily relied, the decline had many causes, among them weak moral leadership and the rise of Christianity with its otherworldly (i.e., monastic) preoccupations.

Gibbon offered little by way of original material. He and his generation carefully selected the most reliable sources, scrutinized them through the eyes of time, and objectively decided which portions merited mention in a post-medieval world. Many historians of the Enlightenment era scorned their Late Antiquity Christian counterparts (especially John Malala) as apocalyptic sensationalists and slaves to a deterministic agenda in which the Church might eventually

[33] Barthold Georg Niebuhr, *History of Rome,* trans. William Smith and Leonhard Schmitz (London: Classic Reprints, 2016). The few women mentioned, like Cleopatra, rarely received a fair hearing. See the first chapter, "That Egyptian Woman," in Stacy Schiff's *Cleopatra: A Life* (New York: Back Bay Books, 2010).

emerge victorious.[34] The disenchantment with the Church after the Protestant Reformation eroded that naïve worldview. Gibbon sought to understand the importance of Rome not only for non-Catholic Christians but also for the rising British Empire that was so eager to mimic the success of Rome while avoiding her sad fate.

Gibbon's historiography focused on the external dynamics like barbarian invasions, but he never asked what climate features might have caused famine, nor did he have sufficient evidence to answer the question. He tended to view the failure as a long and slow downward spiral rather than a cyclical process of demographic decline and periodic rejuvenation in which nature (in the form of climate, disease, and earthquakes) dealt blow after blow from which both the Western and the Eastern Empires increasingly lacked the vigor to recover.[35] This historiography diminished the importance of the Mediterranean environment, and it suffered from a blind spot in its near-exclusive focus on anthropocentric causes for the rise and decline of civilizations.

By the late twentieth century, historians started to realize that non-anthropocentric reasons such as climate disaster and disease also played significant roles in the long, downward spiral of cultures into the abyss.[36] To understand the role that *non*-anthropocentric causes played in these declines, scientists turned to new methodologies such as examinations of tree rings, speleothems, marine varves, ice cores, pollen samples, isotopes, tephra analysis, bones, and even bugs.[37] Comparisons of recent well-documented data (like rainfall, temperature, sunspots, or

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[34] Peter Sarris addresses this modern contempt candidly. He writes, "It is perhaps worth pausing to consider that…our sources lived through the events they described, and we did not. …we ought, perhaps to give them the benefit of a doubt." See Peter Sarris, "The Justinianic Plague: Origins and Effects," *Continuity and Change* 17, no. 2 (2002): 169-182.
[35] Edward Gibbon, *The Decline and Fall of the Roman Empire,* II (New York: The Modern Library, 1985).
[36] Kenneth L. Gage et al. "Climate and Vectorborne Diseases," *American Journal of Preventative Medicine* 35 (2008): 436-450.
[37] Harry Kenward, "Do Insect Remains from Historic-Period Archaeological Occupation Sites Track Climate Change in Northern England?" *Environmental Archaeology* 9 (2004): 47-59.

vegetation) with precise measurements of tree or speleothem growth bands, have allowed scientists to create "proxy data" for accurate models of ancient climate.[38] This information offers unique insights into precipitation, temperature, solar irradiance, and even Antiquity-era anthropogenic activity that helps fill the gaps that the older historiographical approaches of megalomania (like Plutarch and Petrarch) often neglected.[39]

This scientific approach does not pass judgments on the contribution of Gibbon et al: they made remarkable contributions based on the limited information available to them at the time. This interdisciplinary historiography, however, integrated new scientific data as it arrived, and thereby eliminated the Enlightenment hubris that ascribed civilizational failure to the fathers of Rome and Constantinople at the expense of ignoring the heavy hand of Mother Nature.

Indeed, the third historiographical approach has emerged to fill this void. It was a child of the green revolution that sought to determine how the environment might have played a role in the past and asserted that scientists needed to consider the natural causes of events previously interpreted as heavenly signs. Since the 1960s, several new scientific methodologies have played a crucial role for the scholars dedicated to deciphering this enigmatic part of Roman history. In the past two decades, these interdisciplinary methodologies have made rapid progress in accuracy and consistency. For example, recently acquired proxy data from sources like tree rings and ice cores suggests that the Roman Empire ascended during a warm and humid climate but began its decline ca. 150 CE when the climate became colder, drier, and less stable.

This interdisciplinary method is likely to emerge as the prevailing historiographical approach even if some notable Roman historians continue to disregard the role that climate might

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[38] J. Beer et al. "The Role of the Sun in Climate Forcing," *Quaternary Science Review* 19 (2000): 403, 408.
[39] Plutarch, *The Lives of the Noble Grecians and Romans.* trans. John Dryden (New York: The Modern Library, 1965). Francesco Petrarch, *De Viris Illustribus,* Silvano Ferrone, ed. (Firenze: Casa Editrice Le Lettere, 2003).

have played. This interpretation sees climate and disease as threat magnifiers to other problems but does not see them as the sole cause. Undoubtedly, this multi-disciplinary approach is the best way forward.[40]

Climatology plays a significant role in the historiography of the declines of *other* civilizations. Historians rely extensively on scientific data showing a drop in solar energy levels and precipitation in 2200 BCE to help explain the collapse of the Akkadian Empire, the Old Egyptian Kingdom, the Harrapan Civilization of the Indus River Valley, and early Chinese civilization in the Yangtze River Valley. Most historians accept that climate change played a significant role in the collapse of Bronze Age civilizations ca. 1200 BCE.

Global drought, crop failure, mass starvation, and subsequent economic and political turmoil rocked many other empires in the sixth century and figure into the current national narratives. Chinese historians in 536 CE recorded accounts similar to the Romans of summer frosts, drought, famine, and demographic decline.[41] Chinese scientists corroborate these climate events when they note that thirteen of the 20 coldest decades in the Altai dendrochronological record fall in the sixth and seventh centuries.[42] Modern historians are integrating this science of climate change into the ancient narrative of harvest failures, hunger, and food riots that sparked

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[40] A rival sub-branch of this historiography is a deterministic approach—much like the old Marxist approach—that suggests that climate and environment determine destiny. It minimizes the causes of the decline of Rome discussed in the first three approaches. This approach has gained popularity among those who believe that anthropogenic activity threatens the planet with destruction. Most historians are highly critical of this popular approach that treats climate change as a zeitgeist, and it has not stood up well to scrutiny. There are few advocates of this approach among Roman historians, but this historiography is prominent in many popular histories and anthropologies that prefer a Hegelian dialectical or Braudelian monocausal approach to historical questions.

[41] Buntgen, "Cooling and Societal Change," 6. Climate helped trigger the second wave of westward-moving steppe peoples of Central Asia (Turks and Avars) in 551.Not all historians accept the view that climate change prompted migrations from Central Asia, but many, such as Stathakopoulos, reached those conclusions before much of the most compelling evidence was available. See Dionysios Stathakopoulos, "The Justinianic Plague Revisited," *Byzantine and Modern Greek Studies* 24 (2000): 256-276. Rosanne D'Arrigo, "Spatial Response to Major Volcanic Events in or about AD 536, 934, and 1258: Frost Rings and other Dendrochronological Evidence from Mongolia and Northern Siberia: Comment on R.B. Stothers, 'Volcanic Dry Fogs, Climate Cooling, and Plague Pandemics in Europe and the Middle East'," *Climatic Change,* 42 (1999): 239-246.

[42] Buntgen, "Cooling and Societal Change," 4-5.

the political upheaval among people who viewed such events (much like their Christian counterparts in the West) as signs that the Emperor had fallen out of favor with heaven and was, therefore, a fair target for removal.[43] Adverse climate change contributed to regime change that led to the break-up of Northern Wei China, the decline of Chinese Buddhism, and the eventual unification of China.[44] Chinese historians tie subsequent raids and invasions from Turkic tribes to the country's vulnerability in the decades after the climate catastrophe of 536 CE.

Droughts in Mongolia in the 540s helped drive western Turkic tribes to the Black Sea basin where they arrived in 625 CE. Once a favorable climate returned to Asia in 630, the Chinese counterattacked and defeated the eastern Turkic confederation. The western Turks allied themselves with the Byzantines against the Persians, but this proved only a temporary solution and an eventual Trojan horse for the former.[45] The Byzantine Empire had a brief resurgence in the early tenth century, but after the Battle of Manzikert in 1071 CE, the Turks became the dominant power in the eastern Mediterranean and finally captured Constantinople in 1453. A millennium of decline and migration triggered by climate change and disease had served as the catalyst.[46]

As historian Hubert Robichaux discusses in "The Maya Hiatus and the A.D. 536 Atmospheric Event," the Mayans in the Western Hemisphere experienced a similar hiatus in

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[43] Jie Fei and Jie Zhou, "The possible Climatic Impact in China of Iceland's Eldgja Eruption Inferred from Historical Sources," *Climatic Change 76 (2006): 443-457.*

[44] Margaret Snow Houston, "Chinese Climate, History, and State Stability in AD 536," in *The Years without Summer: Tracing A.D. 536 and its Aftermath,* ed. Joel D. Gunn (Oxford: BAR International Series, 2000): 45-54, 71. The Wei Empire broke up in 534, so it would have been the pre-cooling of the early 530s rather than the catastrophic cooling of the decade after 536 that contributed to its collapse.

[45] The term "Roman" refers to the entire Empire up until the seventh century after which the term Byzantine Empire prevails.

[46] Brooke, *Climate Change,* 348. While this theory is gaining ground among contemporary historians, some historians do not accept this argument and take a minimalist perspective with respect to the role that the Justiniac Plague played in the catastrophic decline of the Eastern Empire after 542. See Lee Mordechai, "Rejecting Catastrophe: The Case of the Justinianic Plague," *Past & Present* 244, no. 1 (August 2019): 3-50.

their cultural development for nearly two centuries after 536 CE.[47] After a brief revival in the eighth century, rapid climate change returned, and a second drought contributed to the collapse of their capital city of Teotihuacán beyond recovery with a loss of several million lives.[48] Since archaeological and scientific evidence forms the bulk of the evidence for that narrative, historians spill little ink ruminating about the moral character of the Mayan leadership. Roman emperors received no such reprieve from climate change.

Finally, the mighty Axumite Empire in modern Ethiopia and Yemen—that in 524 CE was strong enough to deploy 120,000 troops into Arabia to subdue the Jewish Himyarite Kingdom—collapsed a decade later following drought, famine, and plague that followed the climate catastrophe of 536 CE. A few generations after that, Axum lacked the manpower to defend itself against a small band of Arab raiders.[49] African and Asian historians have shown less reluctance to integrate climate data to explain how colder temperatures and reduced evaporation in Arabia ensured abundant vegetation for surplus camel populations needed to transport the Islamic conquerors of Axum, the Levant, and North Africa in the seventh century.[50] Indian historians note that the Gupta Empire peaked just before the mid-sixth century climate catastrophe and then went into decline.

In the modern era, Bruce M.S. Campbell, in *The Great Transition: Climate Disease and Society in the Late-Medieval World* made a strong case that climate change and disease helped turn the late medieval world into its early modern form ca. 1400 CE.[51] Geoffrey Parker, in

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[47] Paul Mayewski et al, "Holocene Climate Variability," *Quaternary Research* 62 (2004): 252.
[48] Hubert Robichaux, "The Maya Hiatus and the A.D. 536 Atmospheric Event," in *The Years without Summer,* ed. Joel D. Gunn (Oxford: BAR International Series 872, 2000), 45-53.
[49] Peter R. Schmidt, "Are there African Traces of the A.D. 536 Event?" in *The Years without Summer,* ed. Joel D. Gunn (Oxford: BAR International Series 872, 2000), 79-85.
[50] Buntgen, "Cooling and Societal Change," 231-236.
[51] Bruce M.S. Campbell, *The Great Transition: Climate, Disease, and Society in the Late-Medieval World* (New York: Cambridge University Press, 2016).

Global Crisis: War, Climate Change and Catastrophe in the Seventeenth Century, linked the Little Ice Age with political upheaval and warfare.[52]

The plethora of written sources in the case of Rome, however, has left many historians stuck in dusty libraries filled with ancient records, reluctant to open the windows and let in fresh air. This tendency is all the more lamentable because when historians interrogate the primary sources properly and integrate natural events into previous historiographies dealing with Rome's decline, the narrative does not change spectacularly. Yet it becomes easier to understand questions like: *why* did the economy falter, *why* did the Huns and Goths move west, and *why* was the plague so devastating? These *whys* can then illuminate the most significant question: why did the Roman Empire decline?

The Third Century: Millennial Birthday

The Roman Empire emerged as a superpower at the warmest, most humid, and most stable time in Mediterranean history—the "Roman Climate Optimum" (RCO) —that lasted from roughly 200 BCE until 150 CE. There were few significant volcanic eruptions between 279 BCE and 535 CE that negatively influenced the region's climate.[53] Gibbon, writing in the late eighteenth century, described Roman life in the mid-second century as the happiest and prosperous age in human history. The sun smiled on Rome for nearly 400 years, which we now know is because solar irradiance peaked between 200 BCE and 135 CE and fostered its rise.

[52] Geoffrey Parker, *Global Crisis: War, Climate Change and Catastrophe in the Seventeenth Century* (Cornwall, UK: Yale University Press, 2013).
[53] Manning, "The Roman World and Climate," 155. Mount Vesuvius' eruption in 79 CE was obviously cataclysmic for the residents of Pompeii and Herculaneum, but as a likely VEI-5 eruption, it was climatically ineffective as a long-term solar forcing agent. Its re-eruption in 472 had an impact on the climate, but only lasted a year or so.

As the reign of Marcus Aurelius ended, however, that same sun turned on Rome. German barbarians threated Rome from the north, climate change made food shortages more common, and the quality of Roman government declined. Still, few thought that these problems were beyond repair. The Empire stumbled along despite the growing challenges.

During the celebration of Rome's millennial birthday in 248 CE, Romans marveled that the Empire had lasted so long and endured so many cycles of expansion and contraction.[54] They noticed, however, that their political and agricultural problems seemed to have increasingly unmanageable solutions.[55] The government found itself unable to maintain the critical infrastructure of the increasingly fetid cities that had become cesspools for parasitic worms, bacteria, and disease. For all the success that the Romans brought with their "aqueducts, roads, irrigation, education, public order, peace, and wine," Rome's tightly packed and squalid streets were breeding grounds for a host of infectious bacteria that waited for the right moment to unleash the full power of their fury.[56] If one served in the Roman Legion, gifted surgeons performed remarkable feats of medicine (unequaled until the seventeenth century) to help heal ghastly wounds of battle. For the average Roman, however, typhus, diarrhea, and dysentery were often fatal conditions.

The Empire in the East, where these political and climatic problems were less severe, continued to thrive. In the West, barbarian invasions, a reeling economy, debased silver coinage, and inflation magnified the political crises.[57] The colder climate brought the so-called Cyprianic Plague that raged from 249 to 262 CE took a particularly devastating toll on the Empire's center

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[54] Kyle Harper, "The Environmental Fall of the Roman Empire," *Daedalus, the Journal of the American Academy of the Arts and Sciences* 10 (2016): 5-15.
[55] Rosen, *Civilizing Climate,* 177-180.
[56] Reg, the tongue-tied leader of the People's Front of Judea in Monty Python's *Life of Bryan* might have challenged the assertion that the Romans had brought "public health" among the benefits on conquest. In the end, Roman neglect of many aspects of public health contributed significantly to their undoing.
[57] Little, *Plague and the End of Antiquity*, 127-132.

of learning: Alexandria.[58] Nevertheless, Rome was not doomed to failure because of this first round of climate-induced calamities.

Some climate instability followed in the third century that paralleled and even triggered many of the economic and political crises.[59] The decline of trade, economic depression, increase in the money supply, and low tax rates led to revenue crises that compelled the raising of taxes (beyond anything seen in the early Empire) and thereby contributed to further economic slowdown.[60] As resources like water became scarcer, the government gave more power to those who controlled them, especially in areas where people were particularly reliant on natural resources of the livelihoods. In Roman North Africa, for example, the governors increasingly struggled to promote an equitable distribution of water resources and often did more to promote the privileges of the well-connected than to promote the general welfare.[61] This political development, combined with Emperor Diocletian's land reforms, created a pre-feudal land-holding class. These landholders grew profitable crops like grapes, olives, chestnuts, walnuts, peaches, prunes, and pistachios. The increasingly alienated and often enslaved peasant class (*coloni*) were less invested in the success of the state than the farmer-soldiers of the Punic War era were.[62]

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[58] Kyle Harper, "Pandemics and Passages in Late Antiquity: Rethinking the Plague of c. 249-270 Described by Cyprian," *Journal of Roman Archaeology* 28 (2015): 228. Dionysius claimed Alexandria lost 62% of its urban population.
[59] C. Martin-Puertas et al. "Late Holocene Climate Variability in the Southwestern Mediterranean Region: An Integrated Marine and Terrestrial Geochemical Approach," *Climate of the Past* 6 (2010): 811-812.
[60] Keith Hopkins, "Taxes and Trade in the Roman Empire (200 B.C.-A.D. 400)," *The Journal of Roman Studies* 70, (1980): 101-125. One sign of the decline in maritime trade is the relative lack of sunken merchant vessels after the third century. Peter Sarris, *Economy and Society in the Age of Justinian* (Cambridge: Cambridge University Press, 2006), 200-227.
[61] Anna Leone, "Water Management in Late Antique North Africa: Agricultural Irrigation," *Water History* 4 (2012): 128; Arlene Miller Rosen, *Civilizing Climate: Social Responses to Climate Change in the Ancient Near East* (New York: Alta Mira Press, 2007), 154-159.
[62] Haldon, *The Empire that Would Not Die,* 225-228, 235. Heather, "The Huns and the End of the Roman Empire," 21-29, 39.

Tree rings and ice cores reveal that solar irradiance took a downturn until ca. 305 and then increased until ca. 370 CE.[63] This climate stability contributed to agricultural prosperity in the East and aided Constantine's revival in the early fourth century.[64] However, global climate variability in the 330s—caused by an abrupt change in the El Niño Southern Oscillation (ENSO)—reduced precipitation from the monsoons in the highlands of Ethiopia as well as the floods of the Blue Nile, and offered Rome another series of economic setbacks.[65] Beginning in 155 CE, the gradual reduction of Egyptian grain imports to Rome meant that the Empire could not meet food quotas for the populous cities of Rome and later Constantinople. These chronic food shortages contributed to growing political instability, which the sun's decreased activity from 370 to 660 CE only further exacerbated.[66]

Beginning ca. 380 CE, Gothic incursions increasingly compromised the Western Empire's territorial integrity almost beyond repair. The weak Western Emperor Honorius' decision to allow entire Germanic tribes to form their own legions (unlike his brother Eastern Emperor Arcadius' preference to integrate Germanic individuals into existing Roman legions) may have been the single worst decision ever made by an emperor. After Honorius ordered the execution in 408 CE of General Flavius Stilicho—a prominent Roman who was responsible for over a decade of victories against Gothic tribes—Rome lacked the resilience that would allow it

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[63] See Figure 1 in the Appendix.
[64] Ulf Buntgen, "Cooling and Societal Change during the Late Antique Little Ice Age from 536 to around 660 AD," *Nature Geoscience* 9 (2016): 231-236.
[65] Emily Black, "The Influence of North Atlantic Oscillation and European Circulation Regimes on the Daily to Interannual Variability of Winter Precipitation in Israel," *International Journal of Climatology* 32 (2012): 1654-1664. Harper, *The Fate of Rome*, 113.
[66] Michael McCormick, "What Climate Science, Ausonius, Nile Floods, Rye, and Thatch Tell Us about the Environmental History of the Roman Empire," in Harris, W.V., ed. *The Ancient Mediterranean Environment between Science and History* (Leiden: BRILL, 2013): 76-79. By 618, the distribution of Egyptian grain exports in Constantinople completely stopped following the Persian invasion. Manning, "The Roman World and Climate," 133.

to bounce back quickly after setbacks like the tragic Battle of Cannae.[67] The stress of relentless barbarian attacks added to an already heavy toll taken by drought and disease and pushed the West to the brink of collapse.

In the Eastern Empire, tree ring records from north-central China reveal prolonged periods of drought that may have contributed to the migration of the Huns and later the Avars westward into Europe in the mid-fourth and mid-fifth century (respectively).[68] The Huns abandoned their increasingly arid Central Asian homeland first between 350 CE and 370 CE and then again between 447 CE and 451 CE (the Great Migration Period) for greener pastures near the lower Danube.[69] The Dulan-Wulan dendrochronological records in northeastern Qinghai Province reveal that the fourth-century megadrought was the worst in the past two millennia.[70] Computer models of northern hemisphere climate conditions based on scientific observation since 1951 show a strong correlation between precipitation in Europe and Central Asia.[71] When matched against dendrochronological records from around the world, the models suggest La Niña-like arid conditions occurred in Central Asia during the times of the Hun-Avar migrations. While this does not prove a direct link between the Hun-Avar migration and drought, the likelihood that a pastoral and nomadic people would stay put in the face of such conditions defies

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[67] The Romans lost the bulk of their entire army in a day but were ultimately able to regroup and defeat Hannibal.
[68] Ellsworth Huntington, "Climatic Change and Agricultural Exhaustion," *The Quarterly Journal of Economics* 31 (February 1917):199-200.
[69] Peter Heather, *Fall of the Roman Empire: A New History of Rome and the Barbarians* (New York: Oxford University Press, 2005), 146-147.
[70] Edward Cook, "Megadroughts, ENSO, and the Invasion of Late-Roman Europe by the Huns and Avars," Harris, W.V., ed. *The Ancient Mediterranean Environment between Science and History* (Leiden: BRILL, 2013), 89-102. The lack of an abundant source of trees in Central Asia means that scientists have had to rely on proxy data from other trees and use computer models to fill gaps in the data. There is no solid evidence that climate played a role in the first migration of the Huns, or Xiongnu, from China after the destruction of their second confederation in Turkestan ca. 35 BCE. By the late second century CE, their core territory was just north of the Aral Sea. Their rapid movement west after 374, however, suggests an urgency to their westward migration that they lacked earlier. See Etienne de la Vaissiere, "Huns et Xiongnu," *Central Asiatic Journal* 49, no. 1 (2005): 2-26 and Maenchen-Helfen, *The World of the Huns,* 18-26.
[71] Ibid., 92-97.

patterns that other (better-documented) pastoralists usually follow. Further evidence of the aridification of Central Asia is the shrunken Caspian Sea that is now about 50 meters lower than it was in Late Antiquity when it almost coalesced with the (now vanishing) Aral Sea.[72] Nevertheless, more paleoclimatological data would help settle the debate.

In the process of their migration, the Huns pushed out more than 100,000 Goth asylum-seekers.[73] Rome's inability to integrate these refugees into society led to tensions and banditry. Roman General Lupicinus' duplicity against Visigoth chieftain Fritigern in 376 and indifference to their plight finally convinced the Goths that war was the only solution.[74] The resulting Battle of Adrianople in 378 ended with a Gothic victory, a loss of two-thirds of the Roman army in the field, and the death of Emperor Valens in the chaotic aftermath.[75] The defeat shredded the last façade of Roman invincibility. Vandals, Lombards, and Burgundians then took advantage of the chaos. The *Hunnensturm* created a highly unstable atmosphere that eventually led to the loss of Italy and Gaul and the capitulation of Rome to the Ostrogoths in 476 CE.[76]

Climate was kinder to the East than the West during the fifth century. Aridity in the western Mediterranean usually correlates to humidity in the eastern Mediterranean and vice versa, and this bipolar climate seesaw pattern has continued over the past four millennia.[77] This alternation broadly means that the aridity in the western and central Mediterranean (Italy, Gaul,

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[72] Huntington, "Climatic Change and Agricultural Exhaustion," 186.
[73] Edward James, *Europe's Barbarians, AD 200-600* (New York: Pearson Longman, 2009), 51.
[74] Jordanes, *Historia Gestae,* 28.
[75] Ammianus Marcellinus, *Historiae* XXXI, 13.
[76] McCormick, "What Climate Science, Ausonius, Nile Floods, Rye, and Thatch Tell Us," 70-71. Heather, "The Huns and the End of the Roman Empire," 4-41.
[77] Dermody, B.J. et al. "A Seesaw in Mediterranean Precipitation during the Roman Period Linked to Millennial-Scale Changes in the North Atlantic," *Climate of the Past* 8 (2012): 637-651. https://doi:10.5194/cp-8-637-2012. Professor Garret G. Fagan, in his *History of Ancient Rome* Great Courses lecture, contemptuously dismisses climate change as a factor in the Empire's decline because he notes that the East continued to thrive. Historians who do not understand how the Mediterranean climate works like a seesaw often make this mistake: the West can be cold and arid while the East can be warm and humid.

Iberia, and the Aegean) that began around 400 hurt Rome; the oscillation accompanied a more humid eastern Mediterranean (Syria, Palestine, Egypt, southeastern Anatolia, and Black Sea provinces) that benefitted Constantinople.[78]

The reduction of solar energy following the eruption of Mount Vesuvius in 472 CE brought more cold temperatures in the West. Cold meant reduced precipitation, grain shortages, and cattle losses in the West. Gregory of Tours reported that Gaul suffered from famine.[79] Jordanes noted that the Danube froze so solid that immigrants could pass over it during winter for the decade after 460, and they did so by the tens of thousands. In 410, the Goths sacked Rome in 410; in 476, they deposed the Roman emperor, Romulus Augustus, and replaced him with one of their own.[80] Jordanes and others recorded that the Ostrogoths like King Theodoric maintained the Roman public infrastructure as well as most of the ceremonial trappings and institutions of the Roman emperors.[81]

In the East, however, climate change was generally for the better. Aridity characterized Anatolia until ca. 500 CE. Beginning ca. 300, three centuries of increased precipitation in the Levant contributed significantly to Roman demographic and economic expansion of the region's agricultural economy. This vitality, in turn, bolstered Roman rule in the area.[82] For example, the Dead Sea's water level rose so high that it covered the village of En-Gedi. Remains of the extensive agricultural terraces, bathhouses, dams, and aqueducts in what has long since been

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[78] Katherine Kuzucuoglu et al. "Mid- to late-Holocene Climate Change in Central Turkey: The Tecer Lake Record," *The Holocene* 21, no. 1, (2011): 173-188, https://doi.10.1177/0959683610384163.
[79] Gregory of Tours, *Historiæ*, II.24. The *Liber pontificalis* also speaks of a famine that struck "the whole world" in the year 537.
[80] Jordanes, *Getica,* V.1.130.
[81] Ward-Perkins, *The Fall of Rome and the End of Civilization,* 72-77. Bailey K. Young, "Climate and Crisis in Sixth-Century Italy and Gaul," in *The Years without Summer: Tracing A.D. 536 and its Aftermath,* ed. Joel D. Gunn (Oxford: BAR International Series, 2000), 35-44.
[82] Bookman, R. et al. "Late Holocene Lake Levels of the Dead Sea," *Geological Society of America Bulletin* 116, no. 5/6 (May/June 2004): 570.

desert seem as out-of-place today as elephants in the Alps did during the Roman Warm Period.[83] Jerusalem reached the pinnacle of population and prosperity around the year 500, and all credited it to δογμα τι θειοϖ or "divine favor."[84] However, this good fortune did not last forever.

The Late Antique Little Ice Age (LALIA) began in the mid-fifth century. It precipitated 250 years of reduced agricultural productivity, periodic harvest failures, and food shortages across the Mediterranean, particularly in elevated areas. Food shortages triggered further caravans of hungry migrants moving south and consuming Roman agricultural produce in their path. Still, the worst was yet to come.

At first, the climate stabilized itself in the early sixth century, which helped enable Rome's second revival under Justinian.[85] More than two centuries of the most extreme drought of the past two millennia ended ca. 500 CE according to salinity values in sediment cores from central Anatolia.[86] With warmer and more humid conditions in the East, agriculture flourished and created a surplus food supply that prevented political unrest and allowed for an ambitious campaign of reconquest and rebuilding. Justinian's ascension offered the hope of a reunited and eventually stable empire. As late as the early sixth century, the early successes of generals Belisarius and Narses against the Goths and the restoration of Italy, eastern Iberia, and North Africa to imperial authority suggested a resurgent empire reminiscent of the early Empire.[87]

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[83] Yizhar Hirschfeld, "A Climatic Change in the Early Byzantine Period? Some Archaeological Evidence," *Palestine Exploration Quarterly* 136, no. 2 (2004): 133-149.
[84] Christopher Jones, "Procopius of Gaza and the Water of the Holy City," *Greek, Roman, and Byzantine Studies* 47 (2007): 455-467.
[85] Nahman Avigad, "A Building Inscription of the Emperor Justinian and the Nea in Jerusalem," *Israel Exploration Journal* 27, no. 2/3 (1977): 145-151.
[86] Jonathan R. Dean et al, "Palaeo-Seasonality of the Last Two Millennia Reconstructed from the Oxygen Isotope Composition of Carbonates and Diatom Silica from Nar Golu, Central Turkey," *Quaternary Science Reviews* 66 (2013): 40. Note the charts that depict the precipitous drop in precipitation (VPDB) after 536 and compare it to the drop in the late nineteenth century that caused so much starvation. By comparison, a less severe drought in Turkey from 1873-1874 reportedly killed 250,000 people and 100,000 head of cattle (40% of the country's herds). One can only speculate how a worse drought might have affected the Romans.
[87] Stephen Mitchell, *A History of the Later Roman Empire AD 284-641* (Malden, MA: Blackwell Publishing, 2007), 423-427; See Figure 2 in Appendix.

Then, in the midst of this rebirth, an abrupt return of drier conditions in the fall season of 536 CE dealt Rome a blow from which she never recovered. Just over a century later, the Eastern Empire was little more than a rump state in Greece and Anatolia. What brought this on?

The long-ignored testimonials of eyewitnesses like Procopius and Cassiodorus offer the most compelling narratives:

> And it came about that during this year that a most dread portent took place. For the sun gave forth its light without brightness, like the moon, during the whole year, and it seemed exceedingly like the sun in eclipse. And from the time when these things happened, men were neither free from war nor pestilence nor any other thing leading to death.[88]

Cassiodorus Senator, who wrote from his estate outside war-ravaged Rome, described "something coming at us from the stars" that led to a dim full moon and a starless night sky. He blamed everything on “things in mid-space that dominate our sight” and the “heat of the heavenly bodies” that could not penetrate the mist:

> Men are alarmed, and naturally alarmed, at the extraordinary signs in the heavens, and ask with anxious hearts what events these may portend. The Sun, first of stars, seems to have lost his usual light and appears bluish. We marvel to…feel the mighty vigor of his heat wasted into feebleness and the phenomena which accompany a transitory eclipse prolonged through a whole year. How strange it is, I ask you, to see the principle star [the sun], and not its usual brightness; to gaze upon the moon, glory of the night, at its full, but shorn of its natural splendor? …We have had a winter without storms, spring without mildness, summer without heat…. Perpetual frost and unnatural drought. The rays of the stars have been darkened with an unusual color; the fruits have been hardened with the passage of time; the grapes are bitter in their old age. But, if this is not to be ascribed to divine providence, we should not be troubled, since, by God’s own command, we are forbidden to look for a sign.[89]

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[88] Procopius of Caesarea, *De Bello Vandalico* IV, 4-10. trans. H. B. Dewing, Loeb Classical Library (Cambridge, MA: Harvard University Press, 1924).
[89] Magnus Aurelius Cassiodorus Senator, *Variae Epistolae,* XII, 25. trans. S.J.B. Barnish (Liverpool: Liverpool University Press, 1992); See Mt. 16:1-4.

The natural archives tell a similar if less dramatic story. Reconstructing solar activity in the mid-sixth century based on Beryllium-10 (^{10}Be) isotopes in tree rings corroborates a story of less sun, less precipitation, and record amounts of volcanic ash that exceed anything since the end of the Bronze Age.[90] Ice cores yield cometary dust around the year 530 when Haley's Comet and the accompanying Eta Aquarid meteor shower passed by and left larger than average amounts of silicon- and nitrogen-rich microparticles in the stratosphere. They also show evidence of seven comets passing by Earth between 532 and 542 CE as opposed to the same number during the previous 30 years.[91]

The cosmic dust settled by 540 CE, but average temperatures did not increase after that because tephra in the ice cores suggests—and dendrochronological records from all over the world further confirm—three massive volcanic events in 536, 540, and 547.[92] Iceland is the prime candidate for the 536 eruption since the tephra in Greenland's Ice-Sheet Project 2 (GISP2) ice cores matches the region.[93] Ice cores from both Greenland and Antarctica reveal the ferocity of the volcanic activity after 536 and suggest that at least some of the volcanos occurred in the tropics given the more substantial impact on global climate. Ilopango in El Salvador and Krakatoa in Indonesia are the leading candidates for the second two, but scientists are still working out the exact details.[94] Krakatoa may have some support in two massive explosions and

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[90] The natural or scientific archives, as opposed to the written archives, is a term commonly used by climate historians like Michael McCormick, Walter Scheidel, Kyle Harper, and Geoffrey Parker to refer to tree rings, speleothems, and ice and sediment cores that offer information about paleoclimate.

[91] Dallas H. Abbott et al. "What Caused Terrestrial Dust Loading and Climate Downturns between A.D. 533 and 540?" *The Geological Society of America Special Papers* 505 (2014): 421-437. Baillie and others were convinced at the time they wrote their articles that cosmic dust alone caused the climatic cooling, however, the confirmation of volcanic activity since his writing makes Baillie's an insufficient explanation for the atmospheric forcing and abrupt climate change.

[92] While the cosmic dust argument has some merit, few scholars have taken it seriously if the number of journal articles is a reliable indicator. The volcanic signals are so overwhelming and come from ice cores in both poles, so the case for atmospheric forcing by volcanic ash is much stronger.

[93] Gibbons, *"Why 536 was 'The Worst Year to be Alive'."*

[94] David Keys, *Catastrophe: An Investigation into the Origins of the Modern World* (New York: Ballantine, 1999), ix. While the archaeological journalist tends towards what he calls "evolved determinism," Keys deserves credit for

in a yellow dust cloud heard and seen by Chinese historians in Nanking in 536 CE.[95] The presence of 80 times the norm of calcium carbonate ($CaCO_3$) and microfossils in Greenland ice cores suggests a tropical volcano ejected coral reef material into the atmosphere. Others suggest a possible asteroid strike in the region.[96] The question merits continual investigation, but climatologists agree upon the consequent global cooling and environmental catastrophe.

These eruptions and the simultaneous occurrence of a Grand Solar Minimum had a further cooling effect.[97] The ash particles took almost a decade to fall back to Earth, and when combined with a cyclical reduction of the sun's energy, created a perfect storm that made for the coldest decade of the past 2500 years and one of the coldest of the past eight millennia.[98] Speleothem testimony corroborates the evidence offered by trees: in 536, there was an abrupt drop in solar radiation, rainfall, and snowfall.[99] The high number of destructive earthquakes and violent volcanoes testifies to the instability of the tectonic plates in the early sixth century.[100] Tropical eruptions also alter ocean temperatures and currents that in turn have the potential to impact global terrestrial temperature and rainfall.[101] Climatologists report a "major centennial-

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starting the historical debate about the significance of 536. Further scientific investigation will eventually throw more light on the issue. Keys himself writes, "Key aspects of change, while triggered by a force of nature, were finally delivered through a plethora of consequent ecological, political, epidemiological, economic, religious, demographic, and other mechanisms that interacted with each other for up to a hundred event-filled years before producing final, irreversible change." R. Dull et al. "Did the TBJ Ilopango Eruption Cause the AD 536 Event?" *AGU Fall Meeting Abstracts* 13 (13–17 December 2010): V13C–2370.

[95] Keys, *Catastrophe*, 251-258. Keys cites the Javanese *Ancient Book of Kings* and the Chinese *History of the Southern Kingdoms.*

[96] Abbott et al. "What Caused Terrestrial Dust Loading," 431.

[97] Steinhilber, "Solar Activity," 6. A Grand Solar Minimum is a series of consecutive eleven-year cycle with no sunspots, reduced solar output, and record low temperatures on Earth.

[98] Ulf Buntgen et al, "2500 Years of European Climate Variability and Human Susceptibility," *Science* 331, no. 6017 (2011): 578-582. See also MGL Baillie, "Dendrochronology Raises Questions about the Nature of the AD 536 Dust-Veil Event," *The Holocene* 4 (1994): 212-217. Of the coldest 40 years between 500 BCE and 2000 CE, seven of them followed the 536. See M. Sigl et al. "Timing and Climate Forcing of Volcanic Eruptions for the Past 2,500 Years," *Nature* 523 (July 30, 2015): 543-549; See Figure 3 in Appendix.

[99] Bar-Matthews, "Speleothems," 378.

[100] Parker notes a striking correlation between the lack of sunspot numbers, volcanic activity, and summer temperatures in the northern hemisphere in the 1640s. Parker, *Global Crisis,* 15.

[101] Larsen, "New Ice Core Evidence for a Volcanic Cause of the AD 536 Dust Veil," 1-5.

scale re-organization of regional climate" in 536 that lasted as late as 829 when the Nile River froze.[102] The climate catastrophe of 536 CE was truly a game-changer for the Romans.[103]

Following frosted and withered crops due to lack of sun, Irish monks recorded a "failure of bread" in the Annals of Ulster between 536 and 539 as well as severely cold weather in the following century.[104] Bishop John of Ephesus noted that the unusual coldness, drought, and darkness lasted for eighteen months, and a feeble shadow of the sun shone for only about four hours. "The fruits did not ripen, and the wine tasted like sour grapes."[105] For many of these sources, the "wine of the fury of God's wrath," the killer earthquake in Antioch of 526, the Justinianic Plague of 542, people "unsurpassed in distress," and a growing number of other bad omens seemed to fulfill the signs that Jesus prophesied would occur just before His Second Coming.[106] The dry fog, cold temperatures, and loss of agricultural workers caused food shortages.[107] Sediment cores reveal that pollen counts from agricultural plants show sharp

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[102] Woodbridge, "Late Holocene Climate," 3381-3392.
[103] Martin Finne et al. "Climate in the Eastern Mediterranean, and Adjacent Regions, during the Past 6,000 Years—A Review," *Journal of Archaeological Science* 38 (2011): 3153-3173.
[104] Francis Ludlow et al. ""Medieval Irish Chronicles Reveal Persistent Volcanic Forcing of Severe Winter Cold Events, 431-1649 CE," *Environmental Research Letters* 8 (2013): 1-10. It is unfortunate that the monks are largely silent in the decades after 542 presumably because of the toll the plague took on their community.
[105] John of Ephesus, *Historia Ecclesiastica,* III. trans. Robert Payne Smith. Reprint Edition (Piscataway, NJ: Gorgias Press, 1853). Zachariah of Mitylene, in *The Syriac Chronicles* 9.19, 10.1, trans. F.J. Hamilton and E.W. Brooks (London: Methuen, 1899) lays out the dates from 24 March to 24 June of the following year.
[106] See Dan 12:2, Rev, 16: 18-20, and Mk 13:24-26. Revelation 16:**18** "Then there came flashes of lightning, rumblings, peals of thunder and a severe earthquake. No earthquake like it has ever occurred since people have been on earth, so tremendous was the quake… the cities of the nations collapsed. God remembered Babylon the Great and gave her the cup filled with the wine of the fury of his wrath." Mark 13: [24] "But in those days [the end of time], after that tribulation, the sun will be darkened, and the moon will not give its light, [25] and the stars will be falling from heaven, and the powers in the heavens will be shaken. [26] And then they will see the Son of Man coming in clouds with great power and glory."
[107] Richard B. Stothers, "Volcanic Dry Fogs, Climate Cooling, and Plague Pandemics in Europe and the Middle East," *Climatic Change* 42 (1999): 713-723.

declines after 536.[108] Harvard professor of medieval history Michael McCormick has called the mid-sixth century "the worst time to be alive."[109]

The subsequent food shortages and malnutrition reduced the fat-storing cells that produce leptin, the hormone that controls the vitality of the human immune system. Examinations of bones and teeth reveal that the famine after the 536 dust veil further weakened millions of people who were more vulnerable to infection and disease. Survivors of famines often migrated to the cities and villages in search of food, thereby increasing the likelihood that those infected with diseases spread them further. This trend exacerbated the impact of one of the most destructive disease outbreaks in human history: the Justinianic Plague.

Evagrius, a Syrian scholar and aid to Gregory of Antioch, documented the dreadful symptoms of the plague's emergence in 541:

> With some people, it began in the head, made the eyes bloody and the face swollen, descended to the throat and then removed them from Mankind. With others, there was a flowing of the bowels. Some came out in buboes that gave rise to high fevers, and they would die two or three days later with their minds in the same state as those who had suffered nothing and with their bodies still robust. Others lost their senses before dying. Malignant pustules erupted and did away with them. Sometimes people were afflicted once or twice and then recovered—only to fall victim a third time and then succumb.[110]

The Greek scholar Procopius reported that plague-mortality figures rose from 5,000 to 10,000 per day in Constantinople, and insisted that half of the Empire's population died by the

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[108] Giovanni Zanchetta, "Multiproxy Record for the Last 4500 Years from Lake Shkodra (Albania/Montenegro)," *Journal of Quaternary Research* 27, no. 8 2012): 780-789. P. Garnsey, *Cities, Peasants, and Food in Classical Antiquity: Essays in Social and Economic History* (Cambridge: Cambridge University Press, 1999), 289. Pollen counts dropped similarly during an arid phase in the region that produced widespread crop failure, famine, and contributed to the collapse of Bronze Age societies; Jessie Woodbridge and Neil Roberts, "Late Holocene Climate of the Eastern Mediterranean Inferred from Diatom Analysis of Annually-laminated Lake Sediments," *Quaternary Science Reviews* 30 (2011): 3387.
[109] Ann Gibbons, "Why 536 was 'the Worst Year to be Alive'," *Science* (November 15, 2018).
[110] Evagrius Scholasticus, *Εκκλησιαστικησ'ιστοριασ*, 4.29.

end of the outbreak.[111] John of Ephesus claimed that residents of Constantinople stopped tallying when the body count reached 230,000, almost half the population.[112] In fact, he recorded that the city ran out of places to put the corpses and so began filling the watchtowers, which soon grew so rank that travelers could smell them from miles away.[113] Between 400 and ca. 550, the Eastern Empire's population of approximately 24 to 26 million may have contracted to between 12 to 19 million, and then to a mere seven to ten million by the early ninth century.[114]

DNA evidence in the teeth of victims unearthed in sixth-century mass graves in Aschheim and Altenerding, Germany, has confirmed that the bacteria responsible for the outbreak was *Yersinia pestis*, or bubonic plague.[115] There have since been discoveries of ancient *Y. Pestis* genomes in Britain, France, and Spain.[116] Good history requires genomic evidence from the Eastern Empire as well. Much like the fourteenth-century Black Death, the Justinianic Plague may have taken a similar toll between 541 and 543.[117]

While the Justinianic Plague stuck primarily to sea and river ports and large cities, it also affected some of the most remote parts of the empire. As Kyle Harper noted, "Across most of the Roman world, ancient landscapes of settlement shriveled up. The state was deprived of

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[111] Procopius, *Historia* 2.23.1-2. Many historians contend this figure is too high.
[112] John of Ephesus, *Historia Ecclesiastica,* III. T.H. Hollingsworth used mathematical models to arrive at a figure of 244,000 dead of 508,000 in his *Historical Demography,* 365-367.
[113] William Rosen, *Justinian's Flea: The First Great Plague and the End of the Roman Empire* (New York: Penguin Books, 2007), 209-216.
[114] Haldon, *The Empire that Would Not Die,* 232. For details on the late-medieval outbreak, see John Kelly, *The Great Mortality: An Intimate History of the Black Death, the Most Devastating Plague of all Time* (New York: Harper Perennial, 2005).
[115] Michaela Harbeck, "*Yersinia pestis* DNA from Skeletal Remains from the 6th Century AD Reveals Insights into Justinianic Plague," *PLOS Pathogens* 9, no. 5 (May 2013): 1-8. This was actually a reconfirmation after some scientists questioned the methodology of a 2004 test. See Ingrid Wiechmann and Gisela Grupe, "Detection of *Yersinia pestis* DNA from Two Early Medieval Skeletal Finds from Aschheim (Upper Bavaria, 6th Century A.D.," *American Journal of Physical Anthropology* 126 (2006): 48-55. Reproducibility is the key to consensus in science.
[116] Marcel Keller et al, "Ancient *Yersinia pestis* Genomes from across Western Europe Reveal Early Diversification during the First Pandemic (541-750)," *PNAS* 116, no. 25 (June 18, 2019).
[117] Harper, *The Fate of Rome,* 244-245; "How Devastating was the Justinianic Plague in the 6th Century?" *New about the Middle Ages,* https://www.medieval.eu/devastating-justinian-plague-6th-century/.

metabolic energy, and painful atrophy set in."[118] Mass graves in Palestine and Greece (where archaeological digs are more active) suggest the same scenario: homes became tombs, and thriving communities (like Aschheim) buried their dead in mass graves and then disappeared.[119]

The archaeological record shows almost no building construction in the decade after 541 except for smaller churches.[120] The once-thriving city of Rome that hosted an estimated one million souls during the early empire was reduced to ten or twenty thousand by the end of the sixth century and cattle grazed in the Forum.[121] The plague came and went every dozen or so years for two centuries before it finally died out.[122] The testimony of the primary sources seemed to Gibbons and others to be too severe to be true. However, historians now suspect that these testimonials were not as prone to overwrought hyperbole as previously thought.[123]

Scientific evidence from various fields increasingly suggests that the Justinianic Plague played a much more prominent role in the decline of the Roman Empire than later generations suspected. The later victories of the Persians in 573 CE and Arab armies a half-century after that suggest that the Empire lacked the vigor and resources to defend the Middle East after the plague hit.[124] In the Western Empire, Justinian was unable to secure his conquests in Italy and North Africa, and his defeat of the Goths accomplished little more than a destruction of Italy so severe

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[118] Harper, *The Fate of Rome,* 248.
[119] McCormick, "Tracking Mass Death during the Fall of Rome's Empire I, II," *Journal of Roman Archaeology* 28, 29 (2015, 2016): 325-357, 1008-1046. doi:10.1017/S1047759415002512, 1008-1046, doi:10.1017/S1047759400073207. While McCormick's inventory of mass graves is an impressive piece of scholarship, it is surprising that archaeologists have discovered so few mass graves in major Roman cities like Constantinople and Antioch that date to the sixth century.
[120] Hugh N. Kennedy, "Justinianic Plague in Syria and the Archaeological Evidence" in *Plague and the End of Antiquity: The Pandemic of 541-750,* ed. Lester Little (New York: Cambridge University Press, 2009): 88-95.
[121] Harper, *The Fate of Rome, 248.* Procopius claimed that in 547, there were only 500 people left in the former imperial city, though this seems to be an extremely low figure.
[122] Dionysios Stathakapoulos, "Crime and Punishment," in *Plague and the End of Antiquity: The Pandemic of 541-750,* ed. Lester Little (New York: Cambridge University Press, 2009): 102-105.
[123] For the effects of the plague on the army, see John L. Teall, "The Barbarians in Justinian's Armies." *Speculum* 40, no. 2 (1965): 294-322.
[124] "The Epidemic of Justinian (AD 542): A Prelude to the Middle Ages," *Acta Theologica Supplementum* 7 (2005): 115-127.

that it recalled the previously quoted words of Tacitus about the price of peace.[125] War and plague made Italy a wasteland with a population a quarter of what it had been at its height.[126] The Gothic War from 535-554 weakened the links between Constantinople and Rome, and in the power vacuum that followed, inadvertently cleared the way for the Lombard invasion and subsequent chaos.[127]

The further dramatic temperature plunge during the late 530s lowered the climatic obstacle that had previously kept the fleas confined to the tropics.[128] Studies of gerbil colonies under various environmental conditions in Kazakhstan reveal that temperatures and humidity levels similar to those that thrived after 536 created an ideal ecosystem for the fleas that host the *Yersinia pestis* bacteria.[129] Analyses of juniper tree-ring proxy data reveal that conditions during the Black Death and the third bubonic pandemic (late nineteenth century until present) were also warmer and wetter after long periods of drought.[130] Bubonic plague originally from Central Asia eventually spread from the backs of black rats on ships that carried traded goods from India and Arabia to the Roman port of Pelusium in Egypt, and from there to every port and city in the empire.[131] While Istanbul has yet to discover the plague pits that reportedly hold the bodies of its tens of thousands of victims, excavations of sixth-century Jerusalem reveal several mass graves.

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[125] Peter Heather, "Goths and Huns," *The Cambridge Ancient History,* XIII: *The Late Empire AD 337-425, ed.* A. Cameron and P. Garnsey (Cambridge: Cambridge University Press, 1998), 487-515.
[126] Ward-Perkins, *The Fall of Rome and the End of Civilization,* 138-142.
[127] Mitchell, *A History of the Later Roman Empire,* 421.
[128] Rosen, *Justinian's Flea,* 167-197.
[129] Nils Chr. Stenseth et al. "Plague Dynamics are Driven by Climate Variation," *PNAS* 103, no. 25 (August 29, 2006): 13110-13115.
[130] Zhibin Zhang et al. "Relationship between Increase Rate of Human Plague in China and Global Climate Index as Reveled by Cross-Spectral and Cross-Wavelet Analyses," *Integrative Zoology* 2 (2007): 144-153. Abundant rainfall improved plant growth and seed production for more prolific gerbils and their parasitic fleas. Anthony J. McMichael, "Paleoclimate and Bubonic Plague: A Forewarning of Future Risk?" *BMC Biology* 8, no. 108 (2010): 1-3.
[131] Harper, *The Fate of Rome,* 214-235.

Only genomic tests will confirm the probability that the thousands of victims were fatalities from *Yersinia pestis* or died of something else.[132]

This integration of science, archaeology, and history allows scholars to weave climate change and decline into a single narrative. Increasingly cold and wet climate reduced Justinian's interest in the conquest of Frankish land west of the Alps since crops like oats and barley failed and so produced less of what the Empire needed. By 543, the plague may have halved the infected population of the Roman Empire. Agathias of Myrina (d. 582 CE), a magistrate from the era, reported that the plague repeatedly hit hard particularly among military-age males (because they had more contact with others).[133] In 588, fiscally strapped imperial authorities reduced military pay by a quarter and provoked a mutiny on the Empire's eastern frontier.[134] Such resentment of imperial parsimony often led to coups and civil war, which often provoked foreign invasion. The demographic decline deprived the East of the manpower to plow the fields and field the armies needed to meet the looming threats from Persia, invading Germanic tribes, and eventually Arab and Turkish armies.[135] Agathias observed that Byzantium's conquering army of 645,000 men—which—under the Empire's greatest general since Caesar, Belisarius, had reconquered Italy, North Africa and southern Spain—could field only 150,000 (many unpaid) after the plague of 542 CE.[136] Indeed, the aged Belisarius was able to round up only 300 veteran

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[132] Caroline Wazer, "The Plagues that Might Have Brought Down the Roman Empire," *The Atlantic* 3 (March 16, 2016): 1-3. David M. Wagner et al, "*Yersinia Pestis* and the Plague of Justinian 541-543 AD: A Genomic Analysis," *The Lancet* 14 (April 2014): 319-326.
[133] Agathias, *Histories,* V, 10, 1-7 trans. Joseph D. Frendo (New York: De Gruyter, 1975), 135-161..
[134] Peter Sarris, "Bubonic Plague in Byzantium," in *Plague and the End of Antiquity: The Pandemic of 541-750,* ed. Lester Little (New York: Cambridge University Press, 2009), 131.
[135] Erik Hildinger, "Belisarius' Bid for Rome," *Military History* (October 1999): 31-37.
[136] Harper, *The Fate of Rome,* 272. Harper notes that this first number is implausibly high. See also Mitchell, *A History of the Later Roman Empire,* 177. Agathias often reconstructed such details to convey what he perceived to be more important truths. See Anthony Kaldellis, "Things Are Not What They Are: Agathias "Mythistoricus" and the Last Laugh of Classical Culture," *The Classical Quarterly* 53, no. 1 (May 2003): 295-300.

cavalrymen to defend Constantinople from two thousand Kutrigurs during the Battle of Melantias in 559.[137]

The Slavic and Germanic tribes north of the Rhine and Danube suffered less from Justinian's Plague as well because of *Yersinia pestis'* preference for warmer climates, international trade networks, and high population densities.[138] Nevertheless, the climate catastrophe of 536 CE had the greatest impact at higher altitudes and northern latitudes.[139] Some of the prime agricultural lands in the Carpathian Mountains and Scandinavia experienced cold so intense that cereal crops failed.[140] Recent archaeological evidence suggests that Scandinavians abandoned three-quarters of their settlements in the mid-sixth century after years of rapid expansion.[141] With domestic wheat crops frozen and a lack of imported grain from the south, they had little to eat but fish if they could manage to get their ships in and out of frozen harbors.[142] The Norse mythological traditions in *Ragnarök* (the twilight of the gods) and *Fimbulvetr* (the mighty winter)—that heralded the final battle of the gods and ended with an incinerated and later reborn Earth—came of age during the sixth century. The *Fimbulvetr* described a black sun without warmth, a starless sky, and three consecutive winters with no summer between them.[143] The number of sacrificial gold deposits increased in the sixth century in an apparent effort to abate the wrath of the Norse gods.[144] Within a generation, grave finds

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[137] Mitchell, *A History of the Later Roman Empire,* 443-444.
[138] Little, *Plague and the End of Antiquity,* 24.
[139] Matthew Toohey et al. "Climatic and Societal Impacts of the Volcanic Double Event at the Dawn of the Middle Ages," *Climatic Change* 136 (2016): 409.
[140] B. Graslund and N. Price, "Twilight of the Gods? The 'Dust Veil Event' of AD 536 in Critical Perspective," *Antiquity* 86 (2012): 428-443.
[141] D. Lowenborg, "An Iron Age Shock Doctrine: Did the AD536-7 Event Trigger Large-Scale Social Changes in the Malaren Valley Area?" *Journal of Archaeological Ancient History* 4 (2012): 1-29.
[142] Andres Tvauri, "The Impact of the Climate Catastrophe of 536-537 AD in Estonia and Neighboring Areas," *Estonian Journal of Archaeology* 18, no. 1 (2014): 30-55. Of note, Tvauri cites a lack of anthropogenic (i.e. grain) pollens in the middle of the sixth century that coincides with the end of the Migration Period.
[143] Carolyne Larrington, trans. *The Poetic Edda.* (Oxford: Oxford University Press: 2014): 11.
[144] Morten Axboe, "The Year 536 and the Scandinavian Gold Hoards," *Medieval Archaeology* 43 (1999): 186-188.

virtually disappear as settlers either died or migrated.[145] The disappearing sun and apocalyptic winters described in *Gotterdammerung* bear a striking resemblance to the eyewitness accounts of Procopius and Cassiodorus.[146]

Across the North Sea, coldness may have prompted the Romano-Celts to abandon their tiled roofs in the late second century in favor of rye thatch since it acted as a better insulator in the colder weather. They also had an abundance of it after they switched crops when warmth-loving wheat failed to grow.[147] While agricultural output declined in part because of land resource mismanagement and neglect, proxy data reveals a great deal about frost and aridification. There is a definite though not a perfect correlation between cosmic rays reaching the atmosphere, cloud cover, and precipitation.[148] Nevertheless, crop swaps were not enough to stem the tide of the wrath to come.

Climate change and disease so devastated the Romano-Celtic residents of England after the early fifth-century "Arthurian revival" that it opened the door for Angles, Saxons, Jutes, Danes, and Frisians to take over largely depopulated agricultural wastelands within a century.[149] Historian Peter Heather estimates that the population declined from 3-7 million to less than one million between the fourth and sixth centuries.[150] The desolation that followed the "fire in the sky" described in *Le Mort d'Arthur* may not be a pure myth but may have an element of truth in

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[145] Bergljot Solberg, Settlement and Social Structure in Norway in the Migration Period (AD 400-550)," *Archaeologia Baltica* 3 (1998): 235-250. Archaeologists in Sweden have noted a lack of querns, cemeteries, and other artefacts in the mid-sixth century suggesting a southern migration. See Birgit Arrhenius, "Helgo in the Shadow of the Dust Veil 536-537," *Journal of Archaeology and Ancient History* 5 (2013): 1-14.
[146] Procopius, *De Bello Vandalico* IV.
[147] McCormick, "What Climate Science, Ausonius, Nile Floods, Rye, and Thatch Tell Us," 84-87.
[148] Gray et al. "Solar Influence on Climate," 18-19.
[149] Elizabeth Jones, "Climate, Archaeology, History, and the Arthurian Tradition: A Multiple-Source Study of Two Dark Age Puzzles," in *The Years without Summer: Tracing A.D. 536 and its Aftermath,* ed. Joel D. Gunn (Oxford: BAR International Series, 2000), 25-34.
[150] Peter Heather, *Empires and Barbarians: The Fall of Rome and the Birth of Europe* (Oxford: Oxford University Press, 2010).

the wasteland that was England (the Roman province closest to volcanic Iceland) after the mid-sixth century eruptions.[151] A diminished Roman Britain succumbed to a colder and drier climate, famine, and plague even before the Anglo-Saxons made a second comeback after the mid-sixth century (during the so-called Migration Cooling Period) after the Romano-Celts chased them from Britain's interior and even back to the Continent half a century earlier.[152]

The plague had hit the urbanized and networked Romano-Celts hard (including the powerful King Maelgwn of Gwynedd (North Wales) who died in 549) but may have largely spared the Germanic invaders with whom there was little trade in the early sixth century.[153] Romanized Celts fled to Brittany, Wales, or Scotland. The Anglo-Saxons slaughtered the Roman Britons or sold them (like young St. Patrick) as *wealh* or slaves (in Saxon: "Welsh").[154] The dearth of the Y (male) chromosome with Romano-Celtic characteristics among the British today suggests that Germanic tribes and later Vikings/Normans killed many of the Romano-Celtic men and spared the women.[155] The *Anglo-Saxon Chronicles* record little of that sort of unpleasant detail. By 626 CE, the Anglo-Saxon *völkerwanderung* made them masters of much depopulated English countryside.[156]

Gibbon consulted many historical archives to explain this, but the *natural archives* of climate variability were mostly unavailable to him. Indeed, the abundant archaeological evidence

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[151] Nick Nuttle, "Tale of King Arthur Points to Comet Catastrophe," *The Times* (UK), September 9, 2000, http://www.freerepublic.com/focus/f-news/1619222/posts. The sixth-century British monk and scribe Gildas described a fire-ravaged wasteland. See Emma Rigby et al, "A Comet Impact in AD 536?" *AOG* 45 (February 2004): 1.24.
[152] Heinz Wanner et al. "Holocene Climate Variability and Change; A Data-Based Review," *Journal of Geological Society* 172, no. 2 (2015): 261.
[153] Martyn J. Whittock, *The Origins of England 410-600* (London: Croom Helm, 1986), 205.
[154] Jones, "Climate, Archaeology, History, and the Arthurian Tradition," 29. The *Oxford English Dictionary* did not corroborate this assertion.
[155] McCormick, "History's Changing Climate," 265, 272.
[156] The forensic evidence of the Justinianic Plague in Britain is only just coming in. Cambridge University archaeologists recently found the first genetic evidence of *Yersinia pestis* in Britain near the Anglo-Saxon settlement of Edix Hill in East Anglia. See "Details of the First Historically Recorded Plague Pandemic Revealed by Ancient Genomes," *Ancient Origins* 21, no. 37 (4 June 2019).

suggested significant climate change since the Roman Warm Period. Baths, aqueducts, and bridges in the middle of deserts with no sign of water anywhere dotted the arid landscape of the southern and eastern Mediterranean even in Gibbon's time.[157] Additionally, archaeologists had yet to unearth the numerous burial inscriptions in Roman Palestine dating to 541 CE.[158] Gibbon could only have dreamed about the data available to contemporary historians.[159] This interdisciplinary approach has moved history closer to the precision and objectivity of the natural sciences.

Time has preserved the great cities in North Africa—once considered the "Granary of Rome"—after the farms ran out of water and the inhabitants abandoned the area.[160] Leptis Magna, Carthage, Cyrenaica, Palmyra, Scythopolis, Heliopolis (near modern Baalbek), and Petra were just abandoned ruins amidst modern deserts.[161] The erection of even longer aqueducts as late as the sixth century confirmed the scarcity of water in many cities, and efforts to irrigate them had become increasingly expensive and ephemeral ventures.[162] Ancient papyri unavailable to Gibbon documented the decrease in production of North African farms advent of the third century.[163]

The mosaics of Ravenna, completed during the 530s and 540s, offer stark contrasts between the time before and after the 536 Catastrophe. The green and happy villages depicted in

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[157] Leah Di Segni, "The Water Supply of Roman and Byzantine Palestine in Literary and Epigraphical Sources," in *The Aqueducts of Israel,* ed. D. Amit and J. Patrich, (Portsmouth, RI: Journal of Roman Archaeology, 2002), 37-67.
[158] Kennedy, "Justinianic Plague in Syria and the Archaeological Evidence," 88-89.
[159] Candida Moss, "Do these Skeletons Hold the Secret to the Fall of the Roman Empire?" *The Daily Beast* (June 15, 2019). The Edix Hill discovery was only published after the due date for this paper.
[160] Oreste Reale and Paul Dirmeyer, "Modeling the Effects of Vegetation on Mediterranean Climate during the Classical Roman Period: Part I Climate History and Model Sensitivity," *Global and Planetary Change* 25 (2000): 163-184.
[161] Yizhar Hirschfeld, "A Climate Change in the Early Byzantine Period? Some Archaeological Evidence," *Palestine Exploration Quarterly* 136, no. 2 (2004): 133-149. See Figure 4 in Appendix.
[162] Huntington, "Climatic Change and Agricultural Exhaustion as Elements in the Fall of Rome," 181.
[163] Harper, *The Fate of Rome,* 266-268.

the apse of St. Apollinaris in Classe disappear in favor of a starker age beset by darkness, famine, and plague. In the Church of San Vitale, Christ the Pantokrator is enthroned on a blue sun flanked by a sneering and scowling angelic court that seems to look with contempt upon a sinful creation.[164] Abel and Melchizedek offer sacrifices to God whose mighty hand reaches down from heaven to cause a shock wave and fiery clouds reminiscent of a plummeting comet that seem to portend the divine wrath to come. The parched and cracked landscape is full of bonfires, dead plants, and frost.[165]

Science reveals that volcanic dust scattered out the longer (yellow, orange, and red) wavelengths of visible light and caused the sun to appear blue—a phenomenon known as the Mie Effect that only occurs when scattered particles are less than 0.85 micrometers.[166] The Royal Geographic Society of London reported blue and green suns (the latter caused by slightly larger particles) in various tropical countries after the Krakatoa eruption of 1883.[167]

Dendrochronology and speleothems reveal that the cold temperatures during the decade after 536 exceeded in severity even the cold of the late medieval Little Ice Age that wiped out Viking settlements in Greenland and North America.[168] The frosty period from 536-660 is called the Dark Ages Cold Period (DACP) or LALIA for good reason.

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[164] Recall that Cassiodorus had observed a blue-colored sun in 536. See Figure 5 in Appendix.
[165] Dionysios Stathakapoulos in "Crime and Punishment," 111, claims "There is no trace of the disease and its impact in any Byzantine work of art." Dr. Ruth Dwyer, a Harvard University visiting lecturer in Art History, disagrees and makes a compelling case for a plague victim pictured in the Sacrifice of Isaac mosaic in San Vitale Church as well as in the poetry of Romanos Melodos. See https://www.youtube.com/watch?v=t4WBALFPmw4.
[166] Mie is the mathematician who in 1908 showed the effect of small particles in the air on light rays. See Figure 6 in Appendix for a mosaic depiction of a blue sun.
[167] David K. Lynch and William Livingston, *Color and Light in Nature,* 2nd edition (Cambridge University Press: 2001). That is, 4,200 years before the present or ca. 2,200 BCE.
[168] Bo Graslund and Neil Price, "Twilight of the Gods? The 'Dust Veil Event' of AD 536 in Critical Perspective," *Antiquity* 86 (2012): 428-443. Archaeologists note a similar widespread disruption of settlement and population dispersion in mid-sixth century Scandinavia.

Beginning about the year 600 CE, the worst drought of the past eleven millennia occurred in the Eastern Empire. Once again, volcanos exacerbated the cold temperatures with massive eruptions between 627 and 629 that caused the death of cattle, cavalry horses, and a general famine.[169] Varve records reveal that it was more severe than the Y4.2KBP Event that triggered the collapse of Mediterranean culture at that time.[170] The high mortality contributed to the Byzantine loss of the Levant to the Islamic Empire after the Battle of Yarmouk in 636.[171] However, a relatively wet period in Anatolia from about 560-750 gave the Byzantine armies the food surplus and economic vitality needed to thwart multiple Arab attacks into the heartland of the Eastern Empire during the seventh century.[172] Varve records from the Arabian Sea region show relatively high monsoonal rainfall between ca. 200 and 600 followed by intense drought.[173] This climate change may help explain the explosion of Arab and camel populations shortly before the Islamic Empire began its conquests.[174]

Climate not only disadvantaged the Byzantines but also aided and abetted their adversaries.[175] Arabia benefitted from climate change in the sixth century as record precipitation turned the arid peninsula into verdant pastures.[176] Earlier floods in Arabia Felix (modern Yemen) were so destructive that they wiped out the twelve-century-old Great Dam of Marib and the

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[169] Conor Kostick and Francis Ludlow, "The Dating of Volcanic Events and their Impact upon European Society, 400-800 CE," *Post-Classical Archaeologies* 5 (2015): 7-30.
[170] That 2,200 BCE. Claudia Migowski et al, "Holocene Climate Variability and Cultural Evolution in the Near East from the Dead Sea Sedimentary Record," *Quaternary Research* 66 (2006): 421-431.
[171] 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* 71 (2009): 27.
[172] D. 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* 26 (2007): 2213.
[173] R. Bookman et al. "Late Holocene Lake Levels of the Dead Sea," 555-571.
[174] Matthew D. Jones et al. "A High-Resolution Late Holocene Lake Isotope Record from Turkey and Links to North Atlantic and Monsoon Climate," *Geology* 34, no. 5 (May 2006): 361-364.
[175] Ronnie Ellenblum, *The Collapse of the Eastern Mediterranean: Climate Change Decline of the East, 950-1072* New York: Cambridge University Press, 2012).
[176] John Brooke, *Climate Change and the Course of Global History: A Rough Journey.* (New York: Cambridge University Press, 2014): 353-354.

nearby Roman trading port.[177] This event resulted in a trade shift to Mecca and Medina—the home of a then-inconsequential caravan trader named Muhammad.[178] The Levant and Arabia saw positive climate change that brought rains to hitherto dry Arabia and created a surplus population of people and camels.[179] More importantly, the Catastrophe of 536, the subsequent plague, and the Persian victories over the Eastern Empire created an apocalyptic atmosphere that was ideally suited to the spread of militant Islam.

When drought returned to the area in the early seventh century, Muhammad persuaded his zealous pastoralist followers to move north and west to greener pastures before they and their animals succumbed to drought.[180] In the seventh century, this aridity may have contributed to an Arab migration from Arabia and into Palestine, Syria, and North Africa.[181] The Levant and North Africa, weakened by drought-induced food shortages and depopulated by plague, soon surrendered to the Islamic Conquest.[182] Additionally, scientists have noted that the hot and dry climate of the Arabian Peninsula was a more difficult environment for *Yersinia pestis* to thrive in, and so the first pandemics spared the nomadic Arabs and Berbers of the worst ravages in the two centuries of plague after 542 CE.[183]

Like their Christian counterparts, Muslims saw the plague as divine punishment for arrogance and sin, but the schadenfreude ended when Muslims, after their conquest of plague-ravaged areas, perished in subsequent epidemics.[184] The earlier territorial loss of the Holy Land

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[177] Keys, *Catastrophe,* 59-61.
[178] Ibid., 68-70.
[179] Ibid. Brooke notes: "It may well turn out that Islamic achievements were based in some measure in the stronger southerly flow of the Atlantic winter westerlies." See also Richard Bulliet, *Cotton, Climate, and Camels in Early Islamic Iran: A Moment in World History* (New York: Columbia University Press, 2009).
[180] Lamb, *Climate History and the Modern World,* 154, 168.
[181] Mitchell, *A History of the Later Roman Empire,* 459-460.
[182] Sakia Hin, *The Demography of Roman Italy: Population Dynamics in an Ancient Conquest Society 201 BCE-14 CE* (New York: Cambridge University Press, 2013).
[183] Little, *Plague and the End of Antiquity*, 8, 24; Rosen, *Civilizing Climate,* 159-162.
[184] Ibid*,* 28. See also Koran Al-Araf 7:133.

to the Persians represented a devastating psychological blow to the Chalcedonian Christians in the region who viewed these events as further signs of a loss of divine favor and the end of the world.[185] By the early seventh century, Persian land seizures resulted in a seventy percent loss of imperial tax revenue.[186] The Slavs and Avars had taken over most of the Balkans and deprived the East of its prime recruiting grounds for troops. By the end of the seventh century, the Eastern Empire had lost its *machtgelüst* beyond Anatolia.

Further west, after an eight-century humid phase, lake sediment records a sharp reduction in olive pollens in Iberia that coincided with the Third Century Crisis.[187] They also reveal an even more arid phase in the Iberian Peninsula that began ca. 400 and spanned the three centuries. Constantinople's inability to revive agriculture there undoubtedly prompted Emperor Justinian's decision not to reinforce his Iberian and African conquests and therefore later left them open to Arab conquest between 642 (when the Empire lost Alexandria) and 692 (when the flag of Islam flew over Carthage).[188] However, it is unclear how much of the region's collapse was attributable to Vandal incompetence and neglect and how much was due to adverse climate change. [189]

To understand how climatologists know so much about paleoclimate, we must explore the scientific techniques that allow scientists to tap into the natural archives.

The Natural Archives and the Decline of Rome

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[185] Keys, *Catastrophe,* 50-51. Gerritt J. Reinink, *The Reign of Heraclius, 610-641: Crisis and Confrontation* (Leuven, Belgium: Peeters Publishers, 2003): 81-94.
[186] Keys, *Catastrophe,* 54-55.
[187] C. Martin-Puertas et al. "The Iberian-Roman Humid Period (2600-1600 cal yr BP) in the Zonar Lake Varve Record (Andalusia, Southern Spain)," *Quaternary Research* 71 (2009): 108-120.
[188] Leone, "Water Management in Late Antique North Africa," 119-133.
[189] Celia Martin-Puertas et al. "The Iberian-Roman Humid Record (2600-1600 cal yr BP) in the Zonar Lake Varve Record (Andalucía, Southern Spain)," *Quaternary Research* 71 (2009): 108-120. The data helps explain how the Umayyad Caliphate so easily overran starving Vandals in 712 in a way that traditional primary sources never did. The arrival of the Vandals in Iberia and North Africa coincided with the end of productive agriculture in that region.

First, the study of tree rings (dendrochronology) offers a rich source of information, and together with polar ice cores, offer the most accurate of the natural archives.[190] Tree rings record not only precipitation levels but also offer insights into the amount of sunlight and temperatures. Some trees, such as the bristlecone pine and the Scots pine, offer a continuous record going back to 3000 BCE and 5500 BCE (respectively) and contain a great deal of information.[191] Over the past century, dendrochronologists and dendroclimatologists have collected well over 7,000 samples from around the world and have used the data to reconstruct ancient climates.[192] Tree rings become narrower in droughts and cold weather, and Roman trees in the sixth century reflect this.[193] Frost rings on trees from Eurasia, Africa, and Mesoamerica all testify to the summer frosts, drought, and a five- to ten-degree (Fahrenheit) drop in temperature in the decade that followed 536 as well continued cool temperature for another 260 years.[194]

Second, geologists examine calcium carbonate deposits on speleothems (cave formations like stalactites and stalagmites) to extract information about precipitation and solar radiation.[195] Oxygen isotope ratios ($\delta^{18}O$) in cave drip-waters reflect both the precipitation and evaporative processes that modify $\delta^{18}O$ at the surface before infiltration into the ground.[196] This data, combined with precise isotopic dating, allows scientists to look at particular flowstone growth

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[190] Friedheim Steinhilber and Jurg Beer "Solar Activity—The Past 1200 Years," *PAGES News* 19, no. 1 (March 2011): 5. Historians McCormick, Harper, Scheidel, and Parker use this term frequently when introducing scientific data derived from natural sources.
[191] Matti Eronen et al, "The Supra-Long Scots Pine Tree-Ring Record for Finnish Lapland: Part 1, Chronology Construction and Initial Inferences," *The Holocene* 12, no. 6 (2002): 673-680.
[192] Larsen, "New Ice Core Evidence for a Volcanic Cause of the AD 536 Dust Veil," 2. Matthew W. Salzer, "Bristlecone Pine Tree Rings and Volcanic Eruptions over the Last 5000 Yr," *Quaternary Research* 67 (2007): 57-68.
[193] Sturt W. Manning, "The Roman World and Climate: Context, Relevance of Climate Change, and Some Issues," in *The Ancient Mediterranean Environment between Science and History* ed. William V. Harris (Leiden: Brill, 2013), 137.
[194] See David Keys, "Catastrophe!" *New Internationalist* 318 (December 1999), 12-17 for a fuller treatment of the collapse of the Teotihuacan culture in Central America in the mid-sixth century because of the cooler climate.
[195] Jurg Lutebacher et al. "A Review of 2000 Years of Paleoclimatic Evidence in the Mediterranean," in *The Climate of the Mediterranean Region,* Pedro Lionello ed. (New York: Elsevier, 2012): 87-185.
[196] McDermott, "Paleo-Climate Reconstruction," 904.

rings to understand climate conditions tens of thousands of years ago. During relatively warm and wet periods, the values of $\delta^{18}O$ and carbon isotope ratios ($\delta^{13}C$) decrease, and they increase during times of aridity.[197] Thus, scientists interpret this data from electron microscopes as proxies for precipitation as well as surface vegetation and deforestation. Like trees, caves are almost ubiquitous, and new data arrives faster than historians can integrate it into their narratives. In Greece, for example, speleothems reveal a cycle of aridity that began ca. 150 CE and continued through 650 CE.[198] Comparisons of results from different caves allow the reconstruction of paleoclimate patterns.[199]

Third, the science of palynology uncovers what sort of plants grew in a given area—whether they be forests, crops, or degraded pastureland—and detects when anthropogenic crops fail through comparisons of pollen counts over time. Palynologists can track the rise of Roman agriculture during the Roman Climate Optimum (RCO) when anthropogenic pollen counts peaked between 50 CE and 200 CE.

Fourth, ice cores from mile-high ice sheets primarily taken from GISP2 as well as Antarctica reveal levels of solar radiation that reach the Earth, the amount of precipitation, as well as what sorts of dust or pollutants were in the atmosphere. The interaction of galactic cosmic ray (GCR) particles with oxygen and nitrogen produces Beryllium-10 (^{10}Be) in the Earth's atmosphere. During periods of high solar activity, there is a corresponding decrease in

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[197] Miryam Bar-Matthews, "Speleothems as Paleoclimate Indicators, A Case Study from Soreq Cave Located in the Eastern Mediterranean Region, Israel," in *Past Climate Variability through Europe and Africa,* ed. R.W. Battarbee et al. (Dordrecht, The Netherlands: Springer, 2004): 363-383.

[198] Martin Finne et al, "Speleothem Evidence for Late Holocene Climate Variability and Floods in Southern Greece," *Quaternary Research* 3518 (2014): 213-227..

[199] Scientists use the same technique to project known data into the unknown and thereby reconstruct the creation of the universe from the time of the Bing Bang to the present. If we accept their reconstructions of events 15 billion years ago, paleoclimatological findings of 1500 years ago do not seem so radical.

the production of cosmogonic radionuclides stored in ice cores and tree rings.[200] The ^{10}Be as well as Carbon-14 (^{14}C) trapped in the ice cores thus create proxies that allow geophysicists to reconstruct the levels of solar radiation (and thus temperature) in a given period.[201] Marine varves, or cores of sediments taken from lakes and oceans, also offer insights into drought, soil erosion, pollen counts, lithology, and tephra layers of volcanic ash that allow reconstructions of paleohydrological events.

Fifth, glaciers advance down mountains during colder and wetter summers and retreat up mountains during warmer summers. Glaciers advance during periods of low solar activity and volcanic forcing.[202] Glaciologists confirm significant glacial retreats in the Alps beginning ca. 400BCE.[203] Glaciers tentatively advanced around the world after the third century CE, accelerated their advance ca. 400, and peaked shortly after the decade between 536 and 545.[204] Except for the more advanced civilization of late medieval and modern Europe, glacier advances have generally coincided with the decline of ancient civilizations ca. 2200 BCE, 1000 BCE, and Late Antiquity, while glacial retreats have corresponded with advances in civilization.[205] Glaciers have retreated in the past century to their highest levels since Roman times owing to solar forcing and elevated levels of carbon dioxide CO_2.[206] A 2015 study of fallen timber from a

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[200] Maura Von Moos et al. "Large Variations in Holocene Solar Activity: Constraints from ^{10}Be in the Greenland Ice Core Project Ice Core," *Journal of Geophysical Research* 111 (2006): 1-14.
[201] Friedheim Steinhilber et al. "9,400 Years of Cosmic Radiation and Solar Activity from Ice Cores and Tree Rings," *Proceedings of the National Academy of Sciences of the United States of America* 109, no. 16 (2012): 5867-5971. A lack of sunspots correlates with a colder climate and gives a similar but less accurate data point, though the record beyond 1610 is less reliable as a proxy for temperature. See L.J. Gray et al. "Solar Influence on Climate," *Reviews of Geophysics* 48 (2010): 2-3.
[202] Gray et al. "Solar Influence on Climate, 22-23.
[203] Manning, "The Roman World and Climate," 135.
[204] Hanspeter Holzhauser et el. "Glacier and Lake-Level Variations in West-Central Europe over the Last 3500 Years," *The Holocene* 15, no. 6 (2005): 7789-801.
[205] Michel Magny, "Holocene Fluctuations of Lake Levels in the French Jura and Sub-Alpine Ranges, and Their Implications for Past General Circulations Patterns," *The Holocene* 3,4 (1993): 306-313.
[206] Delphine Six and Christian Vincent, "Sensitivity of Mass Balance and Equilibrium-Line Altitude to Climate Change in the French Alps," *Journal of Glaciology* 60, no. 223 (2014): 867-878.

glacier on Mont Blanc in France, for example, concluded that the glacier made its most significant advance in the several decades of the early sixth century.[207] Other glaciers tell a similar story.[208] The impact on a subsistence agricultural economy that included higher elevations was catastrophic. These glacial movements corroborate the other science-based narratives.

Sixth, recent advances in biology and genetics allow scientists to examine the bones and teeth of ancient skeletons to determine the health of people alive at the time as well as what might have contributed to their deaths. This data discloses that Roman health declined in the late second century as diseases like typhus, cholera, bronchitis, pleurisy, tuberculosis, gastroenteritis, and colitis took greater numbers.[209] Analysis of Roman femurs suggests that while civilization brought many benefits to Romans, it also took a toll on their overall health. Average heights of Iron Age peoples declined to about 5'4" once Rome occupied an area, and they went up again after Rome vacated the area.[210] The bones, particularly of infants, show stress from malnutrition in the late second century and worse stress in the West during the fifth century. Average life expectancy was in the late twenties; infant mortality was as high as one in three.[211] Finally, bones and teeth preserve the isotopic signature of the foods that people ate: most Romans ate little meat, more fish than their Mediterranean peers, and a whole lot of grain.[212]

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[207] Melanie Le Roy et al. "Calendar-Dated Glacier Variations in the Western European Alps during the Neoglacial: the Mer de Glace Record, Mont Blanc Massif," *Quaternary Science Review* 108, (January 2015): 10.
[208] M. Hoezle et al. "Secular Glacier Mass Balances Derived from Cumulative Glacier Length Changes," *Global and Planetary Change* 36 (2003): 295-306.
[209] Brent D. Shaw, "Seasons of Death: Aspects of Mortality in Imperial Rome," *Journal of Roman Studies* 86 (1996): 132.
[210] Harper, *The Fate of Rome,* 75-77.
[211] Alessandra Sperduti et al. "Bones, Teeth, and History," Walter Scheidel, ed. *The Science of Roman History: Biology, Climate, and the Future of the Past.* (Princeton: Princeton University Press, 2018), 131. Even Emperor Marcus Aurelius—with the best medical minds at his disposal—outlived all but two of his fourteen children.
[212] Michael McCormick, "History's Changing Climate: Climate Science, Genomics, and the Emerging Consilient Approach to Interdisciplinary History," *Journal of Interdisciplinary History* 42, no. 2 (Autumn 2011): 259.

Even migration patterns of bugs can tell us about climate change in Europe in the mid-sixth century. Warmth-loving weevils and beetles (incl. *Heptaulacus sus* and *H. testudinarius*) in Britain retreated from the highlands of Scotland and Wales when the climate cooled to the point where they had to migrate or die.[213] Like humans at the time, they did both. The dynamic distribution of these insects is a reminder to historians and climatologists that climate change and migration are normal in our ecology.[214]

All of these natural archives tell the same story, and they generally complement rather than contradict the evidence offered by the written archives. In fact, they can serve as something equivalent to the time machine that historian John Lewis Gaddis said would allow historians to see the past with more certainty.[215] Yet historians need to exercise caution in how they interpret the evidence they offer; trees, rocks, and bugs do not lie, but errors follow if such evidence is misinterpreted.

The most reliable way to understand paleoclimate is to plot the results from the different proxies on to the same graph and compare results. We must keep in mind that proxies occasionally do not correlate with each other, and the data must either be retested or the hypothesis reformulated. Conversely, data on precipitation can accurately correlate with other historical data, such as wheat prices, land prices, or wages. Indeed, a focus solely on the natural archives might lead historians to conclude that climate change was the sole cause for Rome's decline, but few scientists and historians have reached such mistaken conclusions. Undoubtedly

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[213] Harry Kenward, "Do Insect Remains from Historic-Period Archaeological Occupation Sites Track Climate Change in Northern England?" *Environmental Archaeology* 9 (2004): 47-59.
[214] For the first time in 1500 years, the weevils have returned to northern areas where they have not lived since Roman times because of global warming.
[215] John Lewis Gaddis, *The Landscape of History* (New York: Oxford University Press, 2002), 3.

though, the evidence that environmental catastrophe and climatic change *contributed* to the decline of the Roman Empire is overwhelming.

Nineteenth-century Cambridge scientist and polymath William Whewall was one of the first to employ a consilient approach when he sought scientific input from the likes of genetics and evolutionary biology and then mixed that in with history and archaeology in order to conclude from epistemologically clear evidence.[216] However, while this methodological approach was sound, it did not have an immediate effect upon the historical discipline. In fact, communication between the natural sciences and social sciences was in such a sorry state that British scientist Charles Snow decried it in 1959 when he wrote about the growing estrangement in how the two disciplines came to derive knowledge of the world.[217]

In the case of the Roman Empire, scholars have long sought to understand what transformed a predominantly urban culture in the Mediterranean into a predominantly rural one centered on northwestern Europe. It was neither the triumph of barbarism and religion in the fifth century as Gibbon asserted (though this applies to the Western Empire) nor the Islamic Conquest of the seventh century as Pirenne proposed.[218] Rather, the transformation happened in the *sixth* century, primarily (although not solely) because of climate change, the subsequent agricultural and fiscal crises, famine, migrations, invasions, and plague.[219] The mid-sixth century represents something of a *dénouement* for the historical drama of the Eastern Empire.[220]

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[216] McCormick, "History's Changing Climate," 251-273. Gaddis, *The Landscape of History,* 49. "Consilient" is a term often used by McCormick, Harper, and Scheidel. It literally means a "jumping together" per the 1971 ed. of *OED*, p 861.
[217] Charles P. Snow, *Two Cultures and the Scientific Revolution* (London: Oxford University Press, 1959). Snow was prophetic in noting how useful the scientific archives could be in offering unique insights into pre-history.
[218] Henri Pirenne, "Mahomet et Charlemagne," *Revue Belge de Philologie et d'Histoire* 1 (1922): 77-86.
[219] P. Allen, "The Justinianic Plague," *Byzantium* 49 (1979): 20.
[220] Kennedy, "Justinianic Plague in Syria and the Archaeological Evidence," 93-95.

Comparisons of the ancient sources with a NASA study on ancient volcanic eruptions suggests historians were wrong to dismiss the credibility of the ancient authors who reported such dread portents.[221] Although most climatologists believe that a lack of solar irradiance plays a much more significant role in the onset of cold summers than volcanic ash in the stratosphere, the combination of the two creates a perfect storm for climatic chaos.[222]

The evidence for this abrupt cooling is staggering. Scientists are continually coming up with new and ever more creative ways to discover evidence for paleoclimate change, and temperature estimates combine to offer a history that shows remarkable synchronicity with ancient primary sources. Nevertheless, most interdisciplinary historians and scientists refrain from overstating their case, and research continues to question or support the integrity of previous conclusions.[223] What is clear from all this new evidence is that climate change affected not only the Romans but their neighbors as well.

Climatologists have been studying climate variability now for a generation, and the data, while still relatively sparse, grows at an exponential rate. Historians now understand that the Holocene Age (the last ca. 10,000 years since the end of the last Ice Age) is really an *interglacial* age punctuated by variabilities caused by climate forcing from the tilt of the Earth's orbit, the fluctuating energy cycles of the sun, volcanic eruptions, oceanic and atmospheric currents, and

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[221] Antii Arjava, "The Mystery Cloud of 536 CE in the Mediterranean Sources," *Dumbarton Oaks Papers* 59, (2005): 73–94. It is worth noting that Arjava takes the view that the impact of the mystery cloud of 536 was limited although there has been much more evidence in support of the view that unprecedented volcanic forcing made 536 a watershed event since Arjava went to press in 2005. He does agree, however, that the subsequent food shortage and plague were milestone moments for the Romans. Kostick, "The Dating of Volcanic Events," 29.
[222] Beer et al. "The Role of the Sun in Climate Forcing," 403-415.
[223] Le Roy et al. "Calendar-Dated Glacier Variations," 1-22.

(especially most recently) CO_2 levels.[224] The sun has an eleven-year cycle of sunspots as well as longer cycles that vary from 88 to 208 years.[225] Empires rise and decline on those cycles.

Historians also understand now that proxy data reveals a great deal about the climate of the past through comparisons of what scholars know of climate data from the past 150 years with radioisotopes in tree rings and speleothems, CO_2 bubbles in ice cores, and pollen samples at the bottom of ancient lakes and tributaries.[226] This data has been tested and retested. Scientists revise their theories and reconcile or reject seeming contradictions among various data points.[227]

Geologists have documented high-resolution proxy records for humidity and aridity variability over the past 2500 years based on oxygen isotope analysis of lacustrine sediments from all over the Mediterranean region.[228] This data discloses a pattern whereby the North Atlantic Oscillation (NAO) dominates the winter climate in the Mediterranean, and Indian monsoons dominate the summers of the northern hemisphere. A positive value of the NAO correlates with a westerly flow across the North Atlantic and Western Europe that leads to warmer and wetter conditions over northwestern Europe, drier conditions in the northern and western areas of the Mediterranean, and wetter conditions in the eastern Mediterranean.[229]

At the end of the Roman Climate Optimum, a drop in the wavelet power spectrum of the NAO caused the negative value of the NAO to change to variable, then positive, and it stayed

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[224] Borsato S. Frisia, et al. "Climate Variability in the SE Alps of Italy over the past 17000 Years Reconstructed from a Stalagmite Record," *Boreas* 34 (2005): 446-454.
[225] Beer et al. "The Role of the Sun in Climate Forcing," 408.
[226] Dean et al, "Palaeo-Seasonality of the Last Two Millennia," 35-44.
[227] Data from Soreq Cave are a prime example of the sorts of low-resolution data anomalies that make a completely unified theory about the Mediterranean climate problematic. Orland, "Climate Deterioration," 27-35.
[228] Aleksander Kacanski et al, "Late Holocene Climatic Change in the Balkans: Speleothem Isotopic Data from Serbia," *Radiocarbon* 43, no. 2b (2001): 647-658.
[229] Simon O. Krichak and Pinhas Alpert, "Decadal Trends in the East Atlantic-West Russia Pattern and Mediterranean Precipitation," *International Journal of Climatology* 25 (2005): 183.

that way for a century.[230] At the same time, the Indian monsoon rain system that brings precipitation to northeastern Africa changed its cycle and brought less precipitation to that area. This climatic whipsaw was a double blow for the Roman Empire in the late second century, made its agricultural economy much less reliable, and brought political instability when food shortages resulted.[231]

Much like contemporary Central Americans migrating north after four years of drought associated with El Niño conditions, Germanic tribes moved into the wealthier Roman Empire for food, better jobs, and security.[232] Migration experts have long shown a positive correlation between climate change, food insecurity, and migration.[233] Polls of today's migrants indicate that economic well-being, employment, and family reunification are the most commonly cited motives that induce people to migrate.[234] The calamitous climate change following 536 CE caused mass migrations of Germanic and Slavic peoples south as well as a flight of people from the western Mediterranean to the more hospitable eastern Mediterranean.[235] Gothic rampages in Italy in the fifth century must have been very similar to the gang wars and high murder rate in Honduras today. Emigration from Italy helps explain the economic and demographic growth of the Eastern Empire in the fifth and early sixth century. However, humans were not the only animals migrating or dying.

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[230] Jesper Olsen et al. "Variability of the North Atlantic Oscillation over the past 5,200 Years," *Nature Geoscience* 5 (November 2012): 808-811.
[231] Thomas R. Martin, "Barbarian Migrations and the Fates of Empires," *Ancient Rome: From Romulus to Justinian* (New Haven, CT: Yale University Press, 2012), 190-214.
[232] The UN estimates that dry conditions in 2018 had ruined 280,000 hectares of beans and corn in El Salvador, Guatemala, and Honduras and left more than two million people without reliable access to food. See "Hunger without Borders: The Hidden Links between Food Insecurity, Violence, and Migration in the Northern Triangle of Central America: An Exploratory Study," *World Food Program Report.*
[233] Stephanie Leutert, "How Climate Change is Pushing People North," *The Washington Post*, 7 November 2018.
[234] www.wfp.org/news-release/fao-and-wfp-concerned-about-impact-drought-most-vulnerable-central-america, 24 January 2019. Accessed 29 March 2019.
[235] Brooke, *Climate Change,* 347.

Archaeobotanists note that the Roman predilection for killing predatory animals later contributed to the explosion of the black rat population and the subsequent spread of the Justinianic Plague. Plant and animal species that appear unnecessary or redundant in an ecosystem may become critically important for that system's ability to regenerate itself after disturbances.[236] This predilection for destroying plants and animals that were not useful or profitable proved deadly. The Romans naïvely thought they had conquered and even subdued nature just as they had their enemies and were surprised to find nature so much more resilient.[237]

Admittedly, paleoclimatology's rapid evolution might make historians reluctant to revise established historical narratives. Yet while historians have in their possession only a fraction of the evidence that might be available in a generation, that need not preclude some modest revisions at present.[238] Environmental factors and climate change did not *determine* the course of the Empire, but they did pose a significant challenge to food production and health and contributed to the inequality of an emerging feudal political system.[239]

The decline of the Roman Empire almost entirely correlated with the onset of a colder, drier, and less stable climate. Deforestation and the increase of albedo (the reflectivity of the Earth's surface) did cause a reduction of heat absorption by foliage and thereby reduced rainfall, but the 536 catastrophe was the primary culprit.[240] The climate of the Mediterranean region is particularly vulnerable to the impact of anthropogenic activity, and by the late second century,

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[236] Carl Folke, "Resilience: The Emergence of a Perspective for Social-Ecological Systems Analyses," *Global Environmental Change* 16 (2006): 258.
[237] J. Donald Hughes, *Pan's Travails: Environmental Problems of the Ancient Greeks and Romans* (Baltimore: The Johns Hopkins University Press, 1994).
[238] A. Curras et al. "Climate Change and Human Impact in Central Spain during Roman Times: High-Resolution Multi-Proxy Analysis of a Tufa Lake Record," *Catena* 89 (2012): 31-53, https://doi:10.1016/j.catena.2011.09.009.
[239] William V. Harris, ed. *The Ancient Mediterranean Environment between Science and History* (Leiden: Brill NV, 2013).
[240] H.H. Lamb, *Climate, History, and the Modern World,* 329. See also Oreste Reale and Jagadish Shukla, "Modeling the Effects of Vegetation on Mediterranean Climate during the Classical Roman Period: Part II Model Simulation," *Global and Planetary Change* 25 (2000): 185-214.

deforestation meant that less rain fell on the Empire than during the previous century.[241] The region and its inhabitants remain vulnerable to abrupt climate change.

The integration of these new data points into the historical narrative has allowed scientists and historians to test their theories against the General Circulation Model (GCM) and modify them as required by fidelity to the evidence.[242] Increased interdisciplinary collaboration between historians and scientists who seek to understand the role that climate stress has on human populations has only helped humankind comprehend the significance of the role that Mother Nature plays in civilizational decline.[243] Recently honed scientific processes offer new insights into the better-known political, economic, and demographic pressures that ultimately overcame the Romans.[244]

Developments in climatology and epidemiology also give scientists a better understanding of the relationship between climate and disease. Epidemiologists now know that *Plasmodium falciparum* malaria comes from mosquitos that breed in the stagnant waters of low wetlands, particularly during the rainy seasons.[245] Higher numbers of deaths in the summer (based on Christian epitaphs with recorded death dates) suggest that malaria was a significant killer much like it remains today in developing nations.[246] Aridity often exacerbates the effect of malaria since there is less water flushing stagnant mosquito-laden pools into rivers and streams.

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[241] E. Xoplaki et al. "Wet Season Mediterranean Precipitation Variability: Influence of Large-Scale Dynamics and Trends," *Climate Dynamics* 23 (2004): 63. The Mediterranean Sea is no stranger to climate change: 5.33 million years ago, a breach at the Strait of Gibraltar flooded a previously desiccated basin in less than two years. See Fatima Abrantes et al. "Paleoclimate Variability in the Mediterranean Region," in *The Climate of the Mediterranean Region*, ed. Piero Lionello (London: Elsevier, 2012): 24-25.
[242] See Vivien Gonitz, *Encyclopedia of Paleoclimatology and Ancient Environments* (New York: Springer; 2009) for a full treatment of paleoclimate modeling.
[243] C.J. Caseldine and C. Turney, "The Bigger Picture: Integrating Paleoclimate and Environmental Data with a History of Societal Change," *Journal of Quaternary Science* 25, no. 1 (2010): 88-93.
[244] Shaw, "Seasons of Death," 100-138.
[245] Colin P. Elliott, "The Antonine Plague, Climate Change, and Local Violence in Roman Egypt," *Past and Present* 231 (May 2016): 10.
[246] Shaw, "Seasons of Death," 115.

As invading barbarians destroyed their aqueducts, Roman inability to flush these stagnant pools ensured a favorable climate for mosquito larvae and other disease-carrying bacteria like leptospirosis.[247] The archaeological record suggests that Romans came to associate floodplains with malaria, and many fled to cooler and higher ground even though those areas were less productive in agriculture. This migration contributed to the end of a long period of surplus agricultural production that had freed up people to engage in trade, manufacturing, and leisure.

Paleobiologists now have a better understanding of the diseases that killed Romans. They suspect that the Antonine Plague of 165-180 CE was smallpox and the first indicator that Roman cities and barracks had become havens inadvertently designed to spread disease.[248] Some historians have suggested that one out of ten Romans died, but there is no way of knowing for certain.[249] Taxpayer rolls in the late160s CE suggest that it may have wiped out 70-90 percent of the rural populaton in some parts of Egypt, and the grain exports were never the same after that.[250] Archaeological surveys and data suggest that the populations of Italy, Gaul, and Iberia declined after peaking in the late second century.[251] Afterward, the Romans needed to recruit non-specialized barbarians *en masse* into the army to fill the ranks.

Cyprianic plague of 251-266 CE was probably some sort of hemorrhagic fever like Ebola.[252] The impact of this second epidemic was significant and likely contributed to the monetary crisis and the political anarchy of the third century. One estimate suggests that the population of the Mediterranean fell by a third between 165 CE and 400 CE.[253] The Empire

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[247] Gregory S. Aldrete, ed. "Delayed Effects of Floods," in *Floods of the Tiber in Ancient Rome* (Baltimore: Johns Hopkins University Press, 2006), 149-154.
[248] J.F. Gilliam, "The Plague under Marcus Aurelius," *The American Journal of Philology* 82, no. 3 (July 1961): 225-251.
[249] Adrian Goldsworthy, *How Rome Fell,* 51.
[250] Brooke, *Climate Change,* 344.
[251] Ibid.
[252] Harper, *The Fate of Rome*, 143.
[253] Brooke, *Climate Change*, 344.

managed to recover from these two devastating blows, but the Justinianic Plague of 541-543 CE was another matter.[254] In that case, the combination of severe climate change and disease made recovery in the sixth century a bridge too far.

In the future, new technology is likely to give medical science the keys to confirm these theories. For now, historians have only anecdotal indicators of demographic decline like wheat prices, falling rents and land prices, and missing veterans' lists.[255] Historians must work with the data that they have at their disposal.

Gibbon was correct when he assigned much of the blame for Rome's fall on human activity. Anthropogenic activity played a role in unfavorable climate change in the Fertile Crescent and North Africa. As many of the ancient primary sources and even English economist Robert Malthus noted centuries later, deforestation, overgrazing, the reckless exploitation of fragile environments, and dense urbanization contributed to Rome's decline.[256] For example, palynologists and anthrocologists believe that the harvesting of white oaks to fuel the ravenous kilns of the silver mines denuded vast tracks of land in Iberia, and the removal of beech trees in riparian areas accelerated the erosion and silting of navigable rivers.[257] These practices also reduced the biological diversity that allowed the environment to adjust to abrupt climate change, depleted nutrient-rich soils, and created the sorts of unhygienic environments in which disease bacteria thrived. Simply switching crops often terminated a food crisis.[258]

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[254] Harbeck, "*Yersinia pestis* DNA."
[255] Kyle Harper has looked at wheat prices, land prices, rents, and wages to hypothesize about the impact of the Antonine, Cyprianic, and Justinianic plagues in "People, Plagues, and Prices in the Roman World: The Evidence from Egypt," *The Journal of Economic History* 76, no. 3 (September 2016): 803-839. The steady rise in wheat prices up until 542—followed by a gradual decline--is telling.
[256] J. Donald Hughes, "Ancient Deforestation Revisited," *Journal of the History of Biology* 44 (2011): 43, 52.
[257] Ibid., 49-50.
[258] A survey of legumes, wheat, and barley crops in Greece between 1931 and 1960 revealed a 71%, 28%, and 5% failure rate (respectively). See Peter Garnsey, *Famine and Food Supply in the Graeco-Roman World: Response to Risk and Crisis* (Cambridge: Cambridge University Press, 1988), 10.

When climate change altered both the North Atlantic and the Indian monsoon climate systems, even Rome's mighty aqueducts, granaries, and extensive merchant marine were ill-equipped for the latest challenge. Before 536 CE, Rome could survive bad harvests for a year or two because of its integrated regional trade networks that spanned from Britain to the Euphrates and the Rhine/Danube to the Sahara. Romans could count on reliable surpluses of grain in North Africa to make up for poor harvests in Italy and Gaul, and ships could deliver it in two to three weeks for about two to five denarii per kilogram.[259] Imperial connectivity thereby allowed the Romans to escape the Malthusian trap whereby rising populations run up against the ceiling of limited local resources.[260] Adverse climate change, however, made many of Rome's suppliers less reliable, and the grim hand of Malthus began to reach ominously towards the increasingly empty plates of Romans.

The LALIA contributed much to the economic decline of the Roman and Byzantine Empires, whereas the near-equally severe and even longer-lasting medieval Little Ice Age eventually launched Europe into the Renaissance and the Industrial Revolution.[261] This observation has led historians and climatologists to formulate the sound hypothesis that the lower the level of development of civilization, the more prominent role that adverse climate change plays in its decline.[262]

The evidence indicates that the environmental catastrophe of 536 was ruinous, and its impact eclipsed that of the abdication of the last Roman emperor in 476 CE. Historians might

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[259] Walter Scheidel, "The Shape of the Roman World: Modelling Imperial Connectivity," *Journal of Roman Archaeology* 27 (2014): 18.
[260] Robert Malthus, *An Essay on the Principle of Population* (London: Oxford World's Classics, reprint of 1798).
[261] See Figure 3 in the Appendix for a comparison of the LALIA and the LIA.
[262] Johannes Koder, "Climate Change in the Fifth and Sixth Centuries?" In *The Sixth Century: End of Beginning?* Ed. P. Allen and E.M. Jeffreys. Brisbane: Australian Association for Byzantine Studies (1996): 270-285. This theory also explains why climate change had a less dramatic impact on late medieval Europe than it did on the now-extinct culture of the Anasazi (Pueblo) of the southwest United States.

reconsider the somewhat arbitrary date of 476 given to schoolchildren as the official date of the end of the Roman Empire in recognition that the Empire thrived in the East for another three generations before it found itself unable to cope with the unprecedented stress of harsh climate *and* disease. [263] By 600, Eastern Roman/Byzantine rule in the Middle East was doomed, and Islam eventually took the lead in managing a new ecumenical empire of salvific universalism.[264]

The traditional timeline for the end of the Empire, therefore, needs to shift toward the mid-sixth century.[265] According to GISP2 ice cores, lead pollution from silver coin minting (a key economic indicator for archaeologists) did not fall off in 476 but increased into the early seventh century.[266] When compared with information on buried treasure hordes, this data offers an opportunity to understand the relationships between socio-economic development, climate change, and disease.[267] If the most precipitous decline of the Roman Empire centers on events after 536, then historians need to place more emphasis on Roman influence as a whole and less on the actual city of Rome—a virtual non-player on the world's secular stage since the capital of Italy had moved to Ravenna in 402.

The moniker "Dark Age" takes on a new significance. While many modern historians resist the term because it can imply the extinguishment of the light of reason, the evidence suggests that this post-Antiquity period began with a literal obfuscation of sunlight that inaugurated what English philosopher Thomas Hobbes called a long period of human life that

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[263] Gunn, *The Years without Summer*, 5-20.
[264] Aziz Al-Azmeh, "Islam and Late Antiquity: Historiography and History," in *The Emergence of Islam in Late Antiquity: Allah and His People* (New York: Cambridge University Press, 2014), 1-46.
[265] Gunn, *The Years without Summer*, 5-20. See Figure 7 in Appendix.
[266] McCormick, "History's Changing Climate, 269. Joseph R.. McConnell et al. "Lead pollution Recorded in Greenland Ice Indicates European Emissions Tracked Plagues, Wars, and Imperial Expansion during Antiquity," *Cliodynamica,* (May 19, 2018). http://peterturchin.com/cliodynamica/history-is-now-a-quantitative-science/.
[267] McConnell, "Lead pollution," 5726-5731. Peter Turchin, "The Value of Coin Hordes," *Cliodynamica* (May 26, 2018). http://peterturchin.com/cliodynamica/history-as-quantitative-science-iii-the-value-of-coin-hoards/. James Greenberg, "Plagued by Doubt: Reconsidering the Impact of a Mortality Crisis in the 2nd c. A.D." *Journal of Roman Archaeology* 16 (2003): 413-425.

was "poor, nasty, brutish, and short."[268] Historians do not need to dismiss the contributions of the later partial revivals of the Carolingians, the Byzantines, the Islamic Golden Age, or the medieval scholastics, but there is merit in subdividing the century or so after 536 as the DACP to assist historical understanding in the transition from Late Antiquity to the Early Middle Ages. Indeed, the medieval nations of England, Ireland, Spain, and the Frankish Kingdom, as well as China and Indonesia, emerged out of the forge that followed the collapses after 536 CE.[269]

Seen this way, Justinian, the last Latin-speaking emperor, might represent the last Roman emperor rather than Romulus Augustulus. This DACP thereby marks the beginning of a transition between the Roman and the Greek/Byzantine Empire as well as the dawn of a Middle Age coterminous with the long decline of the Byzantine Empire until its collapse in 1453.[270] The Catastrophe of 536 also absolves Justinian of much of the blame that historians have assigned to him for his stalled *renovatio imperii* in Italy, North Africa, and Persia.[271] Justinian the Great (a long-forgotten title) was on the verge of success until the perfect storm of environmental catastrophe and plague hit.[272] Historians do not blame the Native American chiefs for the smallpox epidemic to which their people fell, nor is it fair to list Justinian among the so-called bad emperors just because his dynamic reign coincided with an unprecedented host of cataclysmic events.[273] Unlucky may be a more fitting moniker: Justinian's resurrected empire re-

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[268] Goldsworthy, *How Rome Fell,* 19. Thomas Hobbes, *Leviathan,* C.B. MacPherson, ed. (New York: Penguin Classics, 1985), 628.
[269] Keys, *Catastrophe,* 105-146.
[270] Karl W. Butzer, "Collapse, Environment, and Society," *Proceedings of the National Academy of the Sciences of the United States of America* 109, no. 10 (March 6, 2012): 1-8.
[271] John Atkinson, "Getting to Know Justinian," *Summa Eloquentia,* 19-29.
[272] See a notional model of population decline in Figure 8 in the Appendix.
[273] J.A.S. Evans sums up Justinian this way: "[His] reign is a recital of earthquakes, floods, invasions, and after 542, repetitions of plague which established permanent cycles of infection." See J.A.S. Evans, *The Age of Justinian: The Circumstances of Imperial Power* (New York: Routledge, 1996), 163. In this respect, Justinian, after he contracted the plague, bears some resemblance to the tragic Fisher King whose impotence and death brought war, drought, and turned the landscape into a wasteland. Charles Oman shares this assessment in *The Dark Ages: 476-918* (Oxford: Rivingtons, 1898): 90-91.

established the social and trade networks that transformed what might have been a local epidemic in Egypt into an empire-wide pandemic that became the *coup de grâce* for the Empire's hopes of a revival. The real price of the pearls, silks, and pepper from the East was not gold but plague.

As with climate, historians now recognize that disease has played an enormous role in the fall of civilizations such as the Incas or the Aztecs. It is time to accord disease a similar place in the decline of Rome, abandon the traditional Enlightenment assumption that humans are the only masters of their destiny, and afford climate and disease their proper places in Rome's decline. Historians of Rome, like their peers in other ancient histories, need to consider climate as the primary extraneous force (followed by climate-induced diseases) that exacerbated the other challenges faced by Rome: lack of manpower, diminished tax base, and the failure to hold the Western Empire.[274]

The Catastrophe of 536 marks not only the real "point of no return" for the Roman Empire but also a very dramatic change in the mentality of ordinary Christians. Modern historian Geoffrey Parker in *Global Crisis* calls such a moment a "tipping point."[275] "Absent the primary impact of exogenous epidemic disease and the secondary impact of abrupt climate change, there

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[274] Stathakopoulos, "The Justinianic Plague Revisited," 256-276. The calamitous decade after 536 also marks a better starting point for the theologically infused Middle Ages. See Reinink, *The Reign of Heraclius,* 90-94. The mindset of many Christians changed radically at this time: the sunless summers, the invasions, and the plague left Christians wondering if God had abandoned them. The loss of the Holy Land and the destruction of the beloved Nea Church in Jerusalem in the eighth century only added to the growing despair. See Avigad, "A Building Inscription of the Emperor Justinian," 145. The completion of this magnificent church prompted Justinian to boast with some justification, "Solomon, I have outdone thee." Indeed, he had. The seeming indifference of Divine Providence had shattered the hopes of some Christians who did not understand why the disease struck so indiscriminately, and many frustrated souls apostatized. This might account for the multiple church burnings in reported by Gregory of Tours. See Gunn, *The Years without Summer,"* 23. Other Christians sought a "back door" for grace through the intercession of Mary, the Θεοτόκος. While devotion to Mary goes back to the earliest days of the Church, the practice of invoking her intercession took off after the Justinianic Plague broke out. Previous appeals were usually to God directly. The Lord Himself might be deaf, they reckoned, but certainly all good sons listen to their mothers, and perhaps the intercession of the Queen of Heaven might compel its King to deliver Christians from further onslaught from the Four Horsemen of the Apocalypse.

[275] Parker, *Global Crisis,* xxvi.

is no reason to think that [the Eastern Roman Empire] might not have continued on a trajectory that was already longer than the entire history of the modern economy."[276] While such moments are difficult to establish, the decade following 536 CE may be the best candidate for that title.

According to John of Ephesus, the climate catastrophes and disease made God seem unapproachable: His mercy seemed beyond reach even with dramatic acts of penance designed to appease the "winepress of Divine wrath."[277] This mentality laid the seeds for some theological and liturgical excesses that continued until reformers called for a more Christocentric focus in intercessory prayers and a return to a theology where Divine mercy was freely given rather than seemingly merited. The process had come full circle by the sixteenth century. On the positive side, Christians found in the various famines and plagues opportunities to prove the superiority of their faith over pagan religions by feeding the hungry, caring for the sick, and burying the dead, even as non-Christians practiced little such obligations of charity.[278] Roman citizens had little use for the pagan religions after the plague, and Christian communities that cared for sick believers may have had a lower mortality rates.[279]

The role of the emperor and state also evolved significantly during the reign of Justinian. After the climate change and plague, the great reconqueror and lawgiver reduced his role to that of the old Republican Roman *pontifex maximus* (i.e., bridge-builder) responsible for the peace between heaven and earth.[280] This liturgical function led to his growing entanglement in theological disputes, and Saint Justinian (in the Orthodox tradition) and his successors established a solid foundation for state domination of the Church that characterized the East until

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[276] Brooke, *Climate Change,* 349.
[277] John of Ephesus, *Historia Ecclesiastica,* III.
[278] Sarah K. Yeomans, "The Antonine Plague and the Spread of Christianity," *Biblical Archaeology Review* (March/April 2017) notes that people turn toward religion in troubled times. The rapid expansion of Christianity in the late second century (like the mid-sixth century) coincided with the Empire's first pandemic.
[279] Rodney Stark, *The Rise of Christianity* (Princeton: Princeton University Press, 1997), 73-94, 113-116.
[280] Mitchell, *A History of the Later Roman Empire,* 416-424.

the fall of the Romanovs.[281] In taking on the role of θειοτατος και ευσεβεστατος ("divine and pious master"), the emperors increasingly neglected true matters of state.[282]

Thereafter, the Byzantine Empire ruthlessly suppressed heresy and took sides in bloody religious conflicts. While in the West, the constant rivalry between Church and State often produced some semblance (however imperfect) of separation between Church and State. In the East, however, there was no such competition, and so the Church's fate gradually became more tethered to that of a failing state. The shackling of Byzantium and the Church partly explains the decline of the Church in the East even well before 1453 where Muslims now constitute a majority in the region.[283]

Lastly, historians need to explore the issues of resilience and stability: what factors contribute to a society's ability or inability to recover from setbacks, particularly concerning the environment and climate change?[284] The Romans never really learned to *manage* change but

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[281] Edward Gibbon, *The Decline and Fall of the Roman Empire Volume II: The History of the Empire from 395 AD to 1185 AD* (New York: The Modern Library, 1983), 729.

[282] Jones, "Procopius of Gaza," 464. When Constantine moved the capitol to Constantinople, political authority followed him there, but religious authority primarily remained in Rome—even after Emperor Theodosius made Christianity the state religion. This allowed for a distinction between political and religious authorities in the West. Justinian, however, blurred that distinction in the East and instituted a policy of caesaropapism.[282] Later European monarchs (Emperor Henry IV, King Henry VIII, Louis XIV, and Tsar Nicholas II) often adopted Justinian's model of governance under direct authority from God in their assertions of state primacy over the Church. French philosophe Montesquieu correctly noted that the original openness of the Roman Republic and Christianity had led to their rapid expansion, whereas the tyranny that followed Justinian laid the seeds for some decline of both the Church and the State. See Mitchell, *A History of the Later Roman Empire,* 417, and Charles-Louis de Secondat, Baron de La Brède et de Montesquieu, *Considerations on the Causes of the Greatness of the Romans and their Decline* Ch. XVIII (New York: The Free Press, 1734). Accessed February 2, 2019. http://www.constitution.org/cm/ccgrd_l.htm.

[283] Mischa Meier, "The 'Justinianic Plague': The Economic Consequences of the Pandemic in the Eastern Roman Empire and its Cultural and Religious Effects," *Early Medieval Europe* 24, no. 3 (2016): 267-292. Historians often make the same case for the fate of the Russian Orthodox Church in the aftermath of the Revolution. *The World Factbook* (Washington: Central Intelligence Agency, 1995), 426.

[284] Adam Izdebski et al, "The Social Burden of Resilience: A Historical Perspective," *Human Ecology* 46 (2018): 291-295. As an example, Izdebski notes that seismic activity in the Mediterranean increased fourfold over the sixth century.

instead merely reacted to it, often too late.[285] Events like the Catastrophe of 536 are part of the game: humans need to prepare for uncertainty and surprise and learn to live with them.[286] Rome's command-and-control approach meant it failed to find a balance with nature and to diversify its food resources to include drought- and frost-resistant grains like rye that might have allowed for more sustainable development.[287] When temperatures dropped, and glaciers advanced down the cultivated fields in the mountains, non-indigenous crops like grapes and olives died off.[288]

Policy-makers and strategists can learn the historical lessons that climate catastrophe offers to modern civilization. Even complex and densely populated societies are not immune from the effects of climate change, and in fact, may be most at risk from it. Analysts now rank climate change as an emerging national security threat and find in Roman vulnerability to climate change a lesson for modern society. More extreme weather events (such as megadroughts, floods, cyclones, and heatwaves) put greater stress on critical ecosystems than ever before, and global efforts are underway to counter the effects.

These weather events have triggered political, societal, economic, and even security threats.[289] Like the Romans, people who live in climate-vulnerable locations like coastal areas, water-stressed regions, and dense urban areas are the most impacted by climate change.[290] New national security challenges from climate change have brought threats to regional stability and heightened socio-political tensions. This process of decline generates adverse effects on food

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[285] Reale, "Modeling the Effects of Vegetation on Mediterranean Climate, 212-213. Computer models suggest that simply reintroducing the vegetation that existed in the Roman Classical Period would produce a significant change in climate and moister conditions in North Africa.
[286] Folke, "Resilience: The Emergence of a Perspective for Social-Ecological Systems Analyses," 255.
[287] G. Barker, *Prehistoric Farming in Europe* (Oxford: Oxford University Press, 1985).
[288] Huntington, "Climatic Change and Agricultural Exhaustion," 176.
[289] Haldon, *The Empire that Would Not Die,* 223.
[290] Dario Camuffo and Silvia Enzi, "The Analysis of Two Bi-Millennial Series: Tiber and Po River Floods." in *Climatic Variations and Forcing Mechanisms of the Last Two Thousand Years,* ed. Phillip D. Jones, 433-450 (Berlin: Springer-Verlag, 1996).

availability and prices, increased risks to human health, and negative impacts on the global economy. The parallels between the challenges during Antiquity and the present have attracted attention among policy-makers who link climate change to wildfires, crop failures, hurricanes, and even outbreaks of Ebola. Think tanks note how climate change causes political instability, weakens state authority, drives immigration, and even causes riots and wars.[291] The Pentagon repeatedly identifies climate change as a "threat magnifier" that has the potential to amplify pre-existing political fault lines.[292] Countries with weak political institutions and under-performing economies are the most vulnerable to climate-linked instability.[293]

The role that CO_2 emissions may play in climate change makes understanding its role even more critical at a time of record warmth.[294] Some scientists warn that a failure to reduce greenhouse gases could cause destructive climate change.[295] The scientific evidence collected thus far suggests that solar forcing has been the primary cause of historic climate change, and

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[291] For example, Syria's worst drought in almost a millennium contributed to a quartering of its wheat production and helped foment the bloody civil war there that has claimed over 300,000 lives and displaced more than three million. See "War and Drought Produce Syria's Worst Wheat Crop in Thirty Years," *Hurriyet Daily News Online*, October 8, 2018, https://www.zamanalwsl.net/en. 4 March 2016. Megadroughts in Afghanistan and Iran have contributed to political instability and violence in those countries. See Kalie Mangelsen, "Afghanistan's Droughts and the International Community's Response," *Publication of the Organization for World Peace*, October 22, 2018, https://theowp.org/reports/afghanistans-droughts-and-the-international-communitys-response/. The terrorist group Al-Shabab exploited the 2011-2013 famine and riots in Somalia to gain political power. See Mark Tran, "Al-Shabaab in Somalia Exploited Aid Agencies during 2011 Famine," *The Guardian,* December 8, 2013, https://www.theguardian.com/global-development/2013/dec/09/al-shabaab-somalia-exploited-aid-agencies-famine. In Mali, extremists exploited the megadrought in the Sahel and started a "food for jihad" program. See "The Sahel: Mali's Crumbling Peace Process and the Spiraling Jihadist Threat," *Watch List.* Publication of the International Crisis Group. 1 March 2017. https://www.crisisgroup.org/africa/west-africa/mali/sahel-malis-crumbling-peace-process-and-spreading-jihadist-threat.

[292] Dan Lamothe, "Climate Change Threatens National Security, Pentagon Says," *The Washington Post,* October 13, 2014, https://www.washingtonpost.com/news/checkpoint/wp/2014/10/13/climate-change-threatens-national-security-pentagon-says/?utm_term=.31950e54ec73.

[293] Christian Parenti, *Tropic of Chaos: Climate Change and the New Geography of Violence.* (New York: Nation Books, 2011).

[294] Martin-Chivelet Javier et al. "Land Surface Temperature Changes in Northern Iberia since 4000 Yr BP, Based on δ13C of Speleothems," *Global and Planetary Change* 77 (2011): 1-12.

[295] Al Gore, *An Inconvenient Truth: The Planetary Emergency of Global Warming and What We Can Do about It.* (New York: Rodale, 2006), 133-155.

volcanos and oceanic wind currents play significant roles.[296] However, it is impossible to reproduce the late twentieth-century warming without reference to anthropogenic forcing.[297] CO_2 levels have never been this high in the Holocene Era, and average temperatures now exceed those of the Roman Warm Period. Because of this, scientists continue to collect evidence to determine what role CO_2 plays in climate forcing.[298]

Coincidence does not prove causality, and no doubt civil strife, war, and resource exhaustion played a role in Rome's collapse, but inter-disciplinarian historians are correct in their assertions that it is narrow-minded to hypothesize that anthropogenic climate change was the sole cause for the decline. Climate change is not new nor always bad.[299] The parallels between human progress and wet/warm climates as well as similarities between migration and parched/frigid climates are not merely matters of coincidence.[300] Global warming has generally had a *positive* effect on evolution: from the creation of the Earth when the sun's energy level was only 75% of its value today to the emergence of first life as well as from the rise of the *homo* genus to the rise of the *sapiens* species.[301] The end of the Ice Age opened the way for the advent of agriculture and the rise of the first advanced civilizations.[302] Both plant and animal populations tend to grow and expand during warm periods and decline and contract during cooler ones, even if many see only trouble in global warming today.[303]

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[296] Beer et al. "The Role of the Sun in Climate Forcing," 403. Gray,"Solar Influence on Climate," 1-53.
[297] Gray,"Solar Influence on Climate," 40.
[298] Heinz Wanner et al. "Mid- to Late Holocene Climate Change: An Overview," *Quaternary Science Review* 27 (2008): 1791-1828.
[299] Huntington, "Climatic Change and Agricultural Exhaustion as Elements in the Fall of Rome," 184. It is also worth noting that climate change cannot be "stopped" as many politicians are wont to do. That said, reducing CO_2 emissions may reduce the global rise in temperatures of the past two decades.
[300] McCormick, "History's Changing Climate," 251-273.
[301] Beer et al. "The Role of the Sun in Climate Forcing," 404.
[302] B. Christiansen and F. C. Ljungqvist, "The Extra-Tropical Northern Hemisphere Temperature in the Last Two Millennia: Reconstructions of Low-Frequency Variability," *Climate of the Past* 8, no. 2 (2012): 765-786, https://doi:10.5194/cp-8-765-2012.
[303] Sakia Hin, *The Demography of Roman Italy: Population Dynamics in an Ancient Conquest Society 201 BCE-14 CE* (New York: Cambridge University Press, 2013).

Conversely, palynological records suggest that the rise of civilizations often led to ecological devastation that in turn played a role in civilizations' decline. Although such declines might then promote ecological renewal in some cases, aridity has had a particularly devastating impact on pastoral-nomadic life and contributed to human migrations during the three major global Dark Ages (2200-1700 BCE, 1200-700 BCE, and 536-900 CE).[304] Demographic declines, economic disintegration, political chaos, and de-urbanization resulted from these migrations. If modern society fails to recognize its impact on the environment, it may help drive the Earth toward a fourth major Dark Age. History on climate change can serve, therefore, as a clarion call for humanity to adjust its environmental policies lest modern society meets the same fate as the ancient Egyptians, Mycenaean Greeks, and Romans.[305]

Conclusion

While the evidence suggests that climate change has been a catalyst for many of the secondary causes that led to Rome's decline, it was not the sole determinate factor. Adverse climate change does not usually undermine a country that has a stable political system, secure borders, a thriving economy, and creative problem-solvers. However, it will exacerbate problems in countries (like Syria and Honduras) with political unrest, porous frontiers, struggling financial systems, and stagnant bureaucracies that only pay lip service to solutions. That latter scenario was Rome and Constantinople in the fifth through the sixth centuries (respectively). The problems that the Eastern Empire faced in the mid-sixth century and those Syrians and

[304] If replicability is an indicator of good historical narrative, as Gaddis asserts, climate change has certainly demonstrated its potency. See Gaddis, *The Landscape of History,* 107.
[305] Sing Chew, "Globalization, Ecological Crisis, and Dark Ages," *Global Society* 16, no. 4 (2002): 333-356.

Hondurans face today are remarkably similar: climate change acted as a trigger for political instability, mass migrations, and eventually the breakdown of civil society.

By 545, the social, political, and economic structures of the Roman Empire were no longer intact, and a new darker age began. Then, when Justinian died in 565, the realistic chances of another Roman revival died along with him, and the Islamic Conquest seventy years later halved the Eastern Empire. Hannibal, Antiochus III, and Mithridates had failed to subdue a less brittle Rome, but the whipsaw of a climate catastrophe and plague took the last ounce of vitality out of the Empire. The Eastern Empire might have survived just the climate change or the plague, but managing *both* within the same century was simply too much for an empire already overwhelmed by invasion and migration. Climate change and disease devastated the agricultural economy, ruined trade, reduced the tax base, drastically diminished the strength of the military, caused famine and civil unrest, undermined confidence in the government's ability to manage its growing problems, and signaled to new aggressors that the time to strike had come.[306] Rome could manipulate nature, but it could never subdue it.

To ignore the role of climate in Rome's decline makes history less useful. Historians must always be mindful of Marc Bloch's student son who asked about the *use* of history.[307] While separated by fifteen hundred years, the Romans' struggles to deal with climate catastrophe and disease are not theirs alone. Like the Romans, contemporary society shares in the timeless battle against Mother Nature and in finding meaning both in the subjugation of nature and in being subjugated. The use of a Roman historical narrative that includes climate change effectively renders the Romans not so much ancient forebears, but rather neighbors in the common struggle

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[306] Sarris, *Economy and Society in the Age of Justinian,* 217-219, 224.
[307] Marc Bloch, *The Historian's Craft: Reflections on the Nature and Uses of History and the Techniques and Methods of Those Who Write it,* Trans. Peter Putnam (New York: Vintage Books, 1953), 3.

of the species to survive climate change and preserve civilization.[308] The past does not have to be a foreign country where they do things differently.[309]

Climate change set the stage for the most significant setback in the history of human civilization: between the fall of the city of Rome and the high Middle Ages, real economic growth was virtually non-existent. Modern civilization has recovered from that collapse and is much less vulnerable to climate change and disease. Modern advances in microbiology, antibiotics, hygiene, and health care significantly reduce the risks of catastrophic collapse. Nevertheless, modern civilization may also succumb to the terrors of climate change if it fails to use the tools developed to mitigate the risks. The fall of Rome reminds meliorists that progress is a fickle commodity: the seemingly irreversible march of advancing civilization is only an asteroid strike or volcanic eruption away from returning humankind to another Dark Age.[310]

Climatologists have noted that the period of climate instability faced by Rome in the third, fifth, and sixth centuries bears some resemblance to the contemporary one. Today the rising numbers of global megadroughts are among the worst since the Y4.2KBP Event.[311] Megadroughts have destroyed great civilizations, and so radically altered the landscape upon which they built their empires, that there was little that could be done to reverse the decline that followed demographic collapse and eventual migration to more favorable climates.[312] Ptolemaic and Roman hydraulic engineers constructed waterwheels to raise water to areas further from the

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[308] Henri Pirenne understood this when he wrote, "If I were an antiquarian, I would have eyes only for old stuff, but I am a historian. Therefore I love life." See Bloch, *The Historian's Craft,* 43.
[309] --To paraphrase the first line of J.P. Hartley's novel *The Go Between.*
[310] Rosen, *Civilizing Climate,* 179-180.
[311] An estimated 80-100 severe weather events took place in the 1970s, whereas today there are typically more than 400 per year.
[312] Peter B. DeMenocal, "Cultural Responses to Climate Change during the Late Holocene," *Science* 292, no. 27 (April 2001): 667-673. Martin Finne et al. "Climate in the Eastern Mediterranean, and Adjacent Regions, during the Past 6,000 Years—A Review," *Journal of Archaeological Science* 38 (2011): 3153-3173.

Nile and revived agriculture there, but lift irrigation could not help when the water was so low that the brackish waters of the Mediterranean Sea moved toward the Upper Nile.[313]

A large number of unresolved questions makes it important not to draw the wrong lessons from history. For example, just how crucial is the environment in the question on the rise or fall of nations, and to what extent does human activity exacerbate the problems associated with climate change? The jury is still deliberating, and there are periods in climate history that lack coherence.[314] Is Jared Diamond correct when he asserted that environmental preconditions offer the best forecast for the fate of nations?[315] There is a preponderance of evidence to the contrary.[316] Climate does not cause history; it creates a context for it to occur and may pose some opportunities and challenges that can influence history and—in less developed societies—even become a primary driver. Does ecological Malthusianism suffer from the same defect that the Christian apocalyptic approach did when it viewed climate change as an omen of the end-times and Mother Nature as a just "punisher" for human disregard for the environment and climate change?[317] Perhaps, and this is where some science seems to become a religion. Were anthropogenic ecological disasters among the leading causes of the decline of Rome? Most

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[313] Nick Marriner et al. "ITCZ and ENSO-like Pacing of Nile Delta Hydro-Geomorphology during the Holocene," *Quaternary Science Reviews* 45 (2012): 84.
[314] Steinhilber et al. "9,400 Years of Cosmic Radiation," 5967. Drew T. Shindell et al. "Solar Forcing of Regional Climate during the Maunder Minimum," *Science* 294 (December 7, 2001): 4102-4106.
[315] Jared Diamond, *Guns, Germs, and Steel: The Fate of Human Societies.* (New York: Norton and Company, 1997).
[316] McCormick, "What Climate Science, Ausonius, Nile Floods, Rye, and Thatch Tell Us," 88. One of the best counter-arguments that calamity is not destiny might be the example of London: in 1665, a smallpox epidemic devastated the population; in 1666, a fire nearly completely devoured it; a long period of violent political instability then followed of the sort that helped bring down Rome. London a century later was the center of the Scientific and Industrial Revolution, the capital of the world's vastest empire, and the most impressive and prosperous city since the Rome of the Caesars. Great Britain found ways of creatively reinventing itself that the Rome of late Antiquity could not. See J. Leasor, *The Plague and the Fire* (London: James Leasor, Ltd., 1962), 256-257.
[317] See Brooke, *Climate Change and the Course of Global History*.

historians say no.[318] Nevertheless, these questions are likely to continue to inspire scholars alike to research the question.[319]

The question is no longer *whether* climate change shapes history, but *how*?[320] Historians must look at all the evidence to identify the biases that come from a previous dearth of environmental data from the revered historical sources whose works form a virtual canon of dogmatic historiography. Science "has shown itself more capable… at eliciting agreement on the validity of results across cultures, in different languages, and among highly dissimilar observers."[321] Studies of climate cycles and patterns on centennial timescales and the development of models to understand climatic variations are important if the next generation of climatologists wants to forecast future changes in climate and advise leaders how to dedicate resources to cope with it.[322] Gaddis is correct when he notes that historians need to "interpret the past for the purposes of the present with a view to managing the future."[323] We must strive to understand the history of ecosystem dynamics, develop best practices to respond to that change, build adaptive capacities to deal with surprises, and support the government institutions and commercial networks that allow it to adapt.

The ahistorical idea that views progress as inevitable blinds many post-modernists and doubtless affects their historiography. Catastrophe preoccupied sixth-century Romans as they

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[318] Kyle Harper, "Civilization, Climate, and Malthus: The Rough Course of Global History," *Journal of Interdisciplinary History* 45, no. 4 (Spring 2015): 565.
[319] Though beyond the purview of this research, one might also ask: How do solar, volcanic, and CO_2 forcing interact to cause global warming? Scientists still lack the evidence to say with certainty given that CO_2 forcing has not been a factor in global warming in the last several hundred thousand years. One model suggests that greenhouses gases may account for about half of the recent temperature variability. See Beer et al. "The Role of the Sun in Climate Forcing," 413. Some scientists even estimate that were it not for the warming trend caused by CO_2, the northern hemisphere might undergo another period of cooling! See Wanner et al, "Holocene Climate Variability," 262.
[320] Harper, "Civilization, Climate, and Malthus," 557.
[321] Gaddis, *The Landscape of History, 37.*
[322] Jones et al. "A High-Resolution Late Holocene Lake Isotope Record," 361.
[323] Gaddis, *The Landscape of History,* 10.

waited for the next and final sign. In geological terms, the Mediterranean climate and tectonics are unstable, and it was especially that way in the sixth century. Rapid climate change, flood damage, deforestation, and soil erosion were frequent in the ancient world.[324] Anthropocentric post-modernists need to refrain from assuming blame for the sorts of ecological disasters that have been endemic to the Earth since its creation and prepare to mitigate the risks of the climate change over which it might have some degree of control. Historians must likewise not project environmental agenda into an interpretation of history, but instead, let the light of history project on to those modern environmental concerns.[325]

The importance of this question—the causes of Rome's decline—has never been more apparent: as the Earth undergoes its most significant climate change since the end of the last Ice Age, history offers some invaluable lessons about how previous civilizations have tried to cope with it. Abrupt or even slow climate change has the potential to dramatically alter standards of living and even put an end to the seemingly unstoppable trend of human progress. Like the ancients, modern peoples have learned to subdue the Earth; climate change, however, is not so easily subdued. Civilizations have historically struggled to cope with adverse climate change, and indeed, many have perished because of it.

While the relatively stable, warm, and humid climate of today makes climate catastrophe seem very remote, the historical evidence suggests that humankind is only one massive volcanic eruption away from another catastrophic global cooling event and simultaneous famine and disease.[326] The dust veil and subsequent nuclear winter conditions from a future eruption of the

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[324] Harris, *The Ancient Mediterranean Environment between Science and History,*186.
[325] Peregrine Horden and Nicholas Purcell. *The Corrupting Sea: A Study of Mediterranean History.* (Oxford: Blackwell Publishers Ltd., 2000).
[326] Disease often follows abrupt climate change. In 2016, two dozen people were infected and a child died from an anthrax outbreak in Siberia. Smallpox had infected a dead reindeer seventy years before, and the melting permafrost re-exposed the disease to the victims. See Michaeleen Doucleff, "Anthrax Outbreak In Russia Thought To Be Result Of Thawing Permafrost," *NPR Morning Edition* (August 16, 2016),

465-mile-wide caldera in Yellowstone National Park might have the same effect on temperature that three large eruptions did for the Romans. An eruption of that caldera ca. 640,000 years ago launched 1,000 km^3 of Earth into the stratosphere and gradually wiped out most life in North America.[327] Modern civilization ignores the climate's impact on health and progress at its own peril.

Understanding the historical significance of climate change and humanity's response is critical to the survival of the species.[328] Contemporary historians have an opportunity to integrate new data into the historical narrative to ensure that the next generation of history students has a more thorough understanding of Mother Nature's hand in the rise and decline of civilizations.[329] At a time of dramatic climate change, knowledge of how ancient societies adapted to it (or failed to adapt to it) will make history a readily practical subject matter for study.

Historiographer Jonathan Theodore, in *The Modern Cultural Myth of the Decline and Fall of the Roman Empire,* argues that the decline of Rome is not a mere matter of historical fact but a complex social construct.[330] Every age and civilization asks why Rome declined and answers the question with its own insecurities in mind. Gibbon had the British Empire in mind. The West in the twenty-first-century is preoccupied with climate change, and so it should come

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https://www.npr.org/sections/goatsandsoda/2016/08/03/488400947/anthrax-outbreak-in-russia-thought-to-be-result-of-thawing-permafrost.

[327] L Siebert et al. *Volcanoes of the World,* 3rd ed. (Los Angeles: University of California Press, 2010), 28–38. Another source, Robert B. Smith and Lee J. Siegel, *Windows into the Earth: The Geologic Story of Yellowstone and Grand Teton National Parks* (New York Oxford University Press, 2000), 47-64 notes a smaller volume of ash for that eruption, but uses the 1,000 km^3 for another two million years ago.

[328] John Haldon, *The Empire that Would Not Die: The Paradox of Eastern Roman Survival, 640-740* (Cambridge, MS: Harvard University Press, 2016): 215-248.

[329] See Susanne Kerner, *Climate and Ancient Societies* (Copenhagen: Museum Tusculanum Press, 2015) for an excellent treatment of lessons learned from ancient societies responding to climate change. Frank McDermott, "Paleo-Climate Reconstruction from Stable Isotope Variations in Speleothems: A Review," *Quaternary Science Reviews* 23 (2004): 913. For example, six thousand years ago, the American Mid-West shifted from forest to prairie in less than a century and dramatically altered human life there.

[330] Jonathan Theodore, *The Modern Cultural Myth of the Decline and Fall of the Roman Empire,* (Manchester: Palgrave Macmillan, 2016).

as no surprise that historians are beginning to deliberate on climate change as a factor. However, climate change is more than just a fashionable obsession: it is a revolutionary discovery based on solid science. Future generations of Roman historians may not share contemporary anxieties about climate change, but they will have a hard time discounting the science that sheds light on the subject. To paraphrase Gibbon's famous maxim, we should not ask why climate change has not been part of the debate, but rather marvel that it has been outside the debate for so long.

Appendix

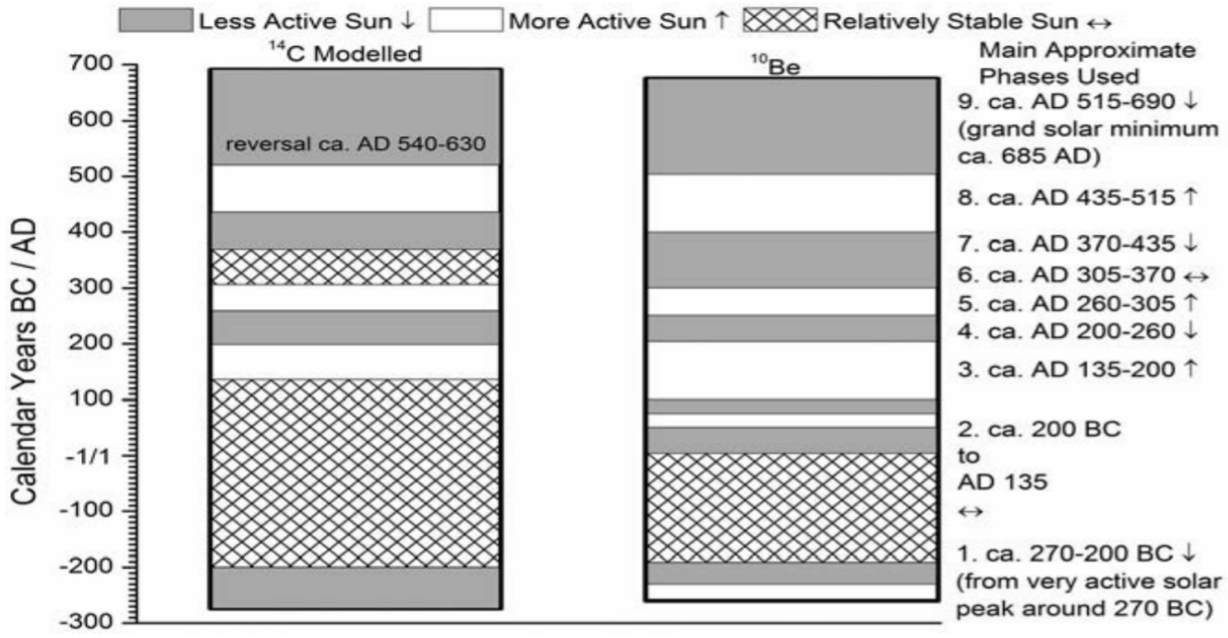

Figure 1: Note how the relatively stable and more active sun correlates with the Roman Climate Optimum, the Roman peak, Constantine's revival, and Justinian's revival, and how the less active sun correlates with the Third Century Crises, the fourth-century decline, and the late sixth century crises.[331]

[331] Manning, "The Roman World and Climate," 134.

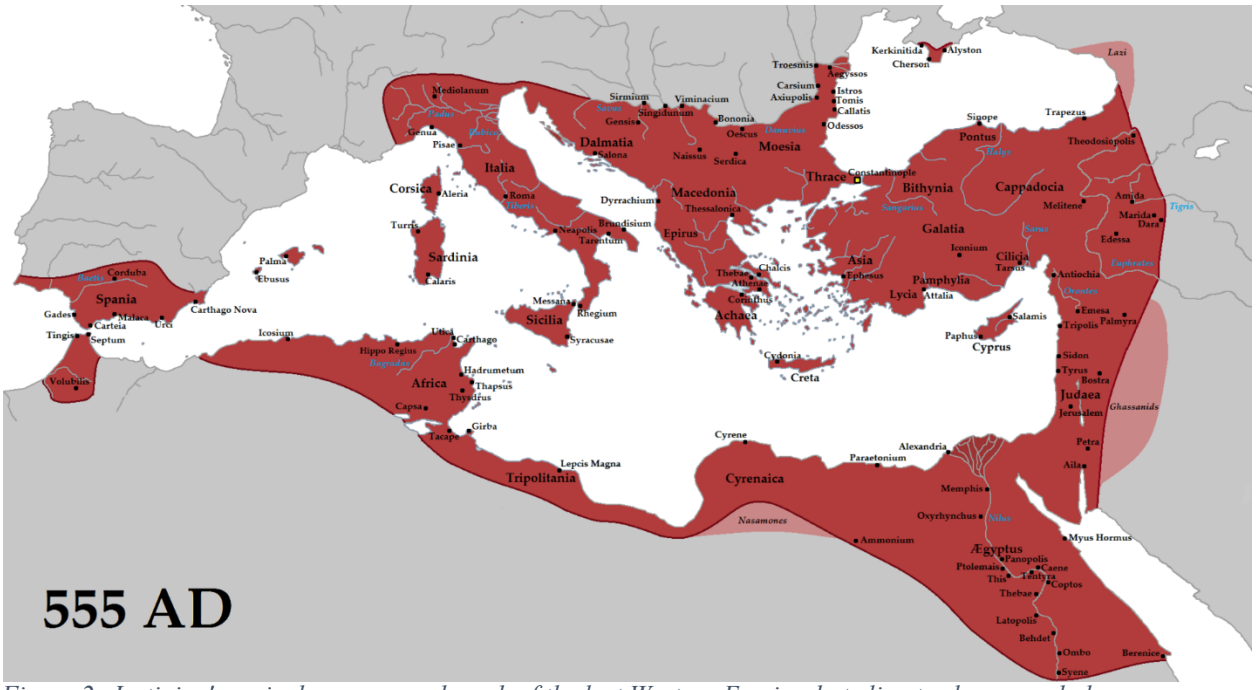

Figure 2: Justinian's revival reconquered much of the lost Western Empire, but climate change and plague gradually undermined these achievements. A century later, the Eastern Empire had been reduced to a rump state in Anatolia.[332]

[332] "Justinian," *Wikipedia*, accessed 26 March 2019.

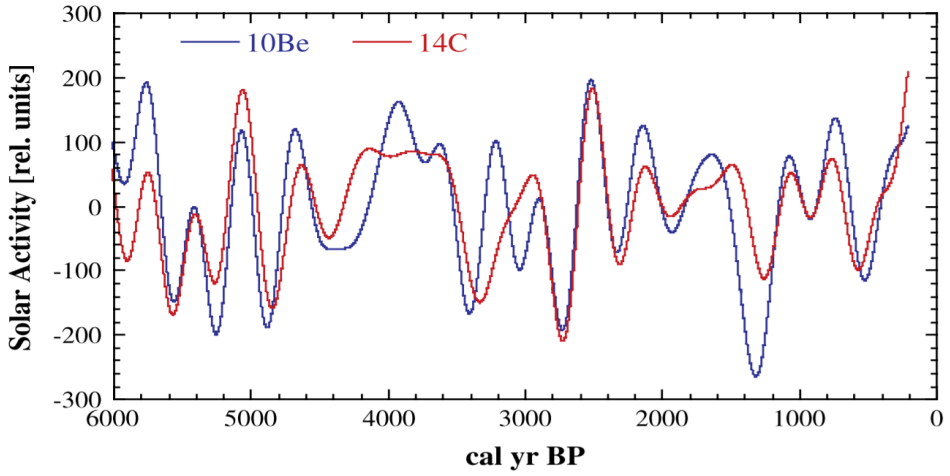

Figure 3: Reconstruction of solar activity based on ^{10}Be and ^{14}C in Greenland ice cores. Note the abrupt drop in solar activity 1500 years ago.[333]

[333] Wanner, "Mid- to Late Holocene Climate Change," 1801.

Figure 4: A view of Scythopolis--one of the many cities that thrived in the sixth century Middle East that was abandoned after climate brought drought to the region.[334]

[334] Avraham Graicer, *Scythopolis,* aerial photograph, date unknown, https://commons.wikimedia.org/w/index.php?curid=441. Accessed 26 March 2019.

Figure 5: Christ Surrounded by Angels, San Vitale and Bishop Ecclesius. Apse. 6Th. Ravenna. Italy. Note Christ enthroned on a blue sun.[335]

[335] Artist unknown, *Christ Surrounded by Angels, San Vitale and Bishop Ecclesius*. Apse of San Vitale Church, Ravenna, Italy, 538-545 CE, photograph taken in July 2016 by the author.

Figure 6: Sacrifice of Abel and Melchizedek in San Vitale Church in Ravenna. Note the apparent shock wave and fiery clouds that may depict the shock wave of a comet or asteroid entering the atmosphere.[336]

[336] Artist unknown, *Sacrifice of Abel and Melchizidek,* San Vitale Church, Ravenna, Italy, 538-545 CE, photograph taken in July 2016 by the author.

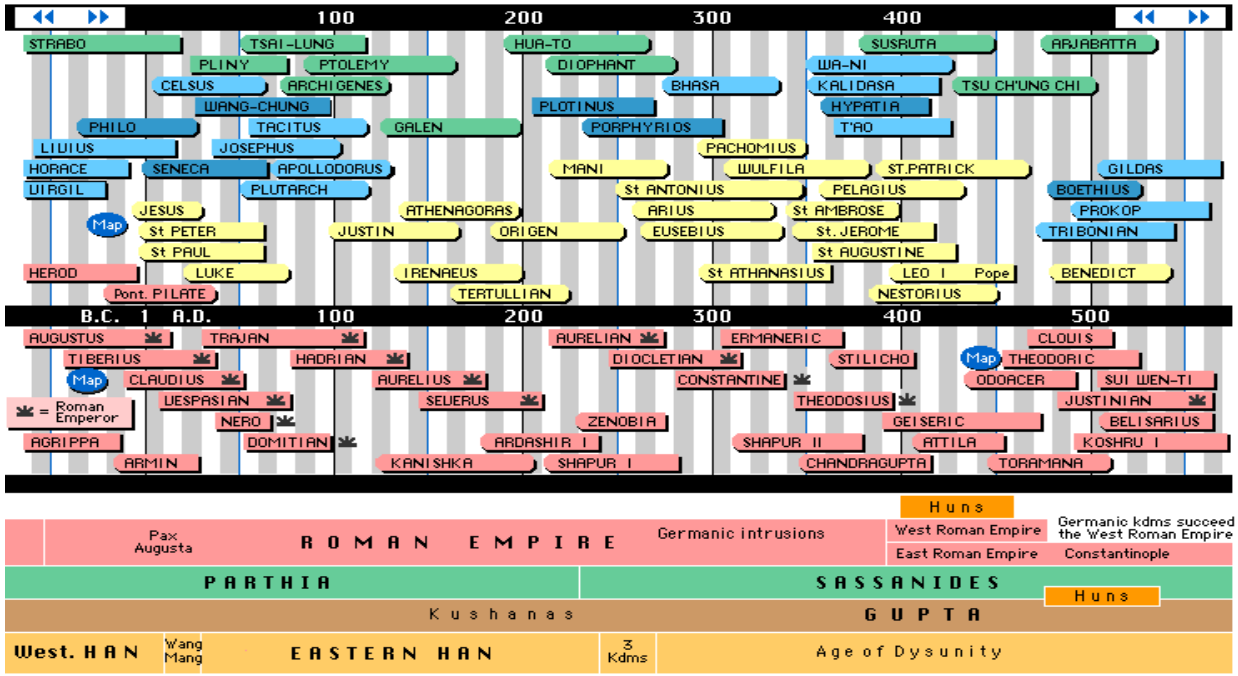

Figure 7: An alternate timeline of the Roman Empire that does not end in 476 but continues into the late sixth century.[337]

[337] Pslimajr, posted January 3, 2008, http://timelinelinhadotempo.blogspot.com. Accessed 26 March 2019.

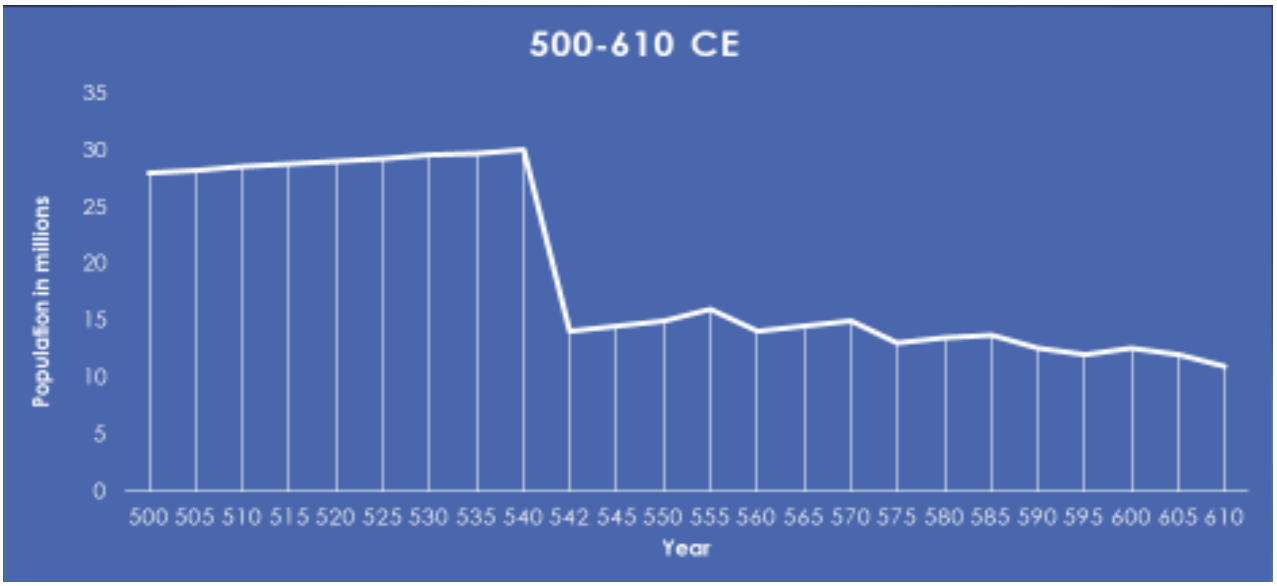

Figure 5: Notional Model of the Eastern Roman Empire Demographic Decline in the sixth Century.[338]

[338] Notional data taken from Harper, *The Fate of Rome*, 245.

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