COMMENTARY

Radiocarbon dating the end of urban services in a late Roman town

Michael McCormick[a,b,1]

The fall of the Roman Empire was a much bigger deal than a generalissimo's deposition in 476 CE of Romulus Augustus (a child puppet ruling the empire's impoverished western half), an event memorized by generations of high schoolers. Recent research has uncovered a big, complex story that still features barbarian migrations and massive religious conversion. But archaeologists have also been unearthing the economic transformations of the age, including dislocation, impoverishment, and urban decline in the western provinces in the 400s, and simultaneous dynamic economic growth and booming cities in the richer, more populous eastern half of the Roman Empire during what Holy Land archaeologists term the Byzantine period. Most specialists now consider the later Roman Empire to have been a going concern into the 600s. Written evidence continues too to grow. New online resources capture hitherto unnoticed, often anonymous, Latin and Greek written records documenting topics like the later Roman Empire's slave society (1). Robust chronological typologies of the changing, ubiquitous, and nearly indestructible late Roman ceramic tablewares (*i*) allow archaeologists to date cheaply (and down to the century or less) different layers of their excavations, and (*ii*) enable new chronotypologies of even more common cooking and transport vessels that expand the evidence every site yields on the crucial question of chronology: When did all of this come to an end? Discarded ceramics provide a first, rough layer of dating for the rapid growth and cessation of the landfill mounds that ringed Elusa, one of the flourishing Byzantine farm towns of the Negev desert, offering a proxy measure for their economic trajectory. But a new study in PNAS by Bar-Oz et al. (2) seeks to pinpoint a turning point in the decline of late Roman or Byzantine urbanism through radiometric dating of trash heaps.

The Negev agro-cities were one of the great success stories in the burgeoning eastern Roman Empire's economy. Thanks to ingenious water management technology and strong urban markets in the prosperous Byzantine Empire of the fourth and fifth centuries CE, towns such as Elusa experienced wealth that probably reflects demand for the pricey, heady, and sweet white wines produced in their hot desert vineyards and carried by camel (Fig. 1) to the ports of Gaza and Ashkelon, whence they were exported as far as Marseilles and even Bordeaux. The wine traveled in characteristic amphoras whose design adapted to the camel racks by which they reached the sea and still testify to their origin when they crop up in excavations from France to Turkey (3).

When and why did these remarkably preserved towns dwindle into abandonment? Debate has continued since their discovery, and the hypotheses mirror broader controversies about the fall of Rome's empire (4). Was it the Persian and Arab invasions in the 600s (5)? Or did oppressive Roman taxes, social structures, and bureaucracy stifle the successful towns (6)? Could climate change in ∼600 CE have desiccated the carefully tended vineyards (7)?

Eight calibrated radiocarbon datings show that the main trash dumps at Elusa ceased receiving garbage no later than ∼550 CE. Other archaeological evidence shows that the town continued to be inhabited nevertheless. Bar-Oz et al. (2) argue that the dump dates document the end of long-standing city services, a turning point toward a downward trend. The Negev towns are part of the bigger discussion about the collapse of the mighty eastern Roman Empire and its thriving cities: archaeological arguments for urban decline were made as early as 1954, but those findings were published in Russian (8) and took decades to generate mainstream research in the West. Now, a generation of archaeologists has uncovered the prosperous cityscapes of the eastern Roman Empire and hints of their dwindling away. Most recently, as Bar-Oz et al. (2) note, archaeogenetics and paleoclimate science are unveiling the extent of what look like exogenous shocks to the resilient Roman system, in the form of rapid climate change and unprecedented disease outbreaks.

Scientists first forced historians to pay attention to eyewitness reports of a solar veiling in the spring of

[a]Initiative for the Science of the Human Past at Harvard, Department of History, Harvard University, Cambridge, MA 02138; and [b]Max Planck–Harvard Reseach Center for Archaeoscience of the Ancient Mediterranean, Harvard University, Cambridge, MA 02138

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[1]Email: sohpchair@fas.harvard.edu.

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Fig. 1. The camel driver Orbikon with his amphora load. From the mosaic pavement of a church at Kissufim, Israel, which stood 5 km from the Roman road connecting the Negev wineries to Gaza. Collection of the Israel Antiquities Authority. Photo © The Israel Museum, Jerusalem.

536 CE that lasted 14 to 18 mo (9). In 2015, polar ice cores showed that this event was volcanic (10); in 2016, climate scientists connected it and subsequent eruptions with a newly reconstructed drop in average summer temperatures of ∼1 to 3 °C across Eurasia from 536 until the 630s at least, defining a Late Antique Little Ice Age (11). In 2018, tephra from a European ice core located that volcano in Iceland (12), which will allow reconstruction of the varying impact of hemispheric cooling.

Unevenly preserved historical records mention great epidemics that struck the Roman Empire, beginning with the Antonine Plague (∼165 to 180 CE) whose pathogen remains unidentified. These great epidemics culminated in the pandemic that bears the name of Justinian, the reigning emperor, and that eyewitnesses describe as a crescendo of death. Starting in 541 and continuing until 750 CE, a terrifying disease pulsed out of the Roman ports of Egypt across the Mediterranean world. Among the first places it struck were the towns along Egypt's Negev border (13), plausibly including Elusa. Ancient DNA (aDNA) has ended debate about the pathogen's identity: After early contested results, multiple laboratories have now robustly identified the pathogen as *Yersinia pestis* (bubonic plague) and reconstructed its genome, setting the stage for a bigger debate founded on archaeology and bacterial phylogeny about the extent and frequency of the waves of death. By coincidence, the first and second robust identifications (14, 15) of the bacterium in burials from around 550 CE took place far from where the disease first emerged, in Bavaria, an exceptionally well-explored region where no one knew that the Justinian Plague had reached. Bavaria offered a kind of "goldilocks" zone, where good conditions allow the recovery of human remains that still bear aDNA of the pathogen that killed them. A third successful study (16) reported much more plague aDNA in the areas it investigated: Positive results from three new sites in Bavaria and the first robust results from Mediterranean France and Spain where historical records claim the disease struck in the 500s. Surprisingly, Anglo-Saxon Britain also yielded *Y. pestis* victims. Mapping each outbreak of a disease that returned regularly for 200 y will be arduous, and it must extend to the Levantine territories of Bar-Oz et al.'s (2) Byzantine Empire, where historical records say the plague began but where environmental conditions are also less favorable for preserving aDNA.

A few have pointed to these exogenous shocks from the climate and disease as critical factors weakening the empire en route to Rome's final fall (17, 18), while others deny their importance in favor of traditional political, social, and military causes (19, 20). Hence the importance of absolute dating ancient landfills (2). While military defeats involving massive death and destruction by fire can be relatively easy to observe archaeologically, economic and urban deterioration leaves more subtle material traces, especially in major ancient cities such as Constantinople (Istanbul) or Alexandria, where modern construction obliterates the delicate residue of ancient decline. Even in permanently abandoned towns like Elusa, it is hard to decipher when, exactly, between ∼500 and 700 change occurred and of what sort. Closely connected with the question of when is the question why. Ceramic-based dates are insufficiently resolved; the absence of roughly datable pots may not mean the absence of people (e.g., if trading networks supplying the tableware changed). This is precisely where the organized removal of trash from late Roman cities offers new insights when its cessation can be robustly and carefully dated by radiocarbon.

There is no sign of violence in these towns' deaths. Did the towns die quickly or slowly? Did they share a common fate or did each die in a different way, for different reasons, at different times? The Weizmann Institute of Science team (2) has developed a promising approach for dating when major changes started, by applying geoarchaeological sediment analysis, quantification, geographic information system data, extensive archaeological dating (ceramics, coins, glass) and, especially, multiple radiocarbon datings to the landfill mounds generated by one of these settlements (2).

Organized trash removal was a regular feature of life of these towns and, probably, of many like them across the empire: The need for its systematic study has been clear for some time (21). The end of such trash removal looks like a robust proxy for the cessation of normal urban services and practices, making it an important marker on Roman towns' path to oblivion. In itself, the change in urban behavior could hold further implications. If trash was no longer being removed but dumped inside the town by individual households, this suggests vacant space, perhaps reflecting declining population; moreover, accumulating garbage attracts pests that feed on it, allowing their populations to grow in closer contact with the human inhabitants. At one site inside late Roman Naples, such dumping in a vacant lot has been archaeologically dated about 100 y earlier than the Elusa results, which fits well with the western Empire's precocious urban decline (22). Among the vermin one could expect in such intramural trash deposits (and which was abundant in the Naples dump) is the black rat (*Rattus rattus*), the assumed main host of *Y. pestis* in the late Roman world. Although devilish to detect archaeologically, excavating these small mammals will be crucial to deciphering the spread and impact of plague.

And that brings us back to the exciting implications of Bar-Oz et al. (2). The new dating overlaps with those two major exogenous shocks on the Roman economy: rapid climate change starting in 536, and the Justinian Plague pandemic beginning in 541 to 542. The chronological coincidence is striking, but it is only the first step in what promises to be stimulating new debate and discoveries about how environmental change, evolving disease and human genetics, and more traditional factors of economics, governance, migration, and culture interacted over the extraordinary age of change, destruction, renewal, and resilience that witnessed the fall of the Roman Empire and the origins of medieval—and modern—West Eurasia and North Africa.

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