

VINTAGE 536: THE EFFECT OF THE LATE ANTIQUE LITTLE ICE AGE ON THE  
VITICULTURE OF SOUTHERN PALESTINE

BY

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(Under the Direction of Jordan Pickett)

ABSTRACT

The towns of Southern Palestine, producers of the famous Gaza wine, saw a marked decline in both wine production and general prosperity following dramatic climate shifts in the mid sixth century. Two natural disasters in the nineteenth century, the eruption of Mount Tambora in 1815 and the introduction of phylloxera to French vineyards beginning in 1863 provide useful proxies. Both events caused significant hunger that exacerbated public health issues in viticulture dependent communities. Indications for poor public health in the nineteenth century proxies include high relative mortality and shorter stature in affected areas. It is likely late antique viticultural communities had similar problems. However, Gaza wine was still produced during and after the Late Antique Little Ice Age. Genetic and literary evidence indicate that intercropping of grape varieties was practiced, which likely prevented total collapse of the regional industry.

INDEX WORDS: Late Antiquity, Viticulture, Wine, Climate, Negev, LALIA,

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DEDICATION

For David F. Stevens

...εὖ μὲν ἀοιδὴν

εἰδότος, εὖ δ' οἴνω καίρια συγγελάσαι.

-Callimachus

Greek Anthology 7.415

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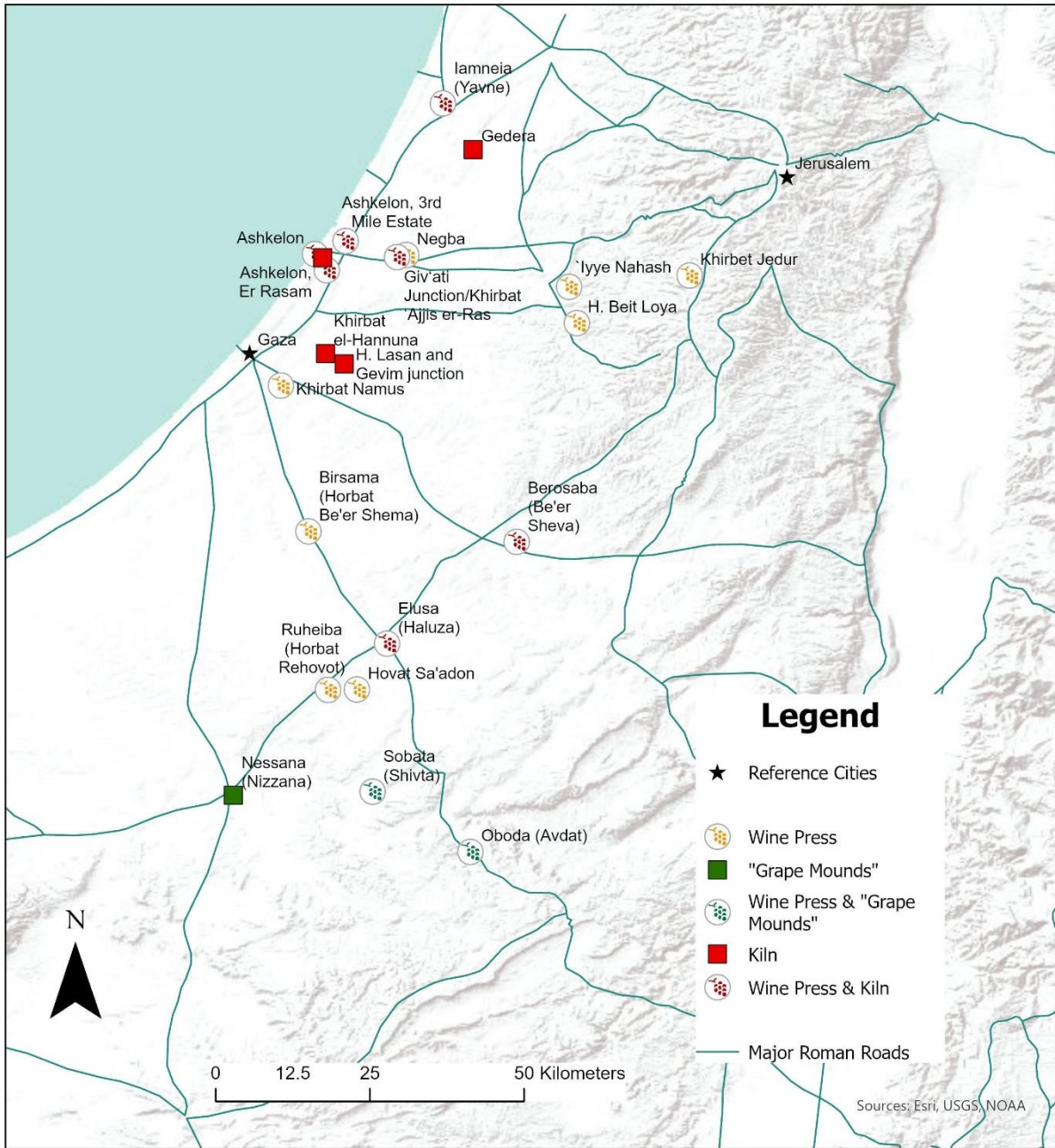


Figure 1: Map of Southern Palestine and excavated cities associated with late antique viticulture (fourth-seventh c. CE). Late antique names are used where known, with modern names inside parentheses. (Map by author.)

## Chapter 1: Introduction

My hometown, Napa California, is worried and has every right to be so. Grape vines, namely *Vitis vinifera*, whose thousands of cultivars are used for table grapes, raisins, vinegar, and wine, are highly sensitive to changes in climate. For example, the average July high temperature in the Carneros region of the Napa Valley, where I grew up, over the last four years has been 27.0°C.<sup>1</sup> In Oakville, a village eighteen miles north of my house, the average July high over the same four years is 29.7°C.<sup>2</sup> This is almost a three-degree difference, which has a profound effect on the varieties of grapes grown in these places. The cooler climate of the Carneros is well suited to Pinot Noir and Chardonnay; Oakville is famous for Cabernet Sauvignon. These grapes were bred to suit climates on opposite sides of France (Burgundy and Bordeaux respectively), and yet the large number of microclimates in Napa Valley make it possible for them to flourish a twenty minute drive from each other.<sup>3</sup> While there is intense debate about exactly which growing factors most impact grapes, whether the soil, the weather, or choices made by vintners have the greatest impact on what the wine tastes like, it is hard to dispute that climate is critical.<sup>4</sup>

While a few degrees make a big difference in what kind of grapes a region can grow, larger shifts in climate can make producing wine grapes very difficult. For example, wine grapes generally do not tolerate hard freezes, high humidity, or tropical areas.<sup>5</sup> In the face of a warming world, contemporary grape growers might have to plant

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<sup>1</sup> "Carneros, Napa - Daily Totals for July."

<sup>2</sup> "Oakville, Napa - Daily Totals for July."

<sup>3</sup> Robinson 1994 s.v Napa, Burgundy, and Bordeaux.

<sup>4</sup> Bohmrich 1996. and Bohmrich 2006.

<sup>5</sup> Robinson 1994 s.v. Climate.

heat tolerant varieties in traditionally cooler locations, change irrigation processes, or plant vineyards in higher elevations to keep the industry going.<sup>6</sup> Some areas that have been rather cold for grapes before, such as southern England, have already begun to make wine of exceptional quality.<sup>7</sup>

It is no surprise then that the looming threat of climate change is something that has the full attention of the wine industry. A lot of ink has been spilled in the popular press about how the wine industry will be affected by climate change, both in the United States and abroad. Two nineteenth century disasters, one triggered by a volcano, another by an insect, had especially dire impacts on human populations highly involved in wine production. This is not a shocking outcome: it is well documented that famine leaves lasting health impacts on survivors and makes the weakened populations more susceptible to disease.<sup>8</sup> Even when other crops ripen properly, as occurred during the French Wine Blight, the resulting drop in income from wine production and the added expense of replanting vineyards made the living people desperate and the yet-to-be-born shorter than their peers. My own ink will be used here to investigate what happened to the wine industry of Southern Roman Palestine during an earlier climate downturn, the Late Antique Little Ice Age (LALIA), when volcanic eruptions rapidly cooled northern hemispheric temperatures by up to four degrees Celsius, for as long as a few decades.<sup>9</sup>

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<sup>6</sup> Hanna 2013. 6907–12.

<sup>7</sup> Asimov 2018.

<sup>8</sup> Modern events that have yielded medical information on how famine negatively impacts long term health include the great Chinese famine (Cheng 2019) and the Dutch famine of 1944/5 (Ravelli1998, Roseboom 2001)

<sup>9</sup> See Sigl 2015, Büntgen 2016, and Newfield 2018.

The consequences of climate-induced problems with viticulture could extend far beyond sour grapes. This is especially true in areas that rely heavily on the wine industry. The towns and villages in the Negev and hinterlands of Gaza and Ashkelon were broadly involved in the wine industry between the fourth and seventh centuries.<sup>10</sup> This is evidenced by the network of winepresses and kilns that specialized in making so-called Gaza jars, also known as Late Roman Amphora or LRA 4, the signature vessel of Gaza wine, that spread across the landscape.

There is a long history of blaming the viticultural problems in the 540s on the arrival of the Plague of Justinian. In a paper published this past May, Avni et al. note “the long-term impacts of the plague on the economy and society in Palestine are reflected in the change of the economic infrastructure, as shown particularly in the decline of the wine industry.”<sup>11</sup> Michael the Syrian, a 12<sup>th</sup> century patriarch and scholar who transmits older sixth century sources, notes that in the wake of the plague’s arrival in the eastern Mediterranean “the season of picking the vineyards was over and no one was found to pluck (the grapes) because people perished in all the earth.”<sup>12</sup>

The most remarkable fact about the wine industry of Southern Palestine is not that it collapsed, but rather that it continued. Authors who lived after the hard years between 536-550 CE, including Gregory of Tours and Corrippus write widely on the virtues of Gaza and Ashkelon wine. Even when Islam, which generally condemns alcohol consumption, became the official religion of the state throughout West Asia, wine production continued. Paulus Aegineta, a seventh century physician and medical

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<sup>10</sup> Ayalon 2009 has valuable information on wine presses; Seligman 2020 discusses kilns.

<sup>11</sup> Avni 2023.

<sup>12</sup> *Michael the Syrian* 9.28.

writer prescribed a mixture of Ashkelon wine, honey, and herbs to help pass kidney stones.<sup>13</sup> In the face of a dramatic and likely disastrous climate event that would have severely damaged the grapevines, southern Palestine remained a famous viticultural area for another century. Although the volume and nature of the wine trade changed: it did not die. This is potentially due to a practice long recommended by Roman agricultural and viticultural writers. It was advised to plant several varieties in one vineyard, both to spread out the work of making wine and to ensure that something would ripen properly, even if the weather was difficult.<sup>14</sup> Some vines must have weathered the worst of the cold years, and the hearty survivors could have been used to revitalize the industry. Recent archaeobotanical work has shown that multiple varieties of grapes, both red and white, grew in the vineyards of the Negev.<sup>15</sup> There is clearly more to be learned, and new tools are developing to deepen understanding. Perhaps further investigation into how a wine industry can recover from climate disasters and would help to keep the rolling hills of Napa green with vines.

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<sup>13</sup> Mayerson 1993.

<sup>14</sup> Columella, *De Re Rustica*, III.20.1-3; Palladius, *Ops Agriculturae*, 3.9.11; *Geoponika*. 5.16.

<sup>15</sup> Cohen 2023.

## Chapter 2: Sea-Colored Sun

### Literary Sources for the Late Antique Little Ice Age (LALIA)

The Dust Veil Event of 536 CE was first noticed in texts by Richard Stothers and Michael Rampino in 1983.<sup>16</sup> The two were collecting evidence of Volcanic eruptions in classical sources. Since then, historians have combed sources from across the Northern Hemisphere looking for further mentions of a persistent dry fog or dimmed sky, along with unseasonable weather, food shortages, drought, or other aspects associated with volcanic winters. One of the reasons the events of 536 CE have attracted so much attention is that it is one of the first climate events with international textual representation, with texts potentially discussing the event in languages ranging from Irish to Korean. Collected here is a summary of the known written sources that mention natural events consistent with volcanic dust veils that occurred between 536-560 CE.<sup>17</sup>

The first category of sources are historians, court academics and men of letters who were alive and writing during 536 CE. They all were part of Justinian's court, or its contemporaries. Cassiodorus was a Roman bureaucrat before he became consul and correspondent with the Ostrogothic king Theodoric in Ravenna, as the latter's *magister officiorum*. Procopius was part of Belisarius' retinue. John the Lydian was a secretary in the palace and received Imperial recognition for his scholarly skills.<sup>18</sup> Procopius, who spent 536/7 in Tunisia, Italy, and maybe Turkey observes the following:

“And it came about during this year that a most dread (δεινότατον) portent took place. For the sun gave forth its light without brightness, like the moon, during this whole year, and it seemed exceedingly like the sun in eclipse, for the beams it shed were not clear nor such as it is accustomed to shed. And from the time

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<sup>16</sup> Stothers and Rampino 1983.

<sup>17</sup> Here, I largely follow Newfield 2018 and Arjava 2005.

<sup>18</sup> All biographies found in *OCD*, *ODLA*, and *ODB*.

when this thing happened men were free neither from war nor pestilence nor any other thing leading to death.”<sup>19</sup>

Cassiodorus, who worked on behalf of the Ostrogoths at Ravenna in Italy during this time, wrote a letter to the deputy assistant of the *Praefectus Praetorio*, Ambrosius, at some point between 536-8.<sup>20</sup> The entirety of the letter is here reproduced for ease of later reference.

“Those who observe the changing order of the world frequently become agitated, since such things often presage what is shown to be contrary to habit. For nothing happens without provocation, nor does the world operate by casual accident, but whatever we see reach a conclusion is known to be a divine plan. Men are held in suspense when kings alter their own policies, and if problems should proceed other than how their practice had prepared them. But who would not be troubled with great curiosity about such events, if, in a way contrary to precedents, something mysterious should seem to come from the heavens? For just as there is a certain comfort in observing the course of seasons in their own particular succession, thus are we filled with great curiosity when such things are thought to be altered.

“What does it mean, I ask, to intently gaze upon the most conspicuous star and not witness its usual brilliance; to observe the moon, the splendor of night, in its full circumference, but absent its natural luster? Together, we all still perceive a kind of sea-colored sun; we marvel that physical bodies lack shadows at midday and that the strength of the sun’s fullest exposure attains only the dullness of a cooling tepidness, which has happened not in the momentary lapse of an eclipse, but for the duration of almost a full year.

“What a terror it is, therefore, to endure daily what usually frightens people only in the swiftest moment! And so, we have had winter without storms, spring without mingled weather, summer without heat waves. How is it now hoped to possibly attain the proper season, when the months that had ripened crops before have cooled intemperately with the northern winds? For what may produce fertility, if the earth does not warm in the summer months? How may buds appear, if the progenitress, rain, does not resume her place? Of all the elements, we find these two opposed, a perpetual chill and a difficult drought. The seasons have changed by not changing and what usually happens with the commingling of showers cannot be procured through dryness alone.

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<sup>19</sup> Procopius *Wars* 4.14.5.

<sup>20</sup> Newfield 2018.

“And therefore, let your prudence overcome future scarcity with previous stores, since there was such blessed abundance in the previous year that provisions may suffice for even the coming months. Let everything that is needed for food be stored. The private citizen will easily find necessary things when public provision has been completed.

“But, lest the present circumstance torments you with great hesitation, return to a consideration of the nature of things and let what seems uncertain to the gaping crowd become understandable by reason. For it is known to be thus disposed by divine arrangement: just as the stars of the current year have assembled in their own domains for cooperative administration, thus winter has been rendered colder and drier than usual. Hence, air laden with snow from excessive cold is not converted to dryness by the heat of the sun, but abiding its acquired density, it blocks the heat of the sun and deflects the view of human frailty. For matter of the middle air governs our ability to see, and we are able to see through this substance only as much as the thinness of its matter allows.

“For this great void, which spreads in the manner of a liquid element between heaven and earth, truly extends our vision, provided it happens to be pure and washed with the brightness of the sun. But, if it is condensed with some mixture, then, as though with a kind of taught membrane, it allows neither particular colors nor the heat of celestial bodies to penetrate. This has also happened frequently in other eras by means of a cloud cover. Hence it is that the rays of stars have been darkened daily the sun by strange color, that the reaper dreads the novel cold, that fruits have hardened at the approach of the season and that the ripening of grapes on the vine is bitter. But if this is ascribed to divine providence, we are not to fret, since by command of that very power, we are forbidden from asking for prodigies. Nevertheless, we are certain that this is hostile to products of the earth, when we no longer see proper foods nourished according to their own demands. Accordingly, let your solicitude behave so that the unfruitfulness of one year may not appear to disturb us, since it was foreseen by the founding rector of our office, that the abundance of a previous year would suffice to soften the penury to follow.”<sup>21</sup>

John the Lydian, in his treatise *On Portents* composed in Constantinople in the 540s, mentions a climate event that predicted hard times. This is the only source that provides a sense of the breadth of the area affected by the dust cloud.

“If the sun becomes dim because the air is dense from rising moisture-as happened in the course of the recently passed fourteenth indication (535/36) for nearly a whole year, when Belisarius held the consular office so that the produce (καρπός) was destroyed because of the bad time-it predicts heavy trouble in

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<sup>21</sup> Cassiodorus *Variae* 12.26.

Europe. And this we have seen from the events themselves, when many wars broke out in the west and that tyranny was dissolved, while India, and the Persian realm, and whatever dry land lies toward the rising sun, were not troubled at all. And it was not even likely that those regions would be affected by the calamity because it was in Europe that the moisture in question evaporated and gathered into clouds dimming the light of the sun so that it did not come into our sight or pierce this dense substance.”<sup>22</sup>

The second major category of written sources for the Mediterranean are chroniclers. These writers tend to have lived after the mid-sixth century, survived anonymously, were composed in a variety of languages (largely Syriac), and were primarily interested in ecclesiastical history. The earliest chronicler to mention the climate event, an anonymous writer dubbed Pseudo-Zachariah Rhetor in modern scholarship, lived and worked during the sixth century. Whoever he was, he probably witnessed the climate event and aftermath. His Syriac chronicle includes two references to a climate event that can be securely dated to 536. The first of these attests that the climate event happened around the same time as, and for the author was an omen addressing, the arrival of Pope Agapetus I in Constantinople.<sup>23</sup> He provides exact dates for the beginning and end of the dust veil event.

“He [Agapetus] came with them to Constantinople in the month of March in [indication year] fourteen, while Severus was there, and Anthimus was the head of the priests. The whole city was disturbed and the earth and all that is upon it shook at the arrival of Agapetus. The sun began to become dark at daytime, and the moon by night, while the ocean was stormy with spray from the 24<sup>th</sup> of the same month of this year until the 24<sup>th</sup> of June of the following [indiction] year fifteen.”<sup>24</sup>

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<sup>22</sup> Arjava 2005, 80.

<sup>23</sup> Pseudo-Zachariah was not fond of Agapetus. He later describes his death, in which Agapetus apparently ate his own tongue, as “a miracle”.

<sup>24</sup> Pseudo-Zachariah Rhetor 9.137. There is a lot of discussion around the translation of “stormy with spray” specifically in Arjava 2005. Arjava suggests a better translation may be “clouded by moisture” or “confused by wet clouds”.

After lots of discussion of church matters and heresy, Pseudo-Zacharias describes the winter of 536/7. The passage is fragmentary but evocative.

“The winter was [so] harsh that from the unusual amount of snow the winged creatures perished, and...there was affliction...that people in...from awful things...not in each place that they were exposed to it.”<sup>25</sup>

Frequently chroniclers who lived after the sixth century incorporate passages from earlier historians whose work has been lost. A prime example is Michael the Syrian (aka Michael Rabo), a twelfth century bishop whose account probably quotes John of Ephesus faithfully.<sup>26</sup> Interestingly, he also provides a duration of the dust veil event, but suggests it lasted eighteen rather than fifteen months.

“In the 15<sup>th</sup> year of Justinian which is the year 854 of the Greeks (536/7 CE), there was a sign in the sun the like of which had never before appeared. If it were not for the fact that we found it recorded in many sources, we would have refrained from mentioning it because it is very difficult to believe. The sun became dark and its darkness lasted one year and a half, which is for eighteen months. Each day the middle of the heaven shone faintly with a shadowy light for four hours, and every man decided that (the sun) would never recover its full light. That year the fruits did not ripen and the wine tasted like squeezed sour grapes.”<sup>27</sup>

Gregory Bar Hebraeus (aka *Gregory Abû'l-Faraj*) copied almost exactly John of Ephesus or Michael the Syrian when he composed his Syriac *Chronicon Syriacum* in the 13<sup>th</sup> c.

“And in the year eight hundred and forty-eight there was a sign in the sun the like of which had never before appeared. The sun became dark and his darkness lasted for eighteen months. Each day the middle of heaven shone faintly with a shadowy light, and every man decided that [the sun] would never recover its full light. That year the fruits did not ripen and the wine tasted like urine.”<sup>28</sup>

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<sup>25</sup> Pseudo-Zachariah Rhetor 10.175.

<sup>26</sup> Arjava 2005. John of Ephesus was also part of Justinian's court for a while.

<sup>27</sup> Michael the Syrian 9.26. Translation from Michael Rabo, and Matti Moosa. 2014. *The Syriac Chronicle of Michael Rabo (the Great): A Universal History from the Creation*. Teaneck, NJ: Beth Antioch Press.

<sup>28</sup> Abû'l-Faraj and Budge 1932.

This same account is largely repeated as well in the anonymous eighth century Zuqnin Chronicle and in the Arabic *Universal History* of Agapios of Menbidj. Both these sources list the event as occurring before 536.<sup>29</sup> Arjava suggests that this kind of chronological error is common among chroniclers.<sup>30</sup>

Sometimes, references to the climate downturn are obscure or indirect. These possible references are worth collecting and are as frustrating as they are illuminating. John Malalas, a sixth century chronicler who lived through the events, includes very little to suggest that any kind of climate event occurred between 536-550 other than in his entry for 543, where he notes that “a shortage of wine occurred”.<sup>31</sup> The *Liber Pontificalis* mentions a famine in Italy in 537 severe enough to provoke cannibalism in Liguria.<sup>32</sup> However, this famine could have been caused by men as much as weather, Italy at the time was mired in war with the Goths. The Zuqnin chronicle mentions an unusually severe winter in 540, when it “snowed three cubits deep”.<sup>33</sup> However, Arjava’s observation that this chronicler, like many, seems to get dates muddled is probably correct. The *Zuqnin Chronicle* puts the hard winter in the immediate aftermath of a devastating earthquake in Antioch.<sup>34</sup> Earthquakes that match the description hit Antioch in 526 and 528, but not 540. Arjava mentions a Merovingian hagiography of Queen Clotilde which remarks, sometime between the death of Clovis in 511 and her death in

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<sup>29</sup> Arjava 2005. The Syrian (Pseudo-Dionysius of Tel Mahre) places the event in 530/1. Agapios of Menbidj places the event in 534/5.

<sup>30</sup> Arjava 2005.

<sup>31</sup> Malalas 1986, 287.

<sup>32</sup> *LP* 60.4.

<sup>33</sup> Dionysius 1996, 68.

<sup>34</sup> Dionysius 1996, 68.

544, there was a bad year for wine in Gaul. This could be related to climate downturns after 536 or 540, or neither.<sup>35</sup>

A sparse handful of papyri from the ancient Mediterranean survive that may point to the climate downturn. Arjava combed all securely datable papyrus documents from between 521 and 560 CE looking for something useful. His findings are sparse. While there might be some small change in the kinds of leases granted, he concludes there is not enough data to make a sticking argument.<sup>36</sup> The singular papyrological document Arjava identifies that may directly involve the climate downturn is a document from Oxyrhynchus dated to 538 CE.<sup>37</sup> In it, a seller (Aurelius Anubis) agrees to compensate a buyer (Aurelius Pamouthis) for a loss because the wine from the most recent harvest went sour. I suspect that this is not an example of wine going sour from insufficient ripening. The word used in the papyrus is ὄξων.<sup>38</sup> This is a misspelling of the genitive plural of ὄξος. The word can mean either poor wine or, more commonly, vinegar.<sup>39</sup> While the ὄξ- root is used in plenty of words that suggest sourness, the literal translation may still be the best one.<sup>40</sup> It's likely Aurelius Anubis' wine was ruined by exposure to acetobacter, a bacterium that converts alcohol into acetic acid, the primary component of vinegar. Climate may have had nothing to do with this document. Aurelius Anubis' product possibly got exposed to too much oxygen or unclean vessels.<sup>41</sup>

A frustrating element of the Mediterranean historical sources is where the climate downturn is not recorded. An illustrative example can be found (or rather not found) in

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<sup>35</sup> Arjava 2005.

<sup>36</sup> Arjava 2005.

<sup>37</sup> *P. Oxy.* 16, 1974. <http://www.trismegistos.org/text/22071>

<sup>38</sup> *P. Oxy.* 16, 1974 ln 10.

<sup>39</sup> *LSJ* s.v. ὄξος.

<sup>40</sup> My favorite is ὄξυρεγγμία, meaning heartburn.

<sup>41</sup> It's worth noting that the name oxygen is derived from ὄξος.

the work of Gregory of Tours. Born somewhere between 536 and 540 CE, Gregory of Tours is one of the primary contemporary sources of late antique history.<sup>42</sup> He is a valuable source for tracking the arrival and spread of the Justinian plague in western Europe. He mentions twenty-two outbreaks that occurred between c. 543-47, complete with details about when the outbreaks occurred, whence disease arrived, and the symptoms.<sup>43</sup> However, there is no mention of colder weather, an obstructed sky, or other common markers of a dust veil event. Gregory of Tours is not the only source conspicuously missing evidence. Marius of Avenches, John of Biclaro, Victor of Tunnuna, and Isidore of Seville are other sixth century chroniclers and historians who do not mention anything consistent with a dust veil event between 535-237 CE.<sup>44</sup> Mentions of the plague appear in the *Life of Symeon the Stylite the Younger*, *Lives of the Monks of Palestine* by Cyril of Skythopolis, and the *Life of Nicholas of Sion*, but none of these mention a contemporary climate catastrophe.<sup>45</sup> This may suggest that the effects of the dust veil may have been limited. Alternately, it may suggest that for some it wasn't worth writing about, or that years of recopying left it out.

Along with a collection of sources from the Mediterranean world, there are literary sources from East Asia that suggest a climate downturn. Like most of the Mediterranean sources, they appear primarily in chronicles compiled after the sixth century and can be frustratingly vague in describing specific occurrences. China is the originator of many of these sources. The *Nanshi Chronicle* (History of the South), dating to the early seventh century, reports "yellow dust" which "fell like snow", so much that "it

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<sup>42</sup> ODLA s.v. Gregory of Tours.

<sup>43</sup> McCormick 2021.

<sup>44</sup> Arjava 2005 and Newfield 2018.

<sup>45</sup> Arjava 2005 and Newfield 2018.

filled scoops when picked up” in 536-537.<sup>46</sup> This is suspected to be dust from the Gobi Desert, whose abundance suggests an especially dry season in the region. A drought in 537 affecting Gansu, Henan, Xi’an, and Shanxi is reported in the *Gujin Tushu Jicheng*, a Qing dynasty encyclopedia. Further droughts are reported across China in 542, 543, 547, and 550. Other Chinese sources report that Canopus was visible at neither the spring nor fall equinox. Since it is the second brightest star in the night sky, and an auspicious sign associated with peace and longevity for rulers, not being able to see it may have been cause for concern.<sup>47</sup> Looking for Canopus on the evening of equinoxes as an auspicious sign, however, is a ritual not dissimilar from the American tradition of looking for a groundhog’s shadow. Both are a day-specific event, and cloudy or clear weather affects the outcome on a year-to-year basis.

The Chinese sources that are accessible to an English reader are problematic. There is not a substantial translation into English of the *Nanshi* chronicle, or the accompanying *Beishi* (History of the North) chronicle. Many of the sources cited by Arjava and Newfield, my guides in reviewing literary evidence, compile mostly the same references in their discussion of Chinese evidence, but do not seem to have been thorough in their evaluation of them. Both are reliant on unpublished research by K. D. Pang and H. H. Chou reported by Stefi Weisburd in *Science News* magazine in the eighties.<sup>48</sup> It seems neither Pang or Chou ever published their findings, even as interest in climate history took off in the ensuing decades. The sources on the snow of Gobi Dust are from David Keys’ controversial work *Catastrophe: An Investigation into the*

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<sup>46</sup> Keys 2000. Key’s book is controversial and is the only source that is quoted with this detail.

<sup>47</sup> Fong 1983, 159.

<sup>48</sup> Weisburd 1985.

*Origins of the Modern World*. It is unclear if any of the sources Newfield or Arjava reference are from authors who read Chinese. A serious, peer reviewed work on the Chinese literary sources for LALIA written by someone with a background in the source language is desperately needed.<sup>49</sup>

Other sources from East Asia are less expansive, but worth mentioning.<sup>50</sup> *Nihon Shoki* a detailed chronicle of Japanese history (going all the way back to the creation of the earth) compiled between 681-720 CE, suggests that 536 was not an easy year. There is a brief mention of people “starving of cold” during the summer.<sup>51</sup> This leads into a courtly discussion of the necessity of public granaries in “preparation for evil years”, the building of new granaries for “extraordinary occasions” and the distribution of food to places struck by famine.<sup>52</sup> The *Samguk Sagi*, the oldest surviving chronicle of Korean History compiled in 1145 CE records several notable events in the region between 536-550. In the Silla kingdoms, located in the southeastern corner of the peninsula, an unseasonably early blooming of peach and plum trees in occurred in 540 and a remarkably late spring snowfall in 541.<sup>53</sup> In the Koguryo Kingdom, which covers most of the northern and central parts of the peninsula, the *Samguk Sagi* observed early blooming of fruit trees in 540 as well as more dramatic problems. “Due to a severe

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<sup>49</sup> I am not the only person concerned about the lack of Chinese source material available in English. There is a four year old thread in Stack Exchange (<https://history.stackexchange.com/questions/51147/what-are-some-chinese-sources-testifying-the-extreme-weather-events-of-535-536-c>) where someone asked about Chinese sources for climate downturns in 536 CE. A number of Chinese sources were quoted and translated by users. These include accounts of terrible weather, famine, and even cannibalism. Since I am not able to track down and verify these translations myself, I do not feel comfortable adding them to the main body of this paper. There is clearly lots to be added to the discussion from Chinese sources.

<sup>50</sup> All of these sources have been translated into English.

<sup>51</sup> Aston 1896, 34.

<sup>52</sup> Ibid.

<sup>53</sup> Shultz 2013.

drought during the spring and summer” the chronicle records for 536 “officials were dispatched to relive the suffering of the people”.<sup>54</sup> The drought was followed by a plague of locusts, making things worse.<sup>55</sup> Unsurprisingly, 537 is recorded as a famine year in Koguryo.<sup>56</sup>

The smallest collection of texts that suggest a major climate downturn in 536-550 comes from the British Isles. These, like many of the Mediterranean and East Asian sources, tend to survive in annals compiled in later centuries and provide few details. They are worth including in the survey, however, since they help demonstrate the scale and expanse of the climate event. *The Annals of Ulster*, compiled in the fifteenth century, mention in the scant list of events from 536 “a failure of bread”.<sup>57</sup> *The Annals of Inisfallen*, compiled in the eleventh century and written in a mix of Irish and Latin, also mention bread failures occurring between 536-39.<sup>58</sup> Some editions of *The Annales Cambriae* put the battle of Camlan, which saw the death of Arthur and Mordred, and an ensuing plague in 537 CE.<sup>59</sup> However, the complicated textual history of this document, as well as the fact that Arthurian myth was well established when this annal was compiled in the tenth century, make it entirely possible that the event was added in order to incorporate an established myth into the historical record.<sup>60</sup>

### Themes and Connections

A large fraction of the Mediterranean textual sources that point to disastrous climate events between 536-550 directly mention grapes or wine. Cassiodorus, in the

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<sup>54</sup> Idem.

<sup>55</sup> Idem.

<sup>56</sup> Shultz 2012.

<sup>57</sup> University College Cork n.d. “The Annals of Ulster U536.3.”

<sup>58</sup> University College Cork. n.d. “Annals of Inisfallen: Annal AI5441 p.69-70.”

<sup>59</sup> Phillimore 1888.

<sup>60</sup> Field 2008.

two letters that immediately precede the description of altered climate in the *Variarum*, suggests raising taxes from Istria, paid in food, on account of their relative prosperity. The letter immediately following the altered climate letter discusses requisitioning supplies from imperial military storehouses and Istrian farmers to supply beleaguered Venetians since “neither wine, wheat, nor millet have been produced by them.”<sup>61</sup> Every one of his letters regarding this policy specifically mention wine (along with oil and grain) among the commodities that Istrians have and others do not.<sup>62</sup> Most of the referenced chroniclers, including Pseudo-Zacharias, John Malalas, Michael the Syrian, and Gregory Bar Hebraeus explicitly mention problems with grapes, specifically that they are sour. This is remarkable in that they are one of the few crops explicitly mentioned in the accounts. Nobody, for example, mentions beans or pomegranates failing. This reinforces that the grapes and wine had great value in the late antique world, and that their failure was a serious problem.

There are consistencies worth noting in sources from East Asia and the Mediterranean basin. Unseasonable weather, especially drought and cold, are widely reported between 536-550. Officials were called upon to provide aid, primarily through food, to affected populations. The mention of unseasonal flowering of Korean plums and peaches especially catches my attention. Like grapes, stone fruit trees both hold significant symbolic meaning in many East Asian cultures and are used to make alcohol. As much as Cassiodorus may have been dismayed for his grapes and lost wine, the Korean chroniclers may have been dismayed for their plums and lost *maesil-ju*.

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<sup>61</sup> Cassiodorus 12.26.1.

<sup>62</sup> Cassiodorus 12.22.1, 12.23.1, 12.24.1, and 12.26.1.

## LALIA: The Scientific Investigation

After Stothers and Rampino bridged the scientific and classical communities in the eighties understanding of the scope, severity, and source of the eruptions that sparked LALIA has been gradually evolving. A wide variety of nature's primary sources have been mined for knowledge, including trees, caves, lakebeds, and icecaps. Like with the literary sources, there are still a lot of gaps in our knowledge, especially when it comes to the specificities of which regions were impacted, for how long, and to what degree. What is clear is that the effects were dramatic. "Of the sixteen coldest summers north of the equator since 500 BCE" Newfield notes "six occurred between 536 and 550".<sup>63</sup> The single coldest decade of the common era in Europe was the 540s.<sup>64</sup> Summer temperatures in Europe in 536 were between 1.6-2.5 degrees centigrade cooler than the previous thirty-year mean, depending on how one calculates the dip.<sup>65</sup> While the Mediterranean texts suggest a twelve-to-eighteen month anomaly, paleoclimatology shows this was more of a fifteen-year-long depression.<sup>66</sup> The "ice age" title is not given undeservedly.

Investigation of ice cores has given important information to confirm if a historical climate event was the result of a volcano. When a volcano erupts, it spews large amounts of sulfur dioxide into the atmosphere, along with volcanic ash, debris, and other gasses.<sup>67</sup> The sulfur dioxide reacts with water and oxygen in the atmosphere to produce sulfuric acid.<sup>68</sup> This acid condenses and produces a haze which reflects the

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<sup>63</sup> Newfield 2018.

<sup>64</sup> Newfield 2018.

<sup>65</sup> Sigl et al. 2015.

<sup>66</sup> Newfield 2015.

<sup>67</sup> Volcano Hazards Program. n.d. "Volcanoes Can Affect Climate ." U.S. Geological Survey. <https://www.usgs.gov/programs/VHP/volcanoes-can-affect-climate>.

<sup>68</sup> Idem.

sun's light and heat back into space, disrupting the climate system.<sup>69</sup> Some of the acid precipitates out, and may be preserved in sheets of ice. Elevated levels of sulfates in the layers of ice cores, as well as traces of volcanic ash, confirm that a volcano erupted, the time when it erupted, and offers clues to where the historical eruption occurred.

Ice core investigations by Sigl et al. found important details about the clouding that coincide with LALIA. First, it was not one eruption that clouded the sky in the sixth century. It was two. Ice cores from Greenland showed significant sulfate spikes in both 536 and 540 CE.<sup>70</sup> Ice cores from Antarctica showed a spike in 540, but no spike in 536.<sup>71</sup> This suggests that the 536 eruption occurred in the Northern Hemisphere, while the 540 eruption occurred closer to the equator. Several North American volcanoes have been suggested as origins for the 536 eruption on account of the composition of volcanic ash also preserved in the core sample. They include Aniakchak in Alaska, Mono Craters in California, and somewhere in British Columbia.<sup>72</sup> The location of any eruption associated with 540 CE has yet to be determined. Wherever it occurred, the eruption “resulted in up to 10% higher global aerosol loading than the Tambora 1815 eruption reconstructed from our bipolar sulfate records.”<sup>73</sup> The discovery of multiple eruptions helps explain why the climate downturn lasted a long time and suggests why the literary sources don't describe all the problems happening at once. It's likely that different places experienced different effects at different times.

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<sup>69</sup> Idem.

<sup>70</sup> Sigl 2015, fig. 2.

<sup>71</sup> Idem.

<sup>72</sup> Sigl 2015, Extended Data fig. 5.

<sup>73</sup> Sigl 2015.

While ice cores show how the eruption affected the atmosphere, tree rings show how the dust veil event affected living, growing organisms.<sup>74</sup> Dendrochronology studies the patterns of tree rings left in preserved wood. When a tree has ideal temperatures and access to water, it will grow a lot and produce a thick ring.<sup>75</sup> If there is a drought, a cold snap, or other unfavorable conditions, it will produce a thin ring. These rings are especially distinctive in places where there is dramatic seasonal variability, such as at high altitudes. Büntgen et al. 2016 looked at tree rings in the Alps and Altai mountains to reconstruct temperatures from two places in Eurasia. Downed or standing Swiss Pine (*P. cembra*), European Larch (*L. decidua*) and Siberian Larch (*L. sibirica*), were cored and compared.<sup>76</sup> The results showed significantly colder weather in both locations starting in 536 CE. The 540's were 3.2 degrees centigrade cooler than average in the Altai and 1.9 degrees centigrade cooler in the Alps. The chilly weather persisted, especially in central Asia. "Thirteen of the twenty coldest decades in the Altai (Alpine) record" writes Büntgen et al. "fall in the sixth and seventh centuries." Strong correlation between the Alps and Altai records, despite the great distance between them, is strongly suggestive of hemispheric scale cooling after 536/540.

Climate proxies that specifically address the eastern Mediterranean generally and the Levant specifically are much like the literary record from the same area. There are plenty of interesting potential clues, but the resolution is wanting. Region specific studies are necessary because extreme weather can invert all sorts of expectations. For example, while "the Year Without a Summer" after 1815 caused frosty weather in

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<sup>74</sup> Büntgen et al. 2016.

<sup>75</sup> University Corporation for Atmospheric Research. n.d. "Tree Rings and Climate."

<sup>76</sup> Büntgen et al. 2016, Supplementary Information, Table S1. *L. decidua* and *P. cembra* were the sample species in the Alps. *L. sibirica* was the sample species in the Altai.

Europe, it made the Arctic temporarily balmy.<sup>77</sup> Data collected from lake and marine sediments, speleothems, and pollen residues are helping reconstruct LALIA weather, specifically in terms of temperature and precipitation.<sup>78</sup> Computer simulations by Xoplaki et al. – though somewhat problematic due to the unknown geography of the volcanoes responsible for the 536 and 540 eruptions – have shown that between 536-545 CE, both summers and winters in the eastern Mediterranean were significantly colder than usual, with temperatures widely dropping one to three degrees Celsius below their standard levels.<sup>79</sup> This effect was especially drastic during the summer, when large swathes of the Balkans, southern Anatolia, and the northern Levant were potentially nearly three degrees below expected temperatures.<sup>80</sup> Southern Palestine and the Negev may have experienced temperatures approximately two degrees below seasonal expectations.<sup>81</sup> With such conditions, it's no surprise grapes tasted sour or failed to ripen.

LALIA also affected precipitation in the eastern Mediterranean. According to Xoplaki et al.'s simulations, between 536-545, winters were significantly dryer and summers significantly wetter above the thirty-fifth parallel north.<sup>82</sup> Areas north of Crete or Cypress potentially had a rainy summer and dry winter. This is something of an inversion of the Mediterranean climate, and many staple crops of the area, including grapes, rely on hot, dry summers to mature. South of Cypress, however, precipitation

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<sup>77</sup> Pfister 2018, 556.

<sup>78</sup> Xoplaki 2023.

<sup>79</sup> Idem. A sparsely populated chunk of the Sahara in Libya experienced warmer than usual weather in her model.

<sup>80</sup> Idem.

<sup>81</sup> Idem.

<sup>82</sup> Idem.

figures in Xoplaki's models do not appear to be far from normal parameters.<sup>83</sup> Perhaps the Negev was spared the worst of the rain. As more sediments and stalactites are scrutinized, I will return to this analysis.

Potential evidence of increased rainfall, at least for a short time, during late antiquity has been recorded in another part of the Levant. Wadi Queilbeh is in northwest Jordan, near the modern Syrian border<sup>84</sup>. In the Byzantine period Abila, one of the cities of the Decapolis, was the most prominent settlement in the wadi. Abila was home to approximately 12,000 inhabitants during late antiquity.<sup>85</sup> The alluvial soil of the wadi and relatively easy access to water made the area rich farmland, and it is still intensely cultivated today.<sup>86</sup> The access to water was supplemented with aqueducts from local springs and an elaborate rainwater catchment system similar to the ones used by towns in the Negev.<sup>87</sup> A recent investigation of alluvial runoff and debris in Wadi Queilbeh by Lucke et al., dated with a combination of radiocarbon and optically stimulated luminescence dating found "rather limited deposition of settlements during the Roman and Byzantine periods".<sup>88</sup> This suggests that the floodwater management strategies employed by the people of Abila were successful. Very little of their wadi washed away, and a lot of the water found its way into a network of cisterns. However, a massive layer of pebbly debris was deposited on the valley floor sometime between 1423 and 1323 years before present. "This points" write Lucke et al., "to the occurrence of prolonged heavy rainfalls as most important agents of landscape changes, possibly in the context

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<sup>83</sup> Idem.

<sup>84</sup> Lucke et al. 2017.

<sup>85</sup> Idem.

<sup>86</sup> Idem.

<sup>87</sup> Mare 1995.

<sup>88</sup> Lucke et al. 2017.

of the global climate events triggered by volcanism.”<sup>89</sup> Perhaps the same overwhelming floods that hit Abila hit the towns of the Negev. This might be a good line of future investigation for the geologically minded.

Late antiquity saw not only the arrival of waves of water, but also waves of sand.<sup>90</sup> The “largest late Holocene dune mobilization and only Holocene event of substantial dune elongation” occurred between 600-900 CE in and around Elusa.<sup>91</sup> Dunes covered the road from Elusa to Nessana and part of an amphitheater.<sup>92</sup> The expansion of the dunes was likely a result of both anthropogenic and larger climate factors. Increased use of the land from farming, grazing, and habitation likely freed more dust and sand and harmed dune stabilizers.<sup>93</sup> Powerful winds from stormy weather provided the mechanism for dunes to mobilize and grow.<sup>94</sup> This dune expansion may have been what inspired a much-quoted line in the study of Negev viticulture. Procopius of Gaza, a fifth-sixth century sophist, wrote a colleague named Jerome, a native of Elusa, about the state of his hometown. “There will be a day” he writes “when you will see Elusa again and you will weep at the sand being shifted by the wind stripping the grapevines naked to their root.”<sup>95</sup> It is not clear, however, from the dunes if this wind came with rain or just more dust.<sup>96</sup>

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<sup>89</sup> Lucke 2017.

<sup>90</sup> Roskin, Katra, and Blumberg 2013. See also Taxel, Sivan, Bookman, and Roskin 2018.

<sup>91</sup> Roskin 2013.

<sup>92</sup> Roskin 2013.

<sup>93</sup> Roskin 2013.

<sup>94</sup> Roskin 2013.

<sup>95</sup> Mayerson 1985.

<sup>96</sup> Roskin 2013.

## Cultural Impacts

Unusual and inhospitable weather in years the followed 536 CE potentially spawned cultural or societal change, by disrupting food supplies. The decades that followed 536 CE saw migrations out of Arabia, northern Europe, and the Asian Steppes, the spread of Slavic-speakers across Europe, political upheaval in China, the collapse of the Sasanian empire, and the emergence of Justinianic plague.<sup>97</sup> Impacts have been suggested in Mesoamerica, specifically among the Early Classic Maya of Tikal and the residents of Monte Alban in Oaxaca.<sup>98</sup> The residents of what is now the State of Georgia were also touched by LALIA. The transition from The Middle Woodland period to Late Woodland period happened over the sixth century. During the transition in the Etowah Valley, a site two and-a-half hours northeast of Athens, permanent settlements were widely abandoned.<sup>99</sup> The pottery in Northern Georgia became less decorated and more homogenous in design.<sup>100</sup> The consequences of LALIA potentially seep into mythology. Along with migrations, abandonment of settlements, and population drops, Scandinavia saw an ideological shift throughout the early sixth century.<sup>101</sup> Frantic building of ritual sites, a shift away from solar disk motifs, and deposits of large numbers of gold ornaments in caches that can be securely dated to around 536 suggest “unusual and even desperate measures in ritual contexts”.<sup>102</sup> This has led to a controversial

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<sup>97</sup> Büntgen et al. 2016.

<sup>98</sup> Peregrine 2020.

<sup>99</sup> Lilly and Ebb 2000.

<sup>100</sup> Idem.

<sup>101</sup> Nordvig and Riede 2018. An interesting theory posed in this paper is cold wet weather in Scandinavia lead to widespread taint of grain crops by ergot. Not only was there not nearly enough grain, but the consuming remaining grain would make things deeply unpleasant.

<sup>102</sup> Gräslund and Price 2012.

suggestion that LALIA inspired *Fimbulvetr*, the prolonged winter without a summer that is a preamble to Ragnarök.<sup>103</sup>

However, the full extent of the impact of the downturn should not be overly exaggerated. Büntgen sums it up saying “Any hypothesis of a causal nexus between the volcanic-induced sixth-century unprecedented thermal shock and subsequent plague outbreaks, rising and falling empires, human migrations, and political upheaval requires caution”.<sup>104</sup> Correlation and causation still are not the same, even if it would make things easier. LALIA may have been a factor in dramatic changes but it was not the only factor. Just as variables made the weather during LALIA different in different places (wetter in some, dryer in others), preexisting push-pull factors (warfare, political ambitions, disaster preparedness, agricultural buffering strategies, etc.) would influence the results of the downturn. The biggest difficulty in discerning the LALIA’s effects is that it occurred long ago. Surviving contemporary textual sources, while significant, are few. Climate proxies, archaeological data, and even art historical information can provide additional details that come with their own reservations. When a society, such as the residents of Northern Georgia, has no remaining written material, one relies on archeological evidence. Dating in these cases is much less precise, leaving the contribution of climate to social change unclear or irresolvable.

Another variable in the correlation versus causation question is not simply what the past left behind, but also who is writing about it. Interpretations of the archaeological, geological, and historical record are influenced by the author. “Often” notes Newfield “these differences reflect more the intellectual background from which

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<sup>103</sup> Nordvig and Riede 2018.

<sup>104</sup> Büntgen et al. 2016.

they have arisen than the current state of knowledge about the downturn.”<sup>105</sup> He categorizes the minimalist interpretations as coming from “humanists who are shy of natural proxies and tend to write nature out of history” and the most dramatic as coming from academics who “presume that pre-moderns were weak and rigid in the face of abrupt environmental change”. On one extreme, it is written about as “the real beginning of the modern world”, on the other it is at best a “marginal event”.<sup>106</sup> Similarly, the connections between LALIA and mythological events, such as the death of Arthur or *Fimbulvetr*, are difficult to conclusively link.

A moderate approach, for which I would advocate, takes the data of climate proxies and the natural sciences in tandem with the things people left behind, material or textual. To temper more extreme interpretations, it’s helpful to look toward patterns of resilience. While many may have died, many lived. Their survival is worth as much attention as their neighbors’ demise. This seems especially appropriate when considering the Eastern Roman Empire. Resilience is the most impressive feature of “the Empire that would not die”.<sup>107</sup> While deeply impacted by the weather, famine, and plague sparked by LALIA, the Eastern Roman empire held fast for almost another millennium. They are a stellar example of a premodern society that demonstrated strength and perhaps innovation in the face of calamity. If there is to be any utility in looking at past climate disasters, it may come for looking for hints on how to weather change.

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<sup>105</sup> Newfield 2018.

<sup>106</sup> The two extremes here are Keys 2000 and Wickham 2005.

<sup>107</sup> Apologies to Haldon 2016.

## Chapter 3: *Vitus*

### Text Review, Late Roman Winemaking

Romans were no strangers to viticulture in a wide variety of climates. Vines were as much a marker of Roman colonization as roads or Latin loan words. While places that had been previously colonized by wine loving Phoenicians and Greeks often had flourishing vineyards long before Roman conquest, Romans introduced winemaking to more extreme climates.<sup>108</sup> Their establishment of vineyards in colder climates that push the 50° north latitude is the most surprising, including Germany, parts of France, and southern Britain. The fourth century poet Ausonius in his ode to the Mosel River (*Moselle* in French, *Mosella* in Latin) praises her “river banks planted with the sweet-smelling vines of Bacchus (*amnis odorifero iuga vitea consite Baccho*)”.<sup>109</sup> While grapes may have grown in warm spots before their arrival, Romans brought large scale viticulture to Britain. While large scale viticulture left with the legions, an important hold out remains in English, where the word “wine” itself has remained since at least 805 CE.<sup>110</sup> It does not appear connected with the eucharist in English for another two centuries, suggesting it is one of the few Latin derived secular words to stick around until the Norman invasion.<sup>111</sup>

The oldest written source for tracing the history of viticultural practice in a detailed manner are the works of Theophrastus, a third century Hellenistic scholar and early botanist. He is more interested, however, in grape biology than grape husbandry.

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<sup>108</sup> For a good example of Phoenician wine influence, consider the Gozo Phoenician Shipwreck off Malta or the site of Cerro de las Cabezas in Spain.

<sup>109</sup> Ausonius *Mosella* 25.

<sup>110</sup> *OED* s.v. Wine. Earliest attested spelling is “uines”.

<sup>111</sup> *OED* s.v. Wine, first attestation in connection with the Eucharist c.1005 CE.

Cato the Elder's *De Agricultura*, composed in the second century BCE, is the first Latin text to go into the specifics. The first century CE also provided a brace of important sources, Pliny the Elder and Columella. While I have consulted each of these sources in my investigation, I favor the late antique sources. They lived closer to or after my study period and may have absorbed viticultural techniques unknown to earlier authors. However, since the late antique sources heavily reference Roman sources it is worth keeping them in mind.

There are two major primary sources for investigating general agricultural practices in late antiquity. The most valuable primary source is Palladius' *Opus Agriculturae*, a farming manual written in the fourth or fifth century CE. Palladius' text was widely quoted, distributed, and translated in the Middle Ages and early Renaissance.<sup>112</sup> While the manual gives advice on subjects ranging from architecture to veterinary treatments, the crop that gets the most attention are grapevines. The text takes largely from Columella. While it shares a lot in common with other classical farming manuals, *Opus Agriculturae* has several features that make it a uniquely valuable primary source material. Unlike his aristocratically distant predecessors, Palladius seems to have been directly involved in the management of his farms. He directly references his own experience nineteen times within the text.<sup>113</sup> Unsurprisingly, the management of vineyards and winemaking comprise a substantial portion of the book's contents. The other is *Geoponika*, a tenth century CE anthology of classical

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<sup>112</sup> Robinson 1994, s.v. Palladius. Two Middle English translations of Palladius, one in verse, can be found in the Bodleian Library (MS. Duke Humfrey d. 2 & MS. Add. A. 369). They are both examples of the popularity Palladius enjoyed in the Middle Ages that his predecessors did not. Cato, Columella, and Varro were not as well known in the Middle Ages.

<sup>113</sup> Palladius 2013, 11.

farming knowledge. It is one of several anthologies collecting knowledge from the classical world dedicated to (and potentially compiled by) the famously scholarly Emperor Constantine Prophyrogenitus.<sup>114</sup> Five of the book's twenty chapters deal exclusively with viticulture and oenology.<sup>115</sup> While the anthology itself postdates the focus period of my studies, the sources quoted within largely pre-date or are roughly contemporary. The newest authors that can be securely identified in the text were alive during the sixth century.<sup>116</sup> Many of the cited authors, including Xenophon, Homer, Juba II, Virgil, and Aratos are famous for other endeavors. *Geoponika* also preserves passages of otherwise lost agricultural writers. *Geoponika*, is to agronomists what the *Greek Anthology* is to poets. While not compiled in classical antiquity, it is something of a "greatest hits" collection of the best of the oldies.

### **Grapes and Climate**

For a plant with a reputation for heartiness grapevines are surprisingly finicky. Generally, commercially viable vineyards can only be found between thirty and fifty degrees of latitude on either side of the equator.<sup>117</sup> This is because grapevines rely on the length of daylight and temperature to signal when to grow, reproduce, and go dormant.<sup>118</sup> They cannot stand too hot or cold temperatures, refusing generally to grow at temperatures under 10°C and exceeding 35°- 38°C.<sup>119</sup>

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<sup>114</sup> Other works compiled in his court include *De Ceremoniis* and *De Administrando Imperio*.

<sup>115</sup> In Dalby's edition, chapters 4-8.

<sup>116</sup> The most notable sixth century source is Cassianus Bassus, a compiler of a farming manual whose advice for dealing with sick grape vines whose leaves turn red includes irrigating them with urine. Since red leaves *can* be a symptom of insufficient magnesium or phosphorus in the soil, the urine treatment *could* have some efficacy.

<sup>117</sup> Johnson and Robinson 2013, 43.

<sup>118</sup> For further details about the biological mechanisms that drive this light and heat based cycle, see Keller, 2010.

<sup>119</sup> *Ibid.* 61. This is 50°F and 95°-100°F.

Without sufficient spring sunlight and regular daytime temperature reaching about 10°C, grapevines do not leave their dormant winter state. Once the days are sufficiently warm and long, grapes go through a process called budbreak where new leaves and tendrils emerge from the woody mass of older vine. This is a delicate time, as the new growth is susceptible to frost damage from cold snaps or chilly nights. Generally, this process happens in March in most wine growing regions of the Northern Hemisphere, with some variation due to climate and cultivar.<sup>120</sup> By the first of April nearly every grapevine is covered in new foliage, thus beginning the time when one can start calculating degree days. Harvesting grapes occurs between late August and October. After October 31<sup>st</sup>, the shorter days and colder nights send the vines back into dormancy.

As much as grapevines need specific conditions to produce fruit, humans need certain parameters to produce wine. The juice has to contain the correct ratio of sugar and acid. If the grapes are picked before they are ripe the yeast will not have enough sugar to make sufficient alcohol to prevent spoilage and an abundance of acid will make the product sour. In colder wine growing regions, it's not uncommon to add concentrated grape juice or sugar to the fermentation to compensate for under-ripeness, a process called chaptalization.<sup>121</sup> Although the process is named after Jean-Antoine-Claude Chaptal, a chemist in the employ of Napoleon, the process was known to the Romans. Cato the Elder mentions adding concentrated grape juice and vetch flour to correct sour wine.<sup>122</sup> If the grapes are picked past the point of ripeness, the

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<sup>120</sup> Robinson 1998, s.v. Budbreak. In the Southern Hemisphere, budbreak generally occurs in September.

<sup>121</sup> Robinson 1998, s.v. Chaptalization.

<sup>122</sup> Cato, *De Agricultura* 109.

yeast might have an overabundance of sugar. This can cause the yeast to react too vigorously, causing the fermentation to get too hot or alcoholic. Either of these conditions can kill the yeast prematurely, resulting in poor flavored wine and encouraging unwanted microbiological activity. While over or under ripeness is not desirable, winemakers harvest at different stages of ripeness depending on cultivar or desired result. For example, less ripe grapes produce wines with high acid, low alcohol, and light fresh flavors.<sup>123</sup> More ripe grapes can produce highly alcoholic wines with strong, almost spicy flavors.<sup>124</sup> Grapes also must generally be free of pests, mold, fungal growth, and other spoilage before being pressed, as their inclusion can make the product disgusting.<sup>125</sup>

For all their finickiness, grape's need for certain climate parameters to grow makes their ripening somewhat predictable. An important tool for wine makers to predict harvest dates is heat summation. Heat summation is calculated by totaling the number of degrees of average daily temperature over 50°F/10 °C for each day of the growing season.<sup>126</sup> If a winemaker has a week of high temperatures of 20°F, they will accrue 70 degree days. A warmer climate would take a shorter time for a critical sum to be reached, cooler climates a longer time, and inconsistent temperatures would make ripening difficult to predict. There is marked variability among varieties in the number of degrees needed to ripen. Grapes accustomed to colder climates (riesling, pinot noir, chardonnay) generally need fewer degrees to ripen. Grapes accustomed to hot places

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<sup>123</sup> i.e., Riesling, Sauvignon Blanc, or grapes used to make sparkling wine.

<sup>124</sup> i.e. Zinfandel aka Primitivo aka Crljenak Kaštelanski.

<sup>125</sup> It should be noted that occasionally certain kinds of spoilage are encouraged. The most famous case is that of Sauternes, in which white grapes are inoculated with *Botrytis cinerea*. The grey mold sucks water out of the grapes, producing more concentrated juice with a distinctive, perfumy flavor.

<sup>126</sup> Robinson 1998, s.v. heat summation.

(verdelho, sangiovese, zinfandel) need more. Beaune, a city in Burgundy strongly associated with the production of pinot noir and chardonnay, gets about 2300 degree days between April 1<sup>st</sup> and October 31<sup>st</sup>.<sup>127</sup> Florence, the capital of Tuscany and home of sangiovese, gets about 3530 degree days over the same period.<sup>128</sup>

The qualities winegrowing regions, sorted by the expected number of degree days, are categorized using something referred to as the Winkler Index. This classification system is named after Alber Julius Winkler, a long serving professor of Viticulture and Enology at the University of California Davis, and one of the first to formally section California into viticultural regions based on climate.

Heat summation can be expressed as the equation below.

$$GDD = \sum_{i=1}^n (T_i - T_b)$$

In English: The Growing degree days (GDD) equal the sum where  $T_i$  is the average daily air temperature for April 1 to October 31 (  $n = 214$  days), and  $T_b = 10C^\circ$  is the base temperature.  $T_i$  is calculated as the average of the daily maximum and minimum temperature. The daily values of  $T_i - T_b > 0$  are added to the cumulative GDD.<sup>129</sup> With this equation in mind, Winkler made a table of average growing season temperatures in degrees and their relative favorability for large scale viticulture. While several other equations for predicting ripeness have been proposed, including the “heliothermal

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<sup>127</sup> Winkler et al. 1974, Table 3. This calculation uses Fahrenheit.

<sup>128</sup> Idem.

<sup>129</sup> Keller 2010, 61.

index”, and the “latitude-temperature index”, they are mostly more complicated variations on Winkler’s theme.<sup>130</sup>

It is worth stressing that heat summation is a predictive formula, a tool. Any number of slight variations might cause grapes to deviate from the formula, including weather, cultivar, and luck. Shrewd viticulturalists would be sure to check the grapes for ripeness by color, chemical composition, and flavor. However, there is no evidence of late antique usage of refractometers (a tool used to measure sugar content) and we do not have reports on the growing seasons and harvest dates in the sixth century. As a result, keeping heat summation in mind while comparing climate proxies can help predict what may have happened to the vintage during LALIA, especially in the years shortly before and after the cold rolled in.

Cold is perhaps more dangerous to grapes than heat. Cold and wet weather combined is even worse. Once budbreak begins, new growth is easily damaged by frost. Unfavorable microbiological activity is encouraged by dampness, damaging the plants and spoiling fruit before it is ripe. Cool rainy days also do not help grapes accrue the necessary degree days to ripen. Because of this, most of the great winegrowing regions of the world receive the majority of their rainfall in the late autumn and winter while the vines are dormant or relieved of their fruit.<sup>131</sup>

Fungus, including *Botrytis cinerea* (aka grey rot) and *Erysiphe necator* (aka powdery mildew or oidium) is another climate dependent threat. It is the primary reason why winemakers fear the damp. Both *B. cinerea* and *E. necator* are distributed by the

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<sup>130</sup> Huglin and Schneider 1998 and Jackson and Cherry 1988, respectively.

<sup>131</sup> In winegrowing regions below the equator, things are flipped. Grapes from Chile, South Africa, or New Zealand thrive with cool, damp summers and warm winters.

wind and damage leaves, flowers, fruit, and stems. If they attack grape flowers, the fungus can spoil the fruit from the inside out.<sup>132</sup> *B. cinerea* can germinate anywhere between 1°-30°C.<sup>133</sup> Red wine made with *B. cinerea* infected grapes is often discolored, white wine is often brown, and the resulting beverage may taste of iodine.<sup>134</sup> It needs about ninety percent relative humidity, however, to flourish.<sup>135</sup> *E. necator* can start growing in as little as forty-five percent humidity, but thrives at about eighty-five percent humidity and 25° C.<sup>136</sup> Wine made from grapes infected with *E. necator* taste of mushrooms.<sup>137</sup> For this reason, it is important for humidity and moisture to be minimized in vineyards and airflow increased, especially around the grapes themselves.

Late antique winemakers were as aware of the risks from frost and microbiological activity as moderns, generally referring to the latter as “rust”.<sup>138</sup> Palladius suggests planting vineyards facing south in colder areas to prevent frost.<sup>139</sup> A source quoted in the Byzantine *Geoponika* suggests that planting vineyards near the sea or rivers because of their moderating effect on the climate and “the continual cold breezes to which the sites are subject”.<sup>140</sup> The same author addresses “rusts, which attack the vines” and suggests that for planting vineyards one should avoid damp areas

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<sup>132</sup> Keller 2010, 299.

<sup>133</sup> Idem.

<sup>134</sup> Idem. Grapes that become infected later in their development, however, can develop sweeter, honeylike flavors, which makes them prized and used in dessert wines like French Sauternes or Hungarian Tokaji.

<sup>135</sup> Idem.

<sup>136</sup> Ibid. 302

<sup>137</sup> Ibid. 303

<sup>138</sup> Greek ἐρῦσιβη, Latin *robigo*. This conclusion is drawn both from the conditions the is rust is likely to appear (cold, damp), the reported effects it has on the wine (general spoilage), and that many microbiological threats to grapes look like rust (esp. *Phakopsora euvitis*).

<sup>139</sup> Palladius 1.6 and *Geoponika* 5.4

<sup>140</sup> *Geoponika* 5.5. For additional praise of seaside vineyards in a late antique context, see Julian the Apostate’s letter to Evagrius (Letter 25).

“marsh meadows, therefore, should be given up, as far as that is possible.”<sup>141</sup> Columella advises “In the spring see that you have heaps of chaff placed between the rows in the vineyard, When you notice that there is cold which you would not usually expect at the season, set fire to all the heaps; the smoke then will get rid of the fog and mildew”.<sup>142</sup> Other authors quoted in the *Geoponika* suggest burning cow dung in vineyards when there is a threat of frost or rust and adding three crabs, a chopped catfish, or an ox’s right horn to the fuel to prevent damage.<sup>143</sup> The dangers of microbiological activity close to harvest were also noted, a citation in the *Geoponika* remarks that rain close to harvest time will make wine more likely to spoil.<sup>144</sup> Another citation in the *Geoponika* recommends boiling the must from spoiled grapes before inducing fermentation, effectively sanitizing it.<sup>145</sup>

While modern winemakers have a better understanding of grape biology and pests and are able to use more efficient technologies, the methods of reducing damage to vines or the crop have changed surprisingly little. Vines are still planted and manipulated to take full advantage of sunlight, wind, and bodies of water. To prevent frost from forming, modern vintners often install massive fans, light bonfires and smudge pots, or even hire helicopters to warm or circulate chilly air and fog<sup>146</sup>. Unseasonable rain still stirs panic. Rapid deployments of picking crews if rain is forecast are not an uncommon sight in Napa, especially later in the growing season. Even if the

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<sup>141</sup> *Geoponika* 5.5.

<sup>142</sup> Columella, *De Arboribus* 13 and Robinson 1994, s.v. Climate

<sup>143</sup> *Geoponika* 5, 31-33

<sup>144</sup> *Geoponika* 5,43

<sup>145</sup> *Geoponika* 5.47.

<sup>146</sup> Robinson 1994, s.v. Frost. Waking up to hearing the fans kicking on or the smell of burning was a standard start of spring mornings growing up.

grapes were not quite at the point of ripeness the winemakers wanted, it is considered better to have a not-quite perfect fruit than fruit spoiled by mold.

Fruit is not the only part of a grape worth consideration in this matter. During the vegetative phase following budbreak, grapevines put out woody tendrils called canes. These are the parts that carry fruit and leaves and are trained to various shapes and structures. As the season progresses, canes become hard and grow buds. These are the buds that “break” in spring, and they only occur on wood left over from the previous year. Vintners can manipulate the number of buds and growth on a vine by pruning them. This process generally happens when the vine is dormant to lessen the damage. Unwanted canes are cut away, leaving nubs with a handful of buds on them. Pruning keeps vines from becoming overgrown, helps them maintain their shape on the trellis, maintains the quality of the fruit, and allows one to predict the volume of grapes that will be harvested in the next year. Generally, each bud will produce two or three clusters of grapes. These canes can also thicken over time, becoming a trunk or cordons capable of producing new canes.

Too cold weather threatens not only the current year’s harvest, it also threatens next year’s harvest. While dormant, the vines are immune to all but the hardest freezes.<sup>147</sup> After budbreak, new leaves and canes may be damaged beyond repair by frost. Grapes can produce new growth from secondary or tertiary buds, but these tend to be less vigorous and produce significantly less fruit.<sup>148</sup> Budbreak can be delayed by later pruning. This practice is described by Palladius and the *Geoponika*.<sup>149</sup> The latter of

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<sup>147</sup> Robinson 1994, s.v. frost. Sometimes grapevines are buried or coated with ice to secure against the most extreme cases.

<sup>148</sup> Persico, Smith, and Centinari 2021.

<sup>149</sup> Palladius 4.1 and *Geoponika* 5.23.

these sources notes “vines pruned in autumn come into bud more quickly in spring; and if the spring is cold, and hoar frost falls, they will be burned” and suggests that in cold places, the bulk of pruning should happen in February or March.<sup>150</sup> Recent research has shown that late pruning is an effective way of delaying budbreak in colder regions and decreasing damage to the shoots.<sup>151</sup> Pruning still must be completed before budbreak to be effective and is futile if the frost occurs later in the season. Since next year’s harvest is determined by this year’s canes, damage to this part of the grapevine has long repercussions.

When grapes get cold, problems compound. The buds may not open at the right time. Foliage may be damaged. The fruit may never ripen or be tainted by microbiological activity. Even the ability to try again next year may be dashed. If the whole vine itself happens to die, replanting is expensive and requires several years of waiting to get a substantial return on investment. It’s little wonder that there are two cold hardiness monitoring programs for grapes in the United States, one at Cornell University, the other at Washington State University. Finding ways to reverse or prevent this damage is still a field of ardent study.

I suspect that cold damage is what caused the crop failure widely reported in textual sources. If the details reported by Pseudo-Zachariah, that the climate event set in on March 24, are true, budbreak would have been well underway in many places when the sky dimmed. Both the *Geoponika* and *Palladius* assigned budbreak appropriate activities, such as ceasing pruning, to March. The dimming sky would have either delayed budbreak, giving the grapes fewer degree days to ripen, or damaged the

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<sup>150</sup> *Geoponika* 5.23.

<sup>151</sup> Persico et al. 2021.

new shoots. In addition, cold damage to the canes or whole vine would explain why wine shortages were sometimes reported years after the cold snap, as is the case with John Malalas.<sup>152</sup> When grapes get cold, problems compound, both for the grapes and the people who tend them.

### **Why Study Late Antique Wine?**

Wine was an important commodity in late antiquity. While it was, like today, valued for its gastronomical qualities and ability to inflict intoxication, it was far more. Practically, wine was also a way to make calories shelf-stable, easily transportable, and safe from most kinds of vermin. Wine was likely a major source of calories for many residents of the eastern Roman empire.<sup>153</sup> Viticulture produced important culinary products other than wine, namely table grapes, vinegar, raisins, and *defrutum* (grape must syrup). Vinegar, wine, and *defrutum* could be used as preservatives. Pruned vine canes could provide a small amount of fuel and are especially well suited for grilling and smoking meat. While recipes for dolmades (aka dolma) are not recorded until the nineteenth century, I would not be surprised if Byzantine tables were occasionally graced with stuffed grape leaves.<sup>154</sup>

Owning vineyards was an important class marker for aristocratic Romans. Senators were obliged to own land in Italy in the early part of the empire.<sup>155</sup> Along with owning vineyards, knowledge of vineyard management, winemaking, and wine connoisseurship became markers of sophistication. It is little wonder that there is an abundance of surviving written sources on viticulture in Latin. It was generally frowned

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<sup>152</sup> Malalas 1986, 287

<sup>153</sup> Calculations of precisely how much wine a Roman consumed daily vary widely. Factors such as class, age, gender, and religious affiliation play a part. For two contrasting calculations of average wine consumption in late Antique southern Palestine, see Fuks 2021 and Seligman 2020.

<sup>154</sup> Ghanoonparvar 1995.

<sup>155</sup> Purcell 1985.

upon for the senatorial class to profit from mercantile business or money lending. However land speculation was acceptable, vineyard ownership was a wise choice.<sup>156</sup> A vineyard in Campania producing wine that one could serve at a banquet and say “this comes from *my* estate” was an appealing investment for the socially mobile.<sup>157</sup> If the vineyard came with a villa that you could retreat to, either to relax or escape public disgrace, even better. Planting and maintaining large vineyards is a costly endeavor, one that few but the wealthiest could afford. Vineyards require intensive labor at pruning and especially harvest time, are expensive to propagate, and a wide variety of problems can make their produce worthless. A frequently quoted truism in winemaking today is “if you want to make a small fortune in the wine industry, start with a large one”.

If the gamble paid off, vineyards could be exceptionally profitable.<sup>158</sup> Viticultural knowledge occasionally provided social mobility for talented freedmen and their families. Both Suetonius and Pliny the Elder mention Acilius Sthenelus, a freedman’s son who gained a reputation for reinvigorating vineyards. He was hired by the grammarian Remmius Palaemon to revive a neglected vineyard, purchased for 600,000 sesterces, outside Rome. Within eight years, the grapes were purchased by a speculator for 400,000 sesterces while they were still on the vine. Seneca reportedly later purchased the same vineyard for 2,400,000 sesterces.<sup>159</sup> This story illustrates the kind of money a successful vineyard could bring in, either from selling the fruit or the whole farm.

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<sup>156</sup> *Idem*.

<sup>157</sup> This remains, more or less, the case. There are whole industries in Napa that allow the wealthy and famous to put their name on a wine bottle.

<sup>158</sup> Purcell 1985.

<sup>159</sup> Pliny the Elder, *HN* 14.48-52 and Suetonius *Gramm.* 25.

This trend of elite involvement in the wine industry continued well into late antiquity. When the capital moved east, first to Nicomedia then Constantinople in the third century, aristocrats jumped to buy vineyards in Bithynia.<sup>160</sup> The Flavii Apiones, an influential Egyptian family whose members held high imperial offices from the fifth to seventh centuries, were heavily invested in viticulture.<sup>161</sup> One of their members, Strategius II, was serving as *comes sacrarum largitionum* in 536, and later oversaw the reconstruction of the Hagia Sophia.<sup>162</sup> Luckily for historians, the bulk of the enormous Flavii Apiones estates were in Oxyrhyncus. As a result, the workings of their estate are exceptionally well preserved. Having technical knowledge of viticulture remained an important class marker, and potentially a way to make lots of money.

In Southern Palestine, people from a wide variety of classes and walks of life owned vineyards and wine production facilities. The state itself was one owner, the *Saltus Constantinianus* was a large imperial estate somewhere in the Negev.<sup>163</sup> Religious institutions, including monasteries were involved in wine production, as evidenced by presses found in monastic contexts.<sup>164</sup> The Third Mile Estate outside Ashkelon appears to be a well-appointed country estate with industrial farming capabilities, perhaps owned by a wealthy urbanite.<sup>165</sup> The estate's amenities included a convenient location, 4.5 km outside Ashkelon on the *Via Maris*, and a private bathhouse.<sup>166</sup> Its farming and food processing facilities included a combination olive press and grain mill, a fishpond fed by bathhouse runoff, a kiln that produced LRA4 and

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<sup>160</sup> Boulay and Northrup 2016.

<sup>161</sup> Hickey 2012, 2.

<sup>162</sup> Hickey 2012, 11-12.

<sup>163</sup> Decker 2009, 32. The scale and exact nature of this holding is obscure.

<sup>164</sup> Erickson-Gini 2021. The press illustrated in fig.6 was also found in a possible monastic context.

<sup>165</sup> Decker 2009, 54-56.

<sup>166</sup> Idem.

LRA5 amphorae, and several large wine presses.<sup>167</sup> The evidently wealthy owner may have lived on site, or lived in town and come to visit their venture in the suburbs.

Viticulture was not a pursuit limited to the wealthy. Vineyards can grow well in steep, stony, or sandy terrain that is inhospitable to staple crops like grain.<sup>168</sup> The parts of a farm that produce nothing else may be suited to grapes. Since vineyards require year-round maintenance, the biggest investment needed to make a small scale vineyard successful is time. A small vineyard that a farmer tends in his spare time could, in a year with a bumper crop, make its custodian surplus income. However, if the harvest is poor or the wine turns to vinegar, the farmer can fall back on other crops.<sup>169</sup> Thus “viniculture and wine-making turn labor-glut into storage and redistribution credit”.<sup>170</sup> Like pigs who efficiently turn food waste into more food, grapes take marginal land and spare time and turn them into something delicious or cash. Even better, this distilled surplus labor can be kept in the cellar for years.

Evidence from villages, specifically Nessana, suggests that some vineyard property and wine production facilities were locally owned. Evidence can be found in the ruins of the villages themselves. In Oboda, one of the houses had its own wine cave carved from living rock.<sup>171</sup> The multi chambered cellar, capable of holding up to 3,750 liters included a bench ideally suited to hold LRA5 amphorae.<sup>172</sup> This would have been a perfect place not only for keeping and aging wine, but also fermenting it as well. All of these processes go more smoothly in places with consistent cool temperatures, a rare

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<sup>167</sup> Idem. The combined area of the winepresses is 380 square meters.

<sup>168</sup> Horden 2000, 213

<sup>169</sup> Horden 2000, 216

<sup>170</sup> Ibid.

<sup>171</sup> Decker 2009, 58

<sup>172</sup> Ibid.

find in the desert.<sup>173</sup> The Nessana papyri, fragmentary archives that date from the sixth and seventh centuries, occasionally discuss vineyard ownership.<sup>174</sup> A document from Nessana details a division of property, that includes a vineyard, between two soldiers, Zunayn son of Abraham and John son of Asad, and John's sister.<sup>175</sup> One editor suggests "perhaps Zunayn was married to John's sister and the split came about after a divorce."<sup>176</sup> Another fragmentary contract, mentioning a soldier named Menas, takes care to note that the vines in the contract are newly planted and come with posts.<sup>177</sup>

Wine was an important component of late antique medicine. In praise of the wine from his native Bruttium, Cassiodorus asserts that it "It binds faltering bowels, dries weeping wounds, restores a faint breast, and what a skillfully brewed remedy barely succeeds in treating, this offers naturally and unaccompanied."<sup>178</sup> Wines from Southern Palestine were reported to have been especially healthful. Alexander of Tralles, a sixth century physician, suggests using Ashkelon wine specifically as a component to treating a wide variety of ailments, including problems of the eyes, kidneys, spleen, and liver.<sup>179</sup>

Good wine and pretty vineyards are praised in poetry and letters. Ausonius, Nonnus, Corippus, and Julian the Apostate are all notable late antique writers with a special interest in viticulture.

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<sup>173</sup> Ibid. This cellar would have also been an ideal place to conduct other fermentation based food preparation, such as cheesemaking or pickling.

<sup>174</sup> *ODB* s.v. Nessana Papyri.

<sup>175</sup> *P. Ness.* 3. 16

<sup>176</sup> Kraemer 2015, 47.

<sup>177</sup> *P. Ness.* 3. 34

<sup>178</sup> Cassiodorus, *Variae*, 12.12.5.

<sup>179</sup> Mayerson 1993.

## Gaza Wine: Literary Evidence

Ancient wine connoisseurs were as concerned about appellation as their modern counterparts. Horace categorizes dozens of wines by the places they grow in his Odes.<sup>180</sup> Pliny the Elder includes a list of fifty especially agreeable wine appellations around the empire in *The Natural History*.<sup>181</sup> However, when a special occasion or discerning guest called for it, wines tied to a specific region would be served. Between the fourth and seventh century, a wine from Gaza or Ashkelon was a sophisticated and valuable choice.

Wines from southern Palestine were clearly valued. In his description of Dijon, Gregory of Tours notes that the countryside is “very fertile and full of vineyards, which produce for the inhabitants such a noble Falernian that they disdain wine of Ascalon.”<sup>182</sup> This suggests that wines from southern Roman Palestine, specifically Ashkelon, were a luxury, something it was an achievement to match. Gregory had personal ties to Burgundy, so it is no surprise that out of hometown pride he would compare his local wine to two famous appellations.<sup>183</sup> Cassiodorus, a connoisseur who peppers his letters with poetic tasting notes, also compares his hometown’s wine to that from Gaza. In a letter requisitioning wine and cheese from Bruttium for royal banquets, he describes the brew.

“Search, too, for the wine, which antiquity called the *Palmatianum*, wishing to confer praise, because it is not dry or bitter, but pleasing with sweetness. For although it may seem the most remote among Bruttian wines, it has nevertheless been made distinguished practically in popular opinion. For there, it is considered equal to Gazan, and similar to Sabine, noted for its weighty aroma. But since it

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<sup>180</sup> i.e., Caecuban (Odes 1.37), Falemian (Odes 3.1), and Laestrygonian (Odes 3. 16).

<sup>181</sup> Pliny, *HN* 14.8. Wines from the Levant are not mentioned in Pliny’s list.

<sup>182</sup> *Hist. Franc.* 3.19. Dijon is the capital of Burgundy, a region still known for exceptional wine.

<sup>183</sup> *ODLA* s.v. Gregory of Tours, Gregory of Langres. Gregory’s great-grandfather was Gregory of Langes who is buried in Dijon.

has claimed the noblest reputation for itself, let the choicest vintage in this wine be selected, lest the wisdom of the ancients should seem to have named something inappropriately. For it is gently dense with rich sweetness, full and lively, with a forceful bouquet, also white and clear, which diffuses such flavor in the mouth that it rightly seems allocated a name from the palm.”<sup>184</sup>

This letter provides both charming insight into Cassiodorus’ favorite things and about qualities of the wine from Gaza. Firstly, it has the “noblest reputation”. Cassiodorus knows his courtly correspondent will know what wine from Gaza tastes like and that it was valuable. His elaborate descriptions of vines and wines are probably keeping in with the tradition of Roman aristocrats and politicians being well educated in viticultural manners. We also get tasting notes. Crack open a LRA 4 amphora and one would expect to find a full bodied sweet white wine. Other favorable mentions of Gaza wine can be found in Sidonius Apollinaris, Corippus, and Venantius Fortunatus.<sup>185</sup>

Winemaking was also an aspect of the religious life of the residents of southern Palestine. Wine is an essential part of rituals in Christianity, Judaism, and classical paganism. Vines and their products are a fixture of Christian and Jewish scripture. It is no wonder then that images related to viticulture and winemaking are still common motifs in the houses of worship, the specificity of the images used hints at the local importance of the industry. In Jerome’s hagiography of St. Hilarion, a founder of Palestinian monasticism who spent much of his life around Gaza, winemaking is a theme even in the life of an ascetic. Wishing to be “an example of both humility and service” St. Hilarion made a point of visiting other monks “on certain appointed days before the grape harvest (*statibus diebus ante vindemian*)”.<sup>186</sup> The purpose of this trip can be inferred, to bless the

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<sup>184</sup> Cassiodorus, *Variae*, 12.12.3-4.

<sup>185</sup> Seligman 2020.

<sup>186</sup> Jerome 1998. *Vita Hilarionis*, 25. Latin from Mayerson 1985.

harvest before it is gathered in. Jerome writes other monks would follow their leader from monastery to monastery on a sort of mini pilgrimage. Apparently, as many as three thousand monks joined him on the trip. Hilarion performed grape-specific miracles on one of these trips. First, the train of monks attempted to visit the vineyard of a notably stingy brother and found “guards had been posted in the vineyard through which the monks were to pass to frighten away anyone who came close, by throwing stones and lumps of earth or by whirling their slings”.<sup>187</sup> After the unpleasant incident, the train along with St. Hilarion visited a generous brother named Sabas.<sup>188</sup> After conducting Sunday service in the vineyard St. Hilarion blessed the vineyard and invited the three thousand brothers to eat the ripe grapes. The vineyard was not depleted by the visitors, but miraculously “although the vineyard had been estimated to contain one hundred flagons before they touched it, twenty days later it produced three hundred”.<sup>189</sup> Meanwhile “the stingy brother gathered a much smaller harvest than usual and even what he did obtain turned to vinegar”.<sup>190</sup> The story of St. Hilarion reflects the importance winemaking had in southern Palestine. Blessing the harvest is a holy duty, vineyards were appropriate places to celebrate mass, and miracles could happen in the press. It also suggests that monastic institutions were widely involved in the trade.

Scholarly inquiry about the wines of Southern Palestine generally cuts off in the mid seventh century, when Islam became the state religion of the area. Devout Muslims generally avoid alcohol, citing several passages in the Qur’an that may prohibit

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<sup>187</sup> Ibid., 26.

<sup>188</sup> We know the name of the good monk because, according to Jerome, “it is right that we should mention the name of the generous monk, but not the name of the mean one”: *ibid.*, 27.

<sup>189</sup> *Idem.*

<sup>190</sup> *Idem.*

intoxicants generally and wine specifically.<sup>191</sup> While I too will cease the bulk of my inquiry at this point, it is an unfair *terminus ante quem*. The uptake of Islam was not an overnight process. Conversion rates varied widely, often taking centuries in rural areas.<sup>192</sup> For example, there is debate about if Egypt became a majority Muslim nation in the ninth, tenth, eleventh, or fourteenth century.<sup>193</sup> Monasteries in primarily Muslim areas still produced wine. In a catalog of monasteries in Egypt, Arabia, Syria, and Iraq compiled in the ninth century, the author notes which ones make exceptional wine.<sup>194</sup> The monks were not the only people drinking their product. Wine specifically from Ashkelon is featured in the medical writings of Paulus Aegineta, a seventh century Byzantine medical writer widely read in the Islamic world.<sup>195</sup> It is an ingredient both in his treatment for kidney stones and a restorative ointment.<sup>196</sup> An entire genre dubbed “wine poetry” flourished across the Islamic world. Three famous poets from the seventh and eighth centuries, Hassan b. Thabit, al-Akhtal, and Layla al-Akhalayyah mention wine from Baysan (aka Beit She'an) an area north of the study region but still a part of Roman Palestine.<sup>197</sup> I have yet to find specific praise of Gaza wine in Arabic poetry. Since Gaza wine was light colored and renowned for healthful properties, I'd like to imagine it is what the most famous wine poet, Abu Nawas, had in mind when he wrote these lines.

I'll sever worry's aorta with the glass  
For there's no surgeon like the glass for worry  
Pour me fresh, crisp wine, stowed away  
In her cask in a cellar's corner, buried

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<sup>191</sup> *Qur'an* 2:219, 4:43, 5:90. The debate is generally over the interpretation of the word *khamr* (خمر).

<sup>192</sup> Carlson 2018.

<sup>193</sup> Carlson 2018

<sup>194</sup> *CIAP* 3, 122.

<sup>195</sup> Mayerson 1993.

<sup>196</sup> *Ibid.*

<sup>197</sup> *CIAP* 2, 200.

Yellow, with eyes like halves of bells  
Leaving those poured smiling in glee<sup>198</sup>

### **Gaza Wine: Physical Evidence**

While the exact locations where the grapes that went into Gaza wine is a subject of debate, it is widely accepted that they came from the southern part of Roman Palestine.<sup>199</sup> This includes, perhaps surprisingly, towns in the Negev such as Oboda and Sobata which are not exactly verdant today. There are several kinds of evidence that can be used to demonstrate that these places had a significant wine industry. These can be sorted in to three categories; direct evidence of grape growing (archaeobotanical remains, grape mounds, vineyard ownership documents), evidence of winemaking (including wine presses), and evidence of the production of Gaza jars.

Winepresses are among the most widespread and well-discussed artifacts of ancient wine making. Before the invention of refrigerated transportation, grapes had to be pressed close to where they were harvested. Not only is the fruit heavy, it is also fragile. If left in warm weather, it may also spoil quickly or spontaneously ferment. Presses are an almost ubiquitous feature of the late antique landscape. In *Tilling The Hateful Earth*, a holistic work on farming in the late antique Eastern Mediterranean, most dwellings the author chooses as exemplary have a wine press. These range from villas, to monasteries, to two-room shepherd's huts.<sup>200</sup> Pools for trampling grapes and catching juice are often cut into bedrock or made of low-lying and durable material, like stone or mosaic paving. While the upper parts of a winepress, and the press

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<sup>198</sup> Rowell and Abū Nuwās 2017. Abu Nawas died c. 814 CE.

<sup>199</sup> *ODB* s.v. Palestine. For recent debate on how much of the area was devoted to winemaking, see Fuks 2020, Seligman 2020, and Fuks 2021.

<sup>200</sup> Decker 2009, 56 (Third Mile Estate), 51 (Dier Dehes), and 39 (Horvat Kanaf).

mechanism itself often are missing, the parts flush to or sunken in the floor survive well. From measuring the volume of the vats and educated guesses about how long the harvest lasted and how quickly primary fermentation ran, the volume of wine that a site was able to produce can be estimated.<sup>201</sup> For example, an especially large combination kiln and press facility recently excavated in Iamneia (modern Yavne) was capable of producing up to half a million gallons of wine per year.<sup>202</sup>

There is great variety in the scale and design of winepresses used in southern Palestine. The simplest are a treading floor that drains into a basin, where juice was collected and went through primary fermentation. The remains of a mortice for screw press to get the last dregs out of the pomace is also a common feature on treading floors. A good example of this kind of press was excavated in Sobata in the 1930s and was possibly associated with a monastery (fig. 6). It's worth noting that a simple design is not necessarily a careless design, the stone on the treading floor and lining the collection vat are fitted "with extreme precision".<sup>203</sup> More elaborate structures include large treading floors, filtration systems, multiple collecting vats, and paved work areas on the sides. Another feature of more complex presses are chambers that drain on to the treading floor. These have been suggested to be places where grapes could be stored and allow the "first run" of juice, which is expelled only by the weight of other grapes and largely considered to be higher quality, to drain.<sup>204</sup> A press excavated in Ashkelon in 1991 is a good example of a more complex, larger volume operation (fig.7).

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<sup>201</sup> An example of this calculation can be found in Seligman 2020.

<sup>202</sup> Peiser 2021.

<sup>203</sup> Ayalon 2009, No. 70.

<sup>204</sup> Ayalon 2009, No. 59.

Archaeobotany is a recent addition to the tool kit for ancient wine research. The seeds, or pips, of grapes, their pedicels (the nubby bit at the top of the berry), and rachis, tend to be rather durable, surviving burial, digestion,<sup>205</sup> and carbonization.<sup>206</sup> Grape pollen can also be recovered from sediment at the bottom of lakes<sup>207</sup> and cisterns.<sup>208</sup> Occasionally it can be recovered from other sticky surfaces, including plaster.<sup>209</sup> Measuring relative levels of grape traces in archeological contexts can help trace the trajectory of viticulture at a site. There are difficulties finding grape remains. Burnt canes, on account of their low density, are not generally a major, year-round fuel source, so charcoal evidence of viticulture usually is scarce.<sup>210</sup> However, a relatively high ratio of the fuel material charcoal recovered from excavations in Sobata and Nessana was burnt cane, adding further evidence of the intensity of local viticultural activity.<sup>211</sup> Because of their unusual reproduction, grapes do not produce an abundance of pollen. This sometimes makes them difficult to find when analyzing pollen collected in sediment. Also, grapes are usually consumed which makes recovering their tissues difficult.

A potential and enigmatic piece of evidence for late antique viticulture, specifically in the Negev are “grape mounds”. These features, which resemble ant hills studded with rocks or a large stone flowerpot raised above the ground get their name from the Bedouin term for them *Teleilat el-'anab* (lit. Grape hillocks). Phillip Mayerson asked Bedouins about the mounds, and they told him that they “believe that dew in the

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<sup>205</sup> Cohen et al.2023. In this case, the passage of the pip left its DNA intact.

<sup>206</sup> Fuks 2020.

<sup>207</sup> Litt et al. 2012.

<sup>208</sup> Langgut et al. 2021.

<sup>209</sup> Langgut et al. 2021.

<sup>210</sup> Crivellaroand Schweingruber 2013.

<sup>211</sup> Langgut 2021.

stones provides moisture, and that the stones keep the plants cool. The later point was illustrated by plucking a stone from the ground and showing me how cool the underside was".<sup>212</sup> Debate continues about the uses of these mounds, or if they were used for grapes at all. Reasons suggested for their existence include encouraging the condensation of dew to irrigate vines, making the vines easier to hand-irrigate, preventing erosion, encouraging erosion, and giving more clearance so seasonal runoff would go more into flood-irrigated valley floors than collect on hillsides.<sup>213</sup> Alternately, they may be waste piles from digging trenches in which to plant grapevines, which have subsequently eroded.<sup>214</sup> The theory I find most convincing is that they allowed the vines to be trained drooping over the sides of the mound. The resulting plant would look a bit like a weeping willow. In a place with few natural trees but plenty of stone, alternatives that use no wood would be advantageous.<sup>215</sup>

While the use of these mounds is debated, their presence cannot be ignored. They cover large swathes of the landscape, generally hillsides, around late antique towns in the Negev. Generally, these mounds are arranged several meters from each other in regular patterns, such as a line following the contour of a hillside or grids.<sup>216</sup> They cover thousands of hectares surrounding Sobata, 240 hectares around Nessana, and 231.2 hectares around Oboda.<sup>217</sup> The area of grape mound fields around Oboda

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<sup>212</sup> Mayerson 1961, 43.

<sup>213</sup> Seligman 2020.

<sup>214</sup> Mayerson 1961, 44.

<sup>215</sup> For comparison, one might look into the unusual method of growing grapes practiced on equally treeless Lanzarote. Vines are planted at the bottom of pits dug into the tephra. The pit protects the vine from the elements and helps collect dew.

<sup>216</sup> Mayerson 1961, Fig 8.

<sup>217</sup> Kedar 1956 and Mayerson 1959.

alone is larger than Monaco, Disneyland, or 431 American Football fields. If indeed the grape mounds were used to grow grapes, they were used to grow a lot of grapes.

Like many famous luxury products, the package Gaza wine came in is as famous as the contents.<sup>218</sup> Two distinctive amphorae are associated with the wine trade in southern Palestine.

The first critical ceramic is the late Roman amphora 4 (aka Peacock & Williams Class 48/49, Almagro 54, Kuzmanov XIV, Keay 54, Carthage LR amphora 4, and Zemer 53) henceforth called LRA4, or a Gaza Jar. They generally range in length from 40-83 cm, are 25-27cm across at their widest point, and hold between 20-25 liters.<sup>219</sup> The vessels tend to be shaped like dates or torpedoes, with a deep body, somewhat rounded bottom, high D-shaped ring handles, and little to no neck (fig. 10). The shape of the vessels changes over time, becoming longer, narrower, and with a pointier base. The fabric is thick, rough, and dull brown, occasionally grey in the middle.<sup>220</sup> The vessels are often decorated with combed ridges around the top or bottom, and occasionally red paint. Bits of fossilized shell, feldspar, and quartz in the clay match recently fired samples of local clay collected near Gaza, solidifying their origin.<sup>221</sup> Both their primary use as wine vessels and strong association with the southern Palestine in general and Gaza specifically makes it likely that these are the Gaza jars (γαζίτιον) which appear in late antique literary and papyrological sources. These vessels first appear in the archaeological record in the late second or early third century, and do not

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<sup>218</sup> Examples of this phenomenon include champagne bottles and the Tiffany's box.

<sup>219</sup> University of Southampton 2014, "Almagro 54".

<sup>220</sup> 5YR 5/6 for the outer surface, 10Y/R 5/1 for the core. Description from Peacock and Williams 1986, 199.

<sup>221</sup> Peacock 1986, 199

disappear until well into the seventh century. Their shape makes them well suited to bulk packing for long distance travel, either by boat or camel (fig. 3).

The changes of the shape of LRA 4 Gaza Jars have led to several systems of classification. The most streamlined is a system devised by Killibrew and modified by Majcherek, Fabian, and Goren (fig. 10).<sup>222</sup> The earliest design, form 1, is the shortest and thickest and associated with second and third century contexts.<sup>223</sup> Form 2 emerges in the fourth century and is a bit longer, but still rather saggy-bottomed.<sup>224</sup> An imitation of form 2 made in Elusa is form 3.<sup>225</sup> In the fifth to seventh centuries the Gaza jar is longer, narrower, and a pointy-bottomed. Form 4 is the signature shape.<sup>226</sup> There is no appreciable change in the amphora's design over these two centuries. Like the champagne bottle, whose shape has remained largely unchanged since the nineteenth century, the vessel may have found a happy equilibrium of being physically well suited for its function and successfully advertising the festive product inside.<sup>227</sup> It is not uncommon, especially in sixth century contexts, to just refer to all members of the LRA 4 family as Gaza Jars. I will do the same henceforth and refer to the numbers (1-4 on figure 10) if further specification is needed. Because of the sixth century context of this paper, it is a fair assumption that these are all LRA 4 type 4.

The second critical ceramic is the late Roman amphora 5 (aka Kellia 187, bag-shaped, Palestinian bag-shaped, Peacock & Williams 46, or more generally Palestinian

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<sup>222</sup> Fabian and Goren 2002, and see Mayerson 1992, where Killibrew's classification was first published.

<sup>223</sup> University of Southampton 2014.

<sup>224</sup> University of Southampton 2014: Mayerson and Killibrew suggested that forms 1-2 were another kind of jar referred to in papyri, the Ashkelon jar (*ἀσκάλωνιον*). It's worth noting that *ἀσκάλωνιον* is also the ancient Greek term for a shallot. Perhaps the nomenclature of the jar had more to do with its shape than its place of origin.

<sup>225</sup> Fabian 2002.

<sup>226</sup> University of Southampton 2014.

<sup>227</sup> Society for Historical Archeology 2022.

amphora) henceforth abbreviated as LRA 5. They range in size from 39 cm – 43 cm tall, 32cm – 36 cm wide, and hold about 20-25 liters.<sup>228</sup> Usually, they are recognizable from their combed surface. It is an exceptionally popular and persistent vessel. They are made from the first until the eighth century CE.<sup>229</sup> While their fabric suggests they were frequently made in Palestine, local variations crop up throughout Lower Egypt and the Transjordan plateau.<sup>230</sup> Magness recognizes seven different variants of this amphora, differentiated generally by their shape, fabric, era of make, and decoration.<sup>231</sup> Their color ranges from dark red-brown to slightly pink.<sup>232</sup> Their stable, squat shape makes them ideal for keeping in a cellar or setting on a shelf, but may not be the most efficient for long distance trade.

There is a third vessel worth mentioning. A variation of LRA 4 was produced in Elusa, as evidenced by geochemical analysis and the discovery of a fourth-to sixth century kiln in the town.<sup>233</sup> This amphora is sporadically found at sites in the Negev. The form is much like LRA 4, the main difference is the fabric. Amphorae from Elusa have a finer texture and are buff or cream colored, in contrast to the coarse texture and brown-grey shade of their coastal cousins. The first authors to describe the Elusa jar suggest that it may have been a counterfeit Gaza jar or used primarily for local consumption.<sup>234</sup>

Both LRA 4 and LRA 5, in all their variations, traveled widely. Both of these vessels are found a surprising distance from their place of manufacture. LRA 5 amphora

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<sup>228</sup> University of Southampton 2014b.

<sup>229</sup> *Idem.*

<sup>230</sup> *Idem.*

<sup>231</sup> Magness 1993, 223-231.

<sup>232</sup> Magness 1993:2.5YR5/4 and 7.5YR7/4, respectively.

<sup>233</sup> Fabian 2002.

<sup>234</sup> *Idem.*

are found from Alicante Spain to Bulgaria.<sup>235</sup> The LRA 4/Gaza Jar is even more well-traveled. Specimens have been found from Wales to Qana in southern Arabia.<sup>236</sup> Generally, LRA 4 amphora are found in sites that ring the Mediterranean and along major navigable rivers, such as the Danube.<sup>237</sup> The wide distribution of these vessels has drawn a lot of attention from the economically inclined, and suggests that in a darkening age, Gaza wine was a luxury product exported to the very edges of the known world.

The ubiquity of these containers in the late antique Roman world can be well demonstrated from their use in *The Spiritual Meadow*, a collection of fables, hagiographies, accounts of miracles and heresies compiled by John Moschus around the end of the sixth century<sup>238</sup>. In one story an *abba* and his gang of deacons become angry when one of the deacons finds his *omophorion* (μαφόριον) missing. They begin to search the property of the brothers at the monastery. The brother who stole the garment confesses to a pious friend of his “I stole the omophorion and it is in my cell at the bottom of a Gaza jar (ἐγὼ ἔκλεψα τὸ μαφόριον, καὶ ἔστιν ἐν τῷ κελλίῳ μου κάτω εἰς γαζίτιον).”<sup>239</sup> This tale suggests several things. The first is it possibly suggests something about the monk's character. An empty vessel associated with an indulgent beverage in the cell of someone dedicated to pious observance may be damning evidence, even if it did not have stolen goods at the bottom. It also suggests a Gaza amphora is the sort of thing the original audience would have been able to immediately

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<sup>235</sup> University of Southampton 2014b.

<sup>236</sup> Lantos et al. 2020, Fig. 6.

<sup>237</sup> Lantos et al. 2020, Fig. 6.

<sup>238</sup> Moschus 2008.

<sup>239</sup> Nissen 1938.

call to mind. For Moschus' readers this kind of amphora would be both common and distinct enough to warrant specification. In a modern comparison, consider if a McGuffin was hidden in a bag versus if it was hidden in a Crown Royal bag. The latter adds vividness and is an object common enough that it is easy to visualize.

While primarily used for transporting wine, as evidenced by texts and residue analysis, Gaza amphorae were versatile vessels. A good example of the breadth of uses of the container can be found on a papyrus kept at the Gothenberg University library, a list of provisions for military officers, conveniently sorted by which kind of container the foodstuffs come in. Of the Gaza amphora (γαζίτιον) mentioned in the inventory, thirty nine jars contain wine, one walnuts, fifteen sweets, and one holds "salty snacks".<sup>240</sup> Residue analysis of LRA 4 amphorae suggests that along with wine, they were occasionally used to transport olive or sesame oil.<sup>241</sup> Gaza jars proved useful vessels even when broken. LRA 4 amphorae have been found repurposed as braziers, pipes, troughs, part of a bellows for a kiln, building material, and in a burial to prop up the head of the deceased.<sup>242</sup>

The accoutrements of winemaking are a large part of the visual culture of southern Palestine in the fourth to sixth centuries. Three mosaics discovered near Gaza and Ashkelon from three separate sites are of particular interest. All are mosaic floors decorated in an "inhabited scroll" pattern that was very chic in the sixth century.<sup>243</sup> A synagogue found in what is probably the site of Menoia has particularly good examples

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<sup>240</sup> *P. Gott.* 17.4 ἄλικος, I suspect that this is related to ἀλιζω (to add salt) or ἄλις (salt). Perhaps these are salted snacks in contrast to the sweet ones in other jars.

<sup>241</sup> Reynolds et al. n.d., "Late Roman Amphora 4 (LRA 4)/"Gaza" Jars."  
<https://www.levantineceramics.org/wares/857-late-roman-amphora-4-lra-4-gaza-jars>.

<sup>242</sup> Taxel 2018. Chapter 4 covers the many uses of amphorae beyond transporting fluids.

<sup>243</sup> Hachlili 2009, 111–12.

of grape motifs. It shows scrolling loops of grapevines forming medallions. In these hoops are objects associated with Judaism (including a *shofar*, a *lulav*, and a menorah), birds, exotic animals, as well as a yolk-shaped basket heaping with grapes (fig.2).<sup>244</sup> Contemporary mosaics show a burden basket of the type that was slung across the back of a beast of burden, perhaps to bring grapes to a press (fig.4).<sup>245</sup> An anonymous church found near Kissufim shows a camel laden with vessels which look similar to Gaza jars, LRA 4 type 4 to be precise (fig. 3).<sup>246</sup> Since both Kissufim and Menois are close to Gaza, perhaps the artist was incorporating familiar images of the world around them, or perhaps was commissioned to include these images by donors who depended on the wine trade.

The Church of St. Stephen in Birsama is richly decorated with vine motifs. Much like the synagogue, the mosaic on its floor has a scrolling, looping vine motif. Among the vines is an image of a donkey carrying a covered yolk-shaped basket. While the contents of this basket can only be imagined, the shape of the container and covering makes grapes a very likely possibility. Covering grapes is beneficial. It protects them from insects and debris, and hopefully keeps them cool enough to prevent spontaneous unwanted fermentation. The most direct evidence of the area's involvement in the Gaza wine trade comes from an image of two pigeons using a suspended Gaza Jar (LRA 4 type A) as a birdhouse (fig.5). These decorations, as well as the presence of a large winepress, a storeroom filled with Gaza jars (both LRA 4 and 5), and a kiln filled with wasters of both

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<sup>244</sup> Habas 2022.

<sup>245</sup> Ibid.

<sup>246</sup> Ibid. and Peacock and Williams 1986, 198-99.

these jars are strong evidence that not only was winemaking done in this town, it was a prominent industry.<sup>247</sup>

Mapping out the data presented by Seligman, Fuks, Ayalon, and other sources is illuminating (fig 1.). With the exception of Elusa and Berosaba, kilns associated with making LRA 4-5 amphora are clustered by the coast. Winepresses are found wherever people lived. The presence of grape pips and "grape mounds" in Nessana, along with papyrological evidence suggests that it too produced wine. It also demonstrates how much the entire region was invested in wine production.

I suspect that to the wider world; Gaza wine was whatever wine was convenient to ship out of Gaza. Historically, wines generally do not need to be completely from the appellation to put the name of that appellation on their label. Malmsey, a wine popular in renaissance England, took its name from the Greek port of Monemvasia where wines from all over the Greek islands were exported.<sup>248</sup> Likewise, I suspect that Gaza wine did not have to all come from the same place. The name recognition is what mattered. I suspect connoisseurs like Cassiodorus would not have known, nor cared, what percentage of the grapes were highland or lowland Gazan, as long as it looked right and tasted good. More specifically, I suspect the border of the Gaza wine *appellation d'origine* was wherever it was easiest to ship wine out of Gaza rather than Jaffa or Haifa or Alexandria".

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<sup>247</sup> Dolinka 2007.

<sup>248</sup> Robinson 1994, s.v. Malmsey, Malvasia.

## Gaza Wine Production and Settlement Patterns post 536 CE

Investigations of middens in the towns of the Negev show evidence both for the trajectory of winemaking in the towns, and the settlement of the area as whole. The Negev was one of the first frontiers when humans migrated out of Africa. An excavation in Wadi Zin shows evidence that humans were in the area 50,000 years ago.<sup>249</sup> Permanent, largescale settlement in the Negev, however, was an innovation of the fourth century CE.<sup>250</sup> The unusual spike in settlement in late antiquity, along with the “enhanced ecological sensitivity of its arid environment, make it a veritable litmus case for detecting regional decline in the urban record and societal response to LALIA-associated developments by the sixth century CE.”<sup>251</sup> What makes the towns of the Negev unusual is that they were largely abandoned. Other cities in the southern Levant, including Gerasa and Caesarea went through urban changes that reflect “shifting conceptions of the role and function of cities”.<sup>252</sup> Elusa ceased to be a city at all. Like the wine trade, the life of the permanent towns gradually petered out over the sixth and seventh centuries until they ceased to exist at some point during the Early Islamic Period. Exactly why and how this transition occurred is a source of great curiosity. Recent studies make it clear that the fate of the grapes of the Negev was trained to the cities that grew them.

Elusa, the largest settlement in the late antique Negev and perhaps its only proper city, is an illustrative example. Elusa sits at the intersection of two important routes, the “Incense Road” which led from southern Arabia to the port of Gaza and a

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<sup>249</sup> Boaretto 2021.

<sup>250</sup> Bar-Oz, 2019.

<sup>251</sup> Bar-Oz 2019, 8240.

<sup>252</sup> Ibid.

north-south route that linked Jerusalem, the Sinai, and Egypt.<sup>253</sup> The town was established as a waystation by the Nabateans, probably in the third century BCE.<sup>254</sup> When trade declined in the third century CE, Elusa and its neighboring caravansary settlements, including the future wine production centers of Sobata, Nessana, Oboda, and Ruheiba, gradually transitioned to prosperous farming towns with the help of extensive rain catchment systems.<sup>255</sup> Elusa was granted the status of *polis* in 305/6 CE, and became the administrative, military, and religious capital of the area.<sup>256</sup> It was the seat of a bishopric, home of a well-regarded fourth century school of rhetoric, and the site of the only theatre in the Negev.<sup>257</sup> It supported a population of 8000-10,000 people of mixed religious and ethnic backgrounds.<sup>258</sup> Elusa was involved in the wine trade, as evidenced by the presence of wine presses, amphora production facilities, and an abundance of LRA 4/5 sherds in the trash pits on the edge of town.<sup>259</sup>

Elusa's trash shows its prosperity sharply declined in the mid sixth century. Refuse from the city, including ash from fires, organic matter, sand, dust, and broken pottery was deposited in discrete mounds along the northeastern and southern edge of the settlement.<sup>260</sup> This suggests an organized effort to keep the town clean, perhaps carried out by civic services. Radiocarbon dating supported by pottery seriation suggests that waste ceased to be deposited on these mounds during the mid-sixth century.<sup>261</sup> Trash may have instead been deposited in streets or empty lots, but these

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<sup>253</sup> Heinzelmann 2022, 237. The Sinai-Jerusalem road later became an important pilgrimage route.

<sup>254</sup> Ibid.

<sup>255</sup> Ibid.

<sup>256</sup> Ibid.

<sup>257</sup> Idem. 238

<sup>258</sup> Ibid.

<sup>259</sup> Idem. 288.

<sup>260</sup> Idem. 238.

<sup>261</sup> Bar-Oz 2019.

dump sites are more ephemeral in the archeological record. Elusa may have not been able to facilitate waste removal, enforce waste removal, or the population may have fallen and there was less waste. While evidence from the Nessana Papyri, especially documents dated between 674-690 CE suggest that Elusa may have continued to briefly serve as an administrative center into the Islamic period, when it became a dune-covered shadow of the town it had been.<sup>262</sup>

The smaller settlements of the Negev also experienced a change in their waste disposal practices. Outside Nessana, ash from burnt animal dung is a common element of the older, Byzantine layers of their trash pits, but the remains of raw animal dung are scarce.<sup>263</sup> This suggests that byproducts of animal husbandry were diverted for use as fuel, and perhaps as fertilizer.<sup>264</sup> In early Islamic contexts, fresh dung or dung burned upon the mounds is common.<sup>265</sup> Fresh dung on trash mounds suggests that it was not being used as fuel or fertilizer, and the residents of the town had taken to smaller scale farming and herding work.<sup>266</sup>

Trash pits have also yielded the most extensive evidence that the period between 536-550 was detrimental to the Negev wine trade. Fuks et al. compared the ratios of grape and cereal botanical remains and sherds from LRA 4 (Gaza) from Elusa, Sobata, and Nessana. Before the mid third century, grapes have barely any presence in the trash archives. A single pip was found from Roman refuse in Sobata, and grape remains make up only fourteen percent of the grain and grape assemblage in Elusa

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<sup>262</sup> Idem.

<sup>263</sup> Butler 2020.

<sup>264</sup> Idem.

<sup>265</sup> Idem.

<sup>266</sup> Idem.

between 300-450CE (fig. 10).<sup>267</sup> Between 450-500 CE, the ratio changes dramatically, with grape seeds making up nearly forty percent of the grape – grain ratio. LRA4 jars, unattested in the pottery record up to this point, make up twenty four percent of the pottery assemblage of Elusa between 450-550 CE.<sup>268</sup> LRA4 sherds are fifty two percent of the assemblage for Sobata during the same time period. Grape remains also become more prevalent, making up forty-three percent of the grain-grape assemblage in Elusa and forty-two percent of the assemblage from Sobata.<sup>269</sup> Around 550 there is a dramatic break. Grape remains represent only eighteen percent of the grape-grain assemblage in one sample dated to around 550 CE and fourteen percent in another dated between 550-650.<sup>270</sup> LRA4 amphorae make up sixteen and six percent of the assemblages in the respective mounds.<sup>271</sup> This suggests that following LALIA the Gaza wine industry suffered. When literary sources, climate proxies, and grape biology are taken into account, I suspect the decreased grape production and amphorae usage following LALIA were due to problems with the vines.

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<sup>267</sup> Fuks 2020, Table 2.

<sup>268</sup> Ibid.

<sup>269</sup> Ibid.

<sup>270</sup> Ibid.

<sup>271</sup> Ibid.

## Chapter 4: Nineteenth Century Models of Viticultural Disaster

There are two questions that help determine the scale of LALIA's effect on viticulture and populations that relied on grapes and wine for a livelihood. While helpful, the textual and archeological record raises several unanswered questions. First, does unseasonably cold weather triggered by a volcanic eruption have an observable effect on viticulture? Second, do problems with grapevines have a significant impact on the people who rely on them? There are two environmental disasters that occurred in wine-growing regions of Europe during the nineteenth century that can help answer these questions.

LALIA is not the only time climate shifts triggered by volcanic eruptions would impact humans. Several others, including the eruptions of Santorini, Vesuvius, and Krakatoa, have left scorch marks on history. The 1815 eruption of Mount Tambora in Indonesia, and the disastrous "Year without a Summer" that followed in 1816 provide an exceptionally worthy historical parallel for discussing the LALIA. In numerous sources, including Büntgen et al. 2016 and Sigl et al. 2015 specifically reference 1816 as a comparison to 536/540, usually to express how much more severe the earlier eruption was. A volcanic eruption was the genesis of both problems. The nature of the problem being volcanic in origin is confirmed by the sulfates they left behind on icecaps. "Tambora's sulfate anomaly" notes Oppenheimer "is one of the two largest in the Antarctic ice cores for at least 500 years".<sup>272</sup> The eruption in 536, however, "resulted in up to 10% higher global aerosol loading than the Tambora 1815 eruption reconstructed from our bipolar sulfate records."<sup>273</sup> What was bad in the nineteenth century may have

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<sup>272</sup> Oppenheimer 2003.

<sup>273</sup> Sigl 2015.

been even worse in the sixth. Dendrochronological evidence supports widespread cooling triggered by an atmospheric veil for both.<sup>274</sup> Both events were comparatively well documented by a variety of cultures in literary sources.<sup>275</sup> Many literary sources across a variety of cultures documented unseasonable and chilly weather in the wake of both events. Recent warfare in Europe was an additional factor in both situations. Famine, Pestilence, and other misfortune attended both events on an international scale. Both “the Year without a Summer” and LALIA also had profound cultural impacts, perhaps shaping the mythologies that continue to hold sway over the modern world.

### **1816: Cause and Effect**

Between 5 and 15 April in 1815, Tambora, a volcano on the Indonesian island of Sumbawa, raged.<sup>276</sup> The eruption was roughly ten times larger than the one that would shake Krakatoa in 1883, and more than one hundred times larger than the eruption of Mount. St. Helens in 1980 or Vesuvius in 79.<sup>277</sup> It spewed more than 100 cubic kilometers of debris forty kilometers into the atmosphere. In the immediate aftermath volcanic debris, tsunamis, and rapid evacuations halved the population (calculated to have been approximately 170,000) of Sumbawa. The effects of the eruption that next year went beyond blocking out the sun. Widespread cooling disturbed the monsoons that much of Asia and Africa rely on for rain.<sup>278</sup> In India, the rain came and left late. The

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<sup>274</sup> Briffa 1998.

<sup>275</sup> Tillotson 2016. This program provides a good basic introduction to the event.

<sup>276</sup> Behringer 2019.

<sup>277</sup> Smithsonian National Museum of Natural History. n.d.

These figures are calculated using the Volcanic Explosivity Index, a logarithmic scale used to compare the explosivity of volcanoes. Each interval increases by a factor of 10. An Eruption with a VEI of 2 is ten times larger than a VEI 1. The eruption of Eyjafjallajökull which caused so much trouble in 2010 had a VEI of 4. Mount. St. Helens and Vesuvius both were VEI 5. Krakatoa, VEI 6. Tambora and whatever triggered LALIA had a VEI of 7.

<sup>278</sup> Pfister and White 2018.

monsoon arrived in August and persisted through September, when the storms usually recede. As a result, crops were ruined, famine spread, and cholera was particularly virulent in 1816.<sup>279</sup> The eruption blocked and disturbed jet streams over the North Atlantic, driving cold air further south than usual and trapping warm air further north.<sup>280</sup> Snow fell across New England that June.<sup>281</sup> In contrast, the Arctic experienced unseasonably warm weather. Frustrated whalers noted far less sea ice than usual in 1816, and far fewer whales beneath it.<sup>282</sup> The “Year Without a Summer” possibly produced profound effects on human migration, both voluntary and forced. In the first sixteen years of the nineteenth century, the number of English prisoners, many sentenced for sustenance supplementing crimes like theft, transported to New South Wales never exceeded 1,050 per annum.<sup>283</sup> That number went up dramatically after 1816, when food became significantly more expensive, peaking with twenty two ships and 2,746 exiles arriving in 1820.<sup>284</sup> These numbers do not include the many immigrants who came to Australia of their own accord, searching for a new start. The increased population of European transplants and their diseases had disastrous effects on Aboriginal Australians. The events on Sumbawa touched all corners of the earth.

A sense of the impact that the “Year Without a Summer” had on viticulture can be found in the letters of a notable American wine enthusiast. In September of 1816 Thomas Appleton, the United States consul at Livorno, Italy, and a longtime political ally of Thomas Jefferson, included a letter with a massive shipment of Italian wine. After a

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<sup>279</sup> Pfister 2018, 557.

<sup>280</sup> Pfister 2018, 552.

<sup>281</sup> Behringer 2019, 35.

<sup>282</sup> Pfister 2018, 552

<sup>283</sup> Behringer 2019, 260.

<sup>284</sup> Ibid.

discussion of the 258 bottles of wine, including Chianti and Montepulciano, that he has sent to Jefferson via several agents, Appleton adds a concerned note.

“The late Season has been the most extraordinary one, Remember’d by the oldest & most observing farmer. there has not been a Single day, in which Farenheit’s thermometer has risen above 75—generally it mark’d from 65 to 70 degrees; the usual heat in Summer, is from 75 to 83...the greatest part of our grapes have dropp’d from the vines; and the remainder, have not, even yet, arriv’d at perfect maturity; So that, our wine will be dear, and of a very indifferent quality.”<sup>285</sup>

Appleton is warning Jefferson that he will likely not receive as many bottles next year because there may not be much of a harvest in 1816.<sup>286</sup>

Tuscany was not the only wine growing region to face a disastrous year in 1816. In Bolzano/Bolzen in the southern Tyrol, budbreak did not occur until August.<sup>287</sup> Unsurprisingly, the grapes in that town did not ripen that year.<sup>288</sup> A meteorologist in Bremen named Müller noted that along with near daily rain, high wind, and famine in Thuringia, Bavaria and the Rhineland “there was no wine at all”.<sup>289</sup> In parts of Switzerland, the harvest was cancelled on account of early frost and there not being anything to harvest.<sup>290</sup>

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<sup>285</sup> Appleton, Thomas. Letter to Thomas Jefferson. 2013. *The Papers of Thomas Jefferson, Retirement Series*. May 1816 to 18 January 1817, September 27.

<sup>286</sup> Conveniently, it also gives us all the information we need to calculate degree days. In Appleton’s usual year, would get 3,335 degree days F. That’s squarely within a Region III on the Winkler index, a very favorable place to grow wine. However, in 1816, the highest possible number of degree days is 2012.5. This would put it within Winkler Region 1b. It is possible to harvest wine in an area with that number of degree days, Burgundy, The Central Coast of California, and the Rhine valley all get a similar number of degree days and are famous for viticulture. However, the grape cultivars planted around Tuscany tend to need the extra heat to ripen, rather than the heartier kinds planted in cooler places.

<sup>287</sup> Behringer 2019, 30.

<sup>288</sup> Behringer 2019, 20.

<sup>289</sup> Behringer 2019, 34.

<sup>290</sup> Behringer 2019, 64.

## 1816 Grape Harvest Dates (GHD)

As a result of their remarkable, and predictable, sensitivity to changes in temperature, grapes have long been used as a climate proxy by comparing harvest dates. Specifically, grape harvests can give a sense of the average temperature for the period between April 1st (when nearly all grapes have undergone budbreak) and August 31<sup>st</sup> (When harvest begins in earnest). In warmer years, the harvest is early. In colder years, the harvest is late. If you have a degree day equation you can easily calculate an average.<sup>291</sup> The beginning of harvest is an event that is important and exciting. The decision when to pick is made collectively. It is not surprising that it is often noted in civic records. Receipts of payment for laborers and newspaper reports add to the paper trail. The earliest compilation of historical of grape harvest dates (often abbreviated as GHD) was in 1836, when a surveyor from Dijon named Etienne Noirot compiled a list of harvest dates recorded in the Beaune that stretched back to 1385.<sup>292</sup> His aim in this was to show that the climate of Burgundy had changed little in the past 500 years. This dataset, expanded upon and scrutinized in the last couple centuries, is still the largest dataset of harvest dates available. With growing interest in human induced climate change in the twenty first century, the amount of available data on harvest dates around Europe has blossomed. A database of grape harvest dates for twenty-seven wine growing areas across northern Europe was published in 2012, and is available to the public through the National Oceanographic and Atmospheric Administration (NOAA) website.<sup>293</sup> Further scholarship has expanded the region of study. Historical grape

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<sup>291</sup> See *infra* pg. 31

<sup>292</sup> Noirot 1836.

<sup>293</sup> Daux 2012.

harvest date and temperature variability data has been assessed in Serbia,<sup>294</sup> Spain,<sup>295</sup> and Portugal.<sup>296</sup> There is a well-established link between viticultural history and climate history.

When looking at the historical data, 1816 stands out like a sore thumb. Among the thousands of harvest dates collected by Daux et al., the 1816 harvest date is frequently the latest date in each data set (fig 9). In the longest set from Beaune, which is the same one used by Noirot, the average harvest date of the previous five centuries is September twenty-fifth.<sup>297</sup> In 1816, harvest began a month later on October twenty-first.<sup>298</sup> Late October harvest dates were also recorded in Champagne and Bordeaux, both famous wine producing regions whose average harvest date for the last fifteen years had been in September.<sup>299</sup> November harvest dates were recorded in southern Lorraine and around Lake Lemman.<sup>300</sup> There were not nearly enough degree days to produce regular harvests in almost all other regions of Europe. Since the effects of LALIA, as demonstrated by existing climate proxies, were potentially more severe, I suspect that harvests in the wine growing regions of late antiquity were also dramatically delayed, if there was any fruit to pick at all. This data makes it abundantly clear that climate anomalies triggered by volcanic eruptions can have a strong negative impact on grape cultivation and wine production.

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<sup>294</sup> Ruml 2016.

<sup>295</sup> Ramos 2018.

<sup>296</sup> Reis 2018.

<sup>297</sup> Daux 2012.

<sup>298</sup> Idem.

<sup>299</sup> Idem.

<sup>300</sup> Idem.

## 1816 and Swiss Wine Country: A Case Study

People and areas that relied on viticulture suffered with their vines. Daniel Krämer's study of the effects that 1816 had on Switzerland illustrates this point. This is largely due to settlement patterns and agricultural practices surrounding grape growing in nineteenth century Switzerland. Vineyards were an exceptionally profitable and high yielding crop, able to feed two-and-a-half to more than three times as many people compared to regions dedicated to the cultivation of cereal crops or herding.<sup>301</sup> This allowed more farmers to make a living off of smaller plots of land. It is no surprise then that wine growing regions, primarily concentrated along lakes and rivers whose climate moderating effect usually helps temper extreme weather, were among the most densely populated areas of Switzerland in 1816.<sup>302</sup> Areas along the banks of Lake Lemman/Geneva, Lake Biel, Lake Neuchâtel, Lake Zurich, the Rhône and the Bodensee were, and still are, notable wine producing regions.<sup>303</sup> Generally, farmers did not solely grow grapevines, but would keep other crops (such as fruit trees), to mitigate risk and make sure that, if the wine grapes failed or sold at a low price, there was still something to sell.<sup>304</sup> In 1816, there was little to sell, neither from the vines nor insurance crops. The harvest date recorded along Lake Lemman in 1816 is still the latest one recorded.<sup>305</sup> Grapes were brought in on November tenth (fig 9.B).

Nutritional stress can be difficult to measure, especially since famines are sparked by both natural and societal factors. Common ways to find evidence of stress

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<sup>301</sup> Krämer 2015, 331,

<sup>302</sup> Ibid.

<sup>303</sup> Krämer 2015, 371. Abb.6.4, Johnson. 2013. s.v. Switzerland.

<sup>304</sup> Krämer 2015, 332.

<sup>305</sup> Daux 2012.

involve looking through local records. Mortality rates in a population can be calculated by comparing census records or the relative rates of baptisms and funerals in regional churches. Nutritional stress makes getting and staying pregnant more difficult and provides motivation for pregnancies to be voluntarily terminated.<sup>306</sup> Deaths may be triggered by starvation or a host of diseases made worse by insufficient food. Height, which is affected by in utero and childhood nutrition can be deduced from passport<sup>307</sup> or military enlistment<sup>308</sup> records. Crime rates, especially property crime and theft of food, both reflect hunger and growing disregard for social norms.<sup>309</sup>

The resulting famine caused nutritional stress across Switzerland. Men from Entlebuch born during the first decade of the nineteenth century were an average of two centimeters shorter than men born the decade before or after.<sup>310</sup> In 1814 and 1815, property crime accounted for about forty percent of the total number of crimes recorded in Switzerland.<sup>311</sup> In 1816, property crime accounted for more than fifty percent of the crimes and jumped to nearly sixty percent in 1817.<sup>312</sup>

While trouble was experienced across Switzerland, wine county had an especially difficult experience. Among the highest relative mortality rates in Switzerland were experienced in regions that relied heavily on winemaking.<sup>313</sup> In order to determine how various parts of Switzerland were impacted by hunger Krämer “calculated the relative size of annual demographic cohorts, as an effect of births and deaths in a

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<sup>306</sup> Krämer 2015. 332

<sup>307</sup> Krämer 2015. 344

<sup>308</sup> Banerjee 2010.

<sup>309</sup> Krämer 2015. 337.

<sup>310</sup> Ibid. 347.

<sup>311</sup> Ibid. 341.

<sup>312</sup> Idem.

<sup>313</sup> Ibid. 395, Abb. 6.9.

particular year, to serve as an indicator of nutritional stress.”<sup>314</sup> The sizes of demographic cohorts were derived from an 1860 census.<sup>315</sup> The most vulnerable districts in 1817 included Morges, Lavaux, Rolle, Brugg, Neuchâtel, Erlach, and Orbe.<sup>316</sup> All of these areas were significantly invested in viticulture.<sup>317</sup> While other farmers seem to have been sheltered from higher mortality rates, perhaps with the help of foraging, eating what they could harvest instead of selling it, or filching from their neighbors, Swiss winemakers were among the unluckiest of their countrymen. Krämer’s survey shows that, not only does volcano induced cooling have negative impacts on grapevines, people who relied on grapes for a livelihood may have experienced additional hardship.

I would be remiss if I did not give some space to the less grim things the “Year Without a Summer” brought to the world. The first research project on past climate change was instigated by the Swiss Society of Natural Sciences in 1818, inspired by the dramatic advance of glaciers they had witnessed in the previous chilly summers.<sup>318</sup> With a shortage of fodder and horses making travel difficult and expensive, Karl Freiherr von Drais was inspired to work on the “Draisine”, a prototype of the bicycle, which made its public premiere in June 1817.<sup>319</sup> A study published in 2007, looking at art from the fourteenth to twentieth century found “a statistically significant correlation coefficient (0.8) between the measured red-to-green ratios of a few hundred paintings and the dust veil index.”<sup>320</sup> The sunsets in paintings made around 1816 were more intensely red and

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<sup>314</sup> Pfister and White 2018, 553.

<sup>315</sup> *Idem.*

<sup>316</sup> Krämer 2015, 392.

<sup>317</sup> *Ibid.* 371, Abb. 6.4.

<sup>318</sup> Pfister and White 2018.

<sup>319</sup> Townsend 2016.

<sup>320</sup> Zerefos et al. 2007.

orange than ones made while there was less volcanic detritus in the atmosphere. The flaming skies in JMW Turner's *The Decline of the Carthaginian Empire...*, exhibited in 1817, may have been inspired by a side effect of the eruption.<sup>321</sup> In her introduction to *Frankenstein*, Mary Shelley, who was in Switzerland that summer, recalls that 1816 was "a wet, ungenial summer, and incessant rain often confined us for days to the house" inspiring her to write.<sup>322</sup> The "Year without a Summer" is a reminder that volcanically induced climate disasters can have far reaching cultural impacts that are not entirely grim.

There is, however, a problem with comparing the 1816 event with LALIA. The "Year Without a Summer" was a relatively brief period. Grape harvests in 1817 were largely back within normal perimeters.<sup>323</sup> In contrast, disastrous weather kept coming during the LALIA, it was a decades long problem. To confirm that problems with grape harvests have a marked negative effect on the people who grow them, a longer-term problem could provide a useful model. Human ignorance and insects caused another illustrative disaster in the nineteenth century.

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<sup>321</sup> For information on the Turner, please consult "*The Decline of the Carthaginian Empire ...*", Joseph Mallord William Turner, Exhibited 1817." 2023. *Tate*. Tate. <https://www.tate.org.uk/art/artworks/turner-the-decline-of-the-carthaginian-empire-n00499>. It is one of the paintings used by Zerefos et al. 2007 to demonstrate a volcanically reddened sunset. The subject matter of the painting was too appropriate for this subject to not include it. If you are wondering why there is an ellipsis in the title of the painting, Turner titled it *The Decline of the Carthaginian Empire-Rome being determined on the Overthrow of her Hated Rival, demanded from her such Terms as might either force her into War, or ruin her by Compliance: the Enervated Carthaginians, in their Anxiety for Peace, consented to give up even their Arms and their Children*.

<sup>322</sup> Shelley 1831.

<sup>323</sup> Fig 2. The Harvest dates for cases B, C, and D fall neatly within one standard deviation.

## The Great French Wine Blight

A disaster caused by human ignorance struck between 1863 and 1898, when grapevines across Europe sickened and died in waves.<sup>324</sup> France was hit especially hard, so the span is frequently called the Great French Vine Blight. This was the result of the accidental introduction of *Daktulosphaira vitifoliae*, an aphidlike insect commonly called phylloxera. Phylloxera is native to North America and feeds on the roots of grapevines. Native North American grapes, such as *Vitis labrusca*, have a natural resistance to the bug; *Vitus vinifera* has no such resistance.<sup>325</sup> Over a course of three or more years, a phylloxera infected vine will shrivel, lose its leaves, produce poor fruit (if any at all), and die.<sup>326</sup> The problem was remedied when it was discovered that grafting root stock from American grapevine hybrids on to *vinifera* branches preserved the crop. As a result, to this day, nearly all commercial grapevines are grafted combinations of two species of grapevine.<sup>327</sup>

The arrival of phylloxera in France was nothing short of a national disaster. France's economy relied heavily on agriculture. When phylloxera reached the Rhône Valley in 1863, winemaking represented about one-sixth of the total value of French agricultural production.<sup>328</sup> In 1870, eight million people, approximately seventeen percent of the French work force, were involved in wine production.<sup>329</sup> Since a hectare of wine grapes could produce up to five times more value than any other crop, even

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<sup>324</sup> Johnson 2013, 15. There is an exceptionally helpful timeline of Phylloxera spreading on this page.

<sup>325</sup> Robinson 1994, s.v. Phylloxera.

<sup>326</sup> Idem.

<sup>327</sup> Johnson 2013. Most of South America, East Asia, Australia, and areas with soil inhospitable to anything but grapevines are some of the few places where *V. vinifera* cuttings are planted ungrafted, for now.

<sup>328</sup> Banerjee 2010.

<sup>329</sup> Gale 2011, 16.

small-scale framers could make a decent profit from viticulture.<sup>330</sup> By the time grafting procedures which prevented phylloxera damage were introduced in the 1890d's forty percent of French grapevines were already dead.<sup>331</sup> Making vineyards phylloxera tolerant involved ripping out and replanting new vines, a process that came at a tremendous cost. If lined up end to end, the graft stock used to replant France would circle the equator almost eighty times.<sup>332</sup> The restitution of French vineyards cost more than the entire Franco-Prussian war.<sup>333</sup> The blight was also a personal, emotional disaster, especially for a people that still take immense local and national pride in their wine. One farmer, Joseph de Pesquidoux, remarked "The beast wins everywhere. In its wake solitude invades all the land, and the horizon takes on an unfamiliar aspect, made up of empty and desolate space".<sup>334</sup>

Some unusual conditions make the French Wine Blight a useful model for how a collapse of grape vines can cause have wider ripples in a populace. Bignon et al. point out that vineyards were not generally replanted with other agricultural products, the price of wine did not increase significantly, and the affected populations did not generally migrate in response to the crisis. Phylloxera only attacks grape vines, so cereals and other staple crops were unharmed. This allows a limited scope; one can see what happens if the only variable is the health and productivity of grapevines.

The wine blight caused public health and social problems in areas that relied heavily on viticulture. Local credit systems partially collapsed.<sup>335</sup> This, as well as

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<sup>330</sup> Gale 2011.

<sup>331</sup> Bignon 2014.

<sup>332</sup> Gale 2011, 127.

<sup>333</sup> Idem.

<sup>334</sup> Ibid. 16.

<sup>335</sup> Postel-Vinay 1989.

increasingly shrinking incomes put stress on families in places infected with phylloxera. Young children's nutritional status, and consequently adult height, is influenced by their family's income.<sup>336</sup> Banerjee et al. 2010 found that French men from winegrowing areas infected with phylloxera who were born or young children during the blight were an average of 0.5 to 0.9 centimeters shorter than their peers from phylloxera-free winegrowing areas.<sup>337</sup> This is likely the result of nutritional deficiencies. Bignon et al. 2017 found that between 1863 and 1890, crime patterns changed in France. In areas economically reliant on wine, there was an eighteen percent increase in property crimes, such as theft.<sup>338</sup> Violent crime rates, however, decreased by twelve percent across France.<sup>339</sup> The authors of this paper suggest that the rise in localized property crime was due to increased poverty and the drop in violent crime was due to lower consumption of alcohol. The price of wine did not increase, but the populace could no longer afford to overindulge.

It is worth noting that the French Wine Blight was not a total societal collapse. Property crime did not double or triple, it increased by eighteen percent. Violent crime decreased. While children who grew up during the blight were shorter, they did not experience higher levels of mortality, including infant mortality.<sup>340</sup> Banerjee suggests that other factors, such as an interest in providing clean water infrastructure during the time, may have helped mitigate more dramatic consequences of the crisis.<sup>341</sup> Phylloxera

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<sup>336</sup> Banerjee 2010.

<sup>337</sup> Idem. Measurements were derived from data collected by the French military administration. Interestingly, men from winegrowing regions unaffected by phylloxera tended to be taller than their countrymen.

<sup>338</sup> Bignon 2014.

<sup>339</sup> Idem.

<sup>340</sup> Banerjee 2010.

<sup>341</sup> Idem.

may have spurred long-term and serious consequences for the people of French wine country, but it did not decimate them.

While it would be difficult with available information to tell if crime, credit, or stature were affected by LALIA in southern Palestine, these studies provide prospective. The work of Krämer, Banerjee et al., and Bignon et al. all show that there are significant effects on public health and wellbeing when there are widespread problems with grapevines. In addition, the nutritional deficits that harmed nineteenth century viticultural communities would potentially make those same communities susceptible to a pandemic. The Great French Wine Blight demonstrates that the failure of a single high value crop, grapes, can result in significant nutritional, financial, and societal crises. Many commentators, both modern and ancient, suggest that in the wake of LALIA the grape harvest suffered due to people problems.<sup>342</sup> The experience of the French wine blight of the late nineteenth century demonstrates that the reverse is more likely: the people were harmed by a problematic grape harvest.

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<sup>342</sup> Michael the Syrian 9.28, and Avni 2023 remain the oldest and most recent examples.

## Chapter 5: Resilience

### Gaza Wine After LALIA

It's no surprise that LALIA had a significant impact on viticulture in Southern Palestine. What's more surprising, and worth as much attention, is that grape and wine production persisted.

While the volume of wine produced likely declined, Gaza Wine and LRA 4/5 jars still appear in the literary and archaeological record well into the seventh century. Grape skins, pips, pedicels, and charred vine wood are part of the archaeobotanical assemblage of Umayyad Sobata.<sup>343</sup> Grape remains make up a nearly a third of the grain-grape assemblage of Umayyad Nessana.<sup>344</sup> This element of the history of Gaza wine has not been satisfactorily investigated. One reason that there is an abundance of research on historical farming practices in the Negev is a desire to make the desert green. Perhaps this research can guide us in how to protect vineyards from future disasters.

The site of Er Rasim, south of Ashkelon, is a useful model for long term resilience.<sup>345</sup> The site, first excavated in 2019, began life as a Roman agricultural estate in the first century CE.<sup>346</sup> The site was abandoned in the middle of the first century, likely the result of the violence that gripped Ashkelon in 66 CE during the first Jewish-Roman War.<sup>347</sup> The space was used as a graveyard from the second to fourth centuries CE, until a monastic community built a church, winepresses, and kilns on the

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<sup>343</sup> Fuks 2020.

<sup>344</sup> Fuks 2020.

<sup>345</sup> The site is labeled in fig 1.

<sup>346</sup> Erickson-Gini 2021.

<sup>347</sup> Josephus *Jewish War* III.ii.

site. The kilns and wine press are pleasingly symmetrical, three firing chambers in the kiln, three cement and stone presses. A storeroom filled with Gaza jars, turned upside down and neatly stacked, was found beside the church (fig. 11). As further evidence that the vessels were made on site, part of a potter's wheel was found in the collection vat of a wine press. Both the stored Gaza jars and the fragments around the kiln are from the latest version of the Gaza jar, a narrow-bottomed variety made in the sixth and seventh century CE. The site was abandoned some point after 750 CE as evidence by the fragments of Abbasid period pottery and glass sherds recovered from the site, most likely left behind when the site was scavenged for stone.<sup>348</sup> The finds at Er Rasm show that the market for Gaza wine was still viable more than a century after LALIA set in. There was still enough interest and money to set up a large scale, holistic, wine production site.

### **Intercropping As Climate Insurance**

Like modern vintners, Romans recognized many varieties of grapes. These were, like modern varieties, generally sorted by their geographic origin, physical properties, ideal growing conditions, and use. Romans also recognized that certain cultivars were better eaten fresh or preserved as raisins. Palladius comments "Larger grapes of fine appearance, hard-skinned and fairly dry are best kept for the table".<sup>349</sup> Commenting on the qualities of certain grapes and the wines that come from them is a frequent theme in Roman poetry and prose. Sometimes, cultivar wines or vines have symbolic associations. Horace rejoices that the Roman victory at Actium means it's appropriate to

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<sup>348</sup> Erickson-Gini 2021.

<sup>349</sup> Palladius 3.9.3.

bring out Caecuban wine, a rather patriotic beverage since it comes from Latium.<sup>350</sup> Meanwhile, the defeated queen is associated with Mareotic wine, and driven mad by it.<sup>351</sup> Varietal wines were frequently prescribed for specific ailments. Falernian, the most famous and renowned Roman wine, was part of Pliny the Elder's tonic against body odor.<sup>352</sup> Since large scale winemaking is an endeavor of the wealthy in Roman culture, discussions of the merits of certain varieties would not only suggest that the author is well-read and a gourmand, but also of means.

Virgil names a dozen varieties in *Georgics II*, and comments on what makes these particular grapes favored. According to him, Mareotic vines (the kind Horace implied maddened Cleopatra), likely originating from Egypt due to their name, produce white grapes and grow well in light soil.<sup>353</sup> Bumastus, a variety whose Latin name originates from its Greek name βούμασθος (huge breasts), is appropriately famous for large clusters.<sup>354</sup> There is a variety for every need, and interest in writing down what that variety needs to thrive and is capable of producing.

It is worth noting that I will not attempt to match the kinds of cultivars mentioned in Palladius or the *Geoponika* or those grown in the late antique Levant with modern cultivars. While there has been paleogenetic research on grapevine diversity and the cultivation history of *Vitus vinifera*, it is not especially useful or relevant to this project. First of all, the number of possible varieties is extraordinary. There are nearly 10,000

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<sup>350</sup> Horace *Odes*, 1.37.6 and Pliny the Elder *HN* 14.61, 23.35.

<sup>351</sup> *lymphātam Mareōticō*: Horace *Odes* 1.37.14.

<sup>352</sup> Pliny the Elder *HN* 22.43.1. The other ingredient is golden thistle.

<sup>353</sup> *Georgics* II.83-108.

<sup>354</sup> *LSJ* s.v. βούμασθος.

domesticated varieties identified today.<sup>355</sup> The number of varieties in the Roman world was also enormous. Virgil comments, after singing the praises of his favorite cultivars,

“But for the many kinds, or the names they bear, there is no numbering—nor, indeed, is the numbering worth the pains. He who would have knowledge of this would likewise want to learn how many grains of sand on the Libyan plain are stirred by the West Wind”<sup>356</sup>

Put simply, there are too many choices to secure just one.

The exact identities of late antique grape varieties are also hard to determine because of an oddity of grape genetics. Grape genomes are very heterozygous, so the fruit of vines grown from seed will potentially vary widely in flavor, appearance, and yield from not only its parents but its siblings.<sup>357</sup> Virgil was no expert in grape genetics, but notes that seed grown vines “bear nasty clusters of grapes for birds to pillage (*turpis avibus praedam fert uva racemos*)” while grafted shoots “will not slowly pursue whatever skill you wish (*quascumque voles artes haud tarda sequentur*)”.<sup>358</sup> A grape vine takes three to five years to mature, so a winemaker would have to wait a long time before they knew for sure if seed-planted vines would be obedient or nasty. It is no surprise then that people have taken advantage of grape’s ability to reproduce from cuttings or layering from an early date. A vineyard of one cultivar of grape is a field filled with clones. This genetic closeness can make the impact of disease, unfavorable weather, or pests devastating to a variety. Since each vine is just like its neighbor, they are all equally susceptible to threats.

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<sup>355</sup> Liang 2019.

<sup>356</sup> Virgil *Georgics* 2.103-106. Trans. H.R. Fairclough and the author. For a tidy phrase along the same line in Greek, consider Theophrastus’ comment “ὡς ὅσα χώρας εἶδη, τοσαῦτα καὶ ἀμπέλων (as many countries there are, there are as many grapevines)” (*De Causis Plantarum* 4.11.6).

<sup>357</sup> Ramos-Madrigal et al. 2019.

<sup>358</sup> Virgil *Georgics* 2.50-60.

Viticulture, like all agriculture, is always under pressure to improve. Due to the nature of viticulture, it is unlikely (but not impossible) that any specific cultivar cultivated by the Romans would still be around unchanged today. There have been nearly 1500 years of innovation and abandonment between the study period and the time of writing. Viticulturalists have had plenty of time to breed a better vine. Paleogenetic research has uncovered some connections between historical and surviving varieties, but until grape remains from the Levant are widely sequenced, precisely which variety of grapes went into Gaza and Ashkelon wine remains unknown.<sup>359</sup>

The perseverance of the Gaza wine industry was likely due to a practice widely recommended in Latin viticulture manuals, planting several varieties of grape in the same vineyard. The earliest mention of this practice can be found in Columella, who dedicates two whole chapters to the practice in *De Re Rustica*. The practice survived into late antiquity, as shown by its attestation in Palladius, reproduced below.

“Furthermore, one should avoid planting the whole of the dug over area with a single variety of vines, for fear that a year that is unfavorable to that variety should wipe out the hope of the whole vintage. For that reason we shall plant cuttings of four or five outstanding varieties. It will be extremely useful to separate the varieties in different beds, and divide them with parallel walkways.... By this method we shall be able to have flowering and ripening times, which differ between varieties of vines, occurring seasonably for each variety. (No small loss will be involved if ripe fruit is gathered together with late-ripening, since it is unsound to carry out the vintage of one variety seasonably if another unripe variety is mixed in with it, but wasteful to await the late ripening of the other variety.) That is one advantage: another is that because the vintage comes in stages by virtue of the differences in the vines, a smaller number of workers is able to process it and store it variety by variety, and to succeed in keeping each wine pure-flavored, not compromised by another variety. If this method seems

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<sup>359</sup> Savagnin Blanc (aka Traminer, Traminer Weiss, not to be confused with Sauvignon Blanc), a grape that is still grown throughout central Europe and Australia is the oldest known widely cultivated variety. An archaeological sample recovered from Orléans and dated to 1050-1200 CE was an identical match (99.7% and 99.9% percent match on two panels) to Savagnin Blanc: see Ramos-Madrigal 2019. Savagnin Blanc is white grape with a perfumy flavor.

difficult, you should only plant vines together that are a match both in flavor and in times of flowering and ripening.”<sup>360</sup>

Palladius presents two major arguments for the practice of intercropping, it provides insurance for bad years and is more labor efficient. Both of these are attested elsewhere in classical and classical-adjacent sources and deserve elaboration.

Two arguments for a diverse vineyard as an insurance for poor growing years are cited in the *Geoponika*, one from a Greek source and one from Latin. The Greek source, attributed to an obscure author named Sotion, sums things concisely.

“The wisest farmers are those who plant three or four vine varieties in different areas of their vineyard. Depending on one variety causes trouble, whether it is that all the vines bear heavily or they all fail. The reason for planting them separately and not intermixed is that many differences, not only in color but also in strength; and wine made from different varieties has very great differences.”<sup>361</sup>

Columella, the most thorough source on interplanting vineyards, is more specific about how climate variability can impact vineyards. He cautions first against planting only whatever vine the farmer likes best, and advises...

“For there is never a year so mild and temperate as not to inflict some injury upon some variety of the vine: if it is dry, that kind which thrives on moisture is damaged; if rainy, that which delights in dry weather; if cold and frosty, that which cannot endure blighting cold; or if hot, that which cannot bear heat. And, not to run through, at this time, a thousand rigors of the weather, there is always something to work harm to vineyards. Therefore, if we plant but one kind, when that thing happens which is hurtful to that kind, we shall be deprived of the whole vintage; for he who is without plants of different sorts will have no reserve supply. But if we make plantings of various kinds of vines, some of them will escape injury to produce a yield.”<sup>362</sup>

He suggests planting “four or five” kinds of vines, keeping them separate, and be sure to know which vines are which”.<sup>363</sup> While a little ice age probably did not factor on

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<sup>360</sup> Palladius 3.9.11, the parts omitted have to do largely with aesthetics.

<sup>361</sup> *Geoponika* 5.16.

<sup>362</sup> Columella, *De Re Rustica* 3.20.1-3.

<sup>363</sup> Columella, *De Re Rustica* 3.20. 3-4.

Columella's "thousand rigors of the weather", these passages suggest that classical winemakers were interested in preparing for climate extremes by interplanting.

The argument of a diverse vineyard being more labor efficient is also well attested and relevant to the aftermath of LALIA. This is true year-round, and especially helpful during pruning and harvest time. These are the times when grapes are most strongly affected by weather and temperature changes, when the differences between different varieties and their needs are most evident, and when skilled labor and careful planning are most important. In wine growing regions today, harvest and pruning are the two busiest seasons. In Napa, school starts in mid-August so children will be in school and their parents are free to work harvest.<sup>364</sup> Classical and late antique winemakers would also have tried to leverage as much labor as possible during these critical phases. While Palladius gives a thorough explanation of why a diverse but separated vineyard is important during harvest and vintage, Columella explains why it is important during pruning.

"Now the separating of varieties... has a very great advantage, in that the vinedresser can more readily give each its proper pruning when he knows the particular sort in that plot which he is pruning; and this is a difficult practice to observe in vineyards that are planted with many sorts of vines, because the greater part of the pruning is done during the time when the vine is not even bearing distinctive foliage. And it makes a great difference, according to the nature of each stock, whether the vinedresser allows the growth of more or fewer canes, whether he is encouraging the growth of the vine by leaving long shoots or retarding it by close pruning."<sup>365</sup>

The last sentence, regarding the length of shoots, is an especially important detail. As previously explained, the number of canes and number of dormant buds on a vine

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<sup>364</sup> The first day of the Napa Valley Unified School District's 23-24 school year is August 17<sup>th</sup>. Harvesting the grapes used in sparkling wine usually starts shortly after.

<sup>365</sup> Columella, *De Re Rustica* 3.21.6-8.

determines how much growth the vine will have in an upcoming year, and thus the size of next year's harvest. Strategic pruning can also extend the harvest and pruning seasons, and maximizes the utilization of labor. By having grapes ripen in series, rather than all at once, wine presses and fermentation facilities would be consistently filled but not overwhelmed. This efficient work schedule would be especially helpful if much of the local population died, perhaps from plague, or were otherwise displaced.

Palladius implies a third reason why planting more than one variety is a good idea: planting more than one kind of grape allows farmers to make the most of the land they have. Different varieties tend to thrive under specific climate, light, and soil conditions. If the land one wishes to cultivate has a variety of features, one can plant grapes that suit them. Perhaps a winemaker wishes to cultivate steep, east-facing hills ringing a river valley prone to fog. Palladius suggests "in flat ground you will establish a variety of vine that tolerates mists and frosts: in hills, one that tolerates drought and winds".<sup>366</sup> Palladius' advice is sound, the vineyards behind my home were planted like this. The hills are planted with pinot noir. The valley floor is planted with chardonnay. Pinot noir is one of the earliest grapes to go through budbreak, so frost damage is a serious concern.<sup>367</sup> Due to thin skin and densely packed clusters, Pinot noir is especially susceptible to mildew and rot spurred by humidity.<sup>368</sup> Planting it on hills allows it to receive more warming morning sunlight and ventilation. Chardonnay buds after pinot noir and can thrive a wider array of climates.<sup>369</sup> The later budbreak allows the valley floor more time to warm up, and chardonnay can better tolerate humidity. Thus, vintners

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<sup>366</sup> Palladius 3.9.1.

<sup>367</sup> Robinson 1994, s.v. Pinot Noir.

<sup>368</sup> Idem.

<sup>369</sup> Ibid., s.v. Chardonnay.

in both the late antique era and now are able to maximize productivity out of a varied landscape by planting multiple grape varieties.

One study shows potential bioarcheological evidence for planting several varieties of grapes in one site. Numerous grape pips recovered from late antique archaeological sites for genetic analysis, three were recovered from the same context in southern Palestine.<sup>370</sup> These pips were recovered from the floor of a sealed stone room at a cave monastic site in Oboda. The residue that yielded the uncharred pips consisted of animal dung and dried plant material. Carbon dating and context dated the site, and pips to the early Islamic period. Cohen et al. found that the pips (labeled A31, A32, & A33) recovered from the same locus in this room were genetically diverse. The team were able to determine that A32 was most likely a white grape. A33 not only was most likely a dark-colored grape, but that it was “descendent from asswad karech and from it alone either through selfing of one asswad karech plant or the breeding of two asswad karech clones”.<sup>371</sup> Asswad karech, also known as syriki in Greece, is a somewhat rare but still extant grape cultivar that is largely cultivated in Lebanon.<sup>372</sup> This led Cohen et al. to the same conclusion that I found through other means. They suggest that “the “multicropping” cultivation strategy was employed in Avdat (Oboda). Diversifying crops diminishes risks and maximizes the utilization of field space and labor and was commonly practiced with grapes among other crops in the ancient world.”<sup>373</sup>

There are, however, reasons to temper this interpretation. Cohen et al. concede “We are unable to directly relate the sequenced Early Islamic Avdat (Oboda) grape pips

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<sup>370</sup> Cohen et al. 2023.

<sup>371</sup> Cohen et al. 2023.

<sup>372</sup> *Idem.*

<sup>373</sup> *Ibid.*, 23.

to the Byzantine Negev wine industry".<sup>374</sup> Radiocarbon analysis of other organic material from where the pips were recovered shows they date from after the primary focus period of my study, with potential dates ranging from 650-890 CE.<sup>375</sup> This suggests that some winemaking remained in southern Palestine into the Umayyad or Abbasid period. Since the pips were brought into the room by way of animal dung, it is far from certain that these grapes came from the same place. A fox or bird may have come a long way before leaving the pips behind. The grapes are as likely to have come from feral vines as cultivated vineyards. The number of samples recorded is also quite small, and I will not hang a whole argument on such a small hook.

This study is exciting because it demonstrates that it is possible to recover viable genetic information from grape material recovered at late antique archaeological sites. As more relevant sites are discovered and excavated, perhaps more helpful pips will be uncovered.

The process of planting more than one variety as insurance for climate variability allowed the wine industry in Roman Palestine to survive LALIA. As I have demonstrated earlier, the weather downturn between 536 and 550 CE had devastating effects on grapevines, causing the fruit to fail to ripen and to potentially further damage the plant. Subsequently, grape harvest failures likely had significant effects both on health and livelihoods the people of Roman Palestine. Although severely affected, diversity allowed the grape and wine industry to survive.

Counterintuitively, the general depopulation of the Negev exacerbated by plague in the mid sixth century may have benefited the viticultural industry. Delos, once both a

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<sup>374</sup> *Idem.*

<sup>375</sup> *Ibid.*, SI Appendix, Table S1.

major center of religious and commercial activity, experienced significant population decline after repeated looting in the first century BCE. The popular narrative, included on its UNESCO World Heritage site's webpage, is that the island was gradually abandoned after the raids.<sup>376</sup> However, a knot of Delians remained and seem to have made the most of the newly available real estate. A thriving wine industry sprung up on the island, as evidenced by extensive terracing, epigraphical evidence, and an impressive set of late antique wine presses.<sup>377</sup> In a recent study, Emlyn Dodd suggests that the depopulation of the island allowed the smaller community to focus less on sustenance crops and more on cash crops, namely wine grapes.<sup>378</sup> The combination of fewer mouths to feed, more open land to farm, and a prime position on trade routes brought modest prosperity to Delos. Between the third and fifth centuries, two public bathhouses, at least five basilicas and churches, a large commercial area, and Delos' first aqueduct and running water source were constructed.<sup>379</sup> While Delos was no longer the Singapore of the Mediterranean, it was no wasteland. Perhaps the small rebound in Negev viticulture after the worst decades of LALIA was aided by a similar dynamic. It is worth mentioning that Delos was not left unscathed by the sixth century. New coins and sculpture ceased to appear on the island after the mid-sixth century.<sup>380</sup> By the seventh century, the island appears to have been properly deserted.<sup>381</sup> Maybe LALIA crushed the Delian wine industry.

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<sup>376</sup> UNESCO. n.d. "Delos."

<sup>377</sup> Dodd 2020.

<sup>378</sup> *Idem.*

<sup>379</sup> *Idem.*

<sup>380</sup> *Idem.*

<sup>381</sup> *Idem.*

It is likely that several vineyards around Roman Palestine contained some plantings of cold tolerant varieties. Perhaps the vintner wanted to have extra insurance against poor weather. Perhaps they were looking to replicate wines from a colder part of the world. Perhaps their plot was high in the mountains in the Negev, and they had a reason to prepare for frost. Perhaps they were experimenting or plain lucky. When the skies fogged over and LALIA came around and did not go away, lucky vintners would still have something to harvest. Even more importantly, however, is that they would have a ready and local supply of healthy vines to re-propagate their vineyards. Some hearty cuttings from surviving vineyards would be desired and shared or sold to others. This would lead to restitution of damaged vineyards and further insurance against harsh winters. This would have been a lengthy and expensive process, made even more difficult by plague and other turmoil. However, survival and propagation of cold hearty grape varieties is what likely allowed Gaza and Ashkelon wines to remain in late antique glasses.

## Chapter 6: Conclusion

The inclement weather, especially cold, characterized the late antique little ice age. This cold had negative effects on grapevines, a plant so temperature sensitive that its lifecycle is the foundation for a climate proxy.<sup>382</sup> Literary evidence from the late antique Mediterranean supports this, frequently mentioning failed grape harvests in the mid sixth century.<sup>383</sup> This failure was especially damaging to the people of southern Palestine, an area widely invested in winemaking. The scale of investment in the Gaza and Ashkelon hinterlands and the Negev can be deduced from the abundance of winepresses and kilns in settlements, preserved documents, an abundance of grapes and broken amphorae recovered from middens, the way they decorated their churches, and praise people from far away heaped on their wine. Decreases in the ratio of grape seeds and amphorae in their waste pits show that the industry struggled after LALIA rolled in.<sup>384</sup> The blow to the local wine industry was brought by the linked problems of people and grapes, the fortunes of humans following the things they relied upon.

Historical proxies help fill in the gaps. Examining the effects following the eruption of Mt. Tambora in 1815 and the ensuing dust veil event on the population of Switzerland shows that areas that relied on viticulture had a higher mortality rate than areas that relied on other industries.<sup>385</sup> During the Great French Wine Blight of the late nineteenth century, French men from winegrowing areas infected with phylloxera who were infants during the blight were shorter than their peers from phylloxera-free

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<sup>382</sup> Daux 2012.

<sup>383</sup> Cassiodorus 2019, 12.22-26.

<sup>384</sup> Fuks 2020.

<sup>385</sup> Krämer 2015, 371.

winegrowing areas.<sup>386</sup> These discrepancies reflect significant hunger that exacerbated public health issues in viticulture dependent communities. It is likely that the communities who made Gaza wine had comparable experiences to the Swiss and French winemaking communities who weathered ecological disasters in the nineteenth century.

The wine industry of southern Palestine was dented by LALIA but not demolished. Decades after the temperature dropped and the sky clouded over, vineyards in Nessana changed hands, Gaza jars were shipped to faraway places, and the virtues of Gaza wine were praised in poetry and prose. The practice of intercropping grape varieties, reflected in textual and genetic evidence, was a form of climate insurance long used by Romans.<sup>387</sup> This practice likely prevented the total collapse of the wine industry. Someone got lucky and planted a variety that survived.

Occasionally, papyrological and epigraphic evidence allows the family histories of people who survived LALIA to be stitched together. A limestone tombstone found outside of Nessana records the death of Stephanos, son of Khalaf Allah, age twelve, on the 27<sup>th</sup> of October 541.<sup>388</sup> Two more deaths are recorded on the same stone, Dorotheos and Sara. Given the date of the deaths, and the hasty addition of names to a gravestone, it is possible Stephanos, Dorotheos, and Sara were killed by the Justinianic plague. In the 560s-580s, Faysan, son of Khalaf Allah and probable brother of the late Stephanos, was serving in the local camel corps.<sup>389</sup> By 570/1, he was a

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<sup>386</sup> Idem. Measurements were derived from data collected by the French military administration. Interestingly, men from winegrowing regions unaffected by phylloxera tended to be taller than their countrymen.

<sup>387</sup> Columella, *De Re Rustica*, III.20.1-3; Palladius 3.9.11; *Geoponika* 5.16.

<sup>388</sup> Ruffini 2011, 209 The stone is recorded as I. Ness.122. The stone itself is lost.

<sup>389</sup> P. Ness. 39.

moneylender.<sup>390</sup> Faysan's son, Khalaf Allah jr., is involved in the wheat trade and paid high taxes in the early seventh century.<sup>391</sup> Khalaf Allah jr. had a son named Stephanos.<sup>392</sup> After the seventh century the archives run out and no more can be deduced about them. The arc of Khalaf Allah's family is like the arc of his hometown. The mid sixth century brought disaster. Succeeding generations found ways to get by for a while, and even achieved modest prosperity. They show, on a personal scale, resilience in the face of LALIA and the troubles it brought.

I cannot help but think of Napa when I read about Nessana. Recently my hometown also weathered a pandemic. Vintners are preparing for climate change in creative ways including becoming certified firefighters and modifying vineyards and wineries to be better able to fight off flames.<sup>393</sup> Researchers at the University of California Davis, where my father learned to make wine and I learned to read Latin, are trying to find ways to filter out the taste of smoke taint.<sup>394</sup> This year spring was cold and wet so winemakers are predicting that harvest will be delayed by several weeks. I am worried, both about the long and short term outcomes of current events, but hopeful. Human ingenuity and careful viticultural practices have prevented utter collapse before. I have reason to believe they will prevent collapse again.

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<sup>390</sup> P. Ness. 27

<sup>391</sup> P. Ness. 40.

<sup>392</sup> P. Ness. 40.

<sup>393</sup> Long 2023.

<sup>394</sup> Idem.

## Figures



Figure 2: Basket used to carry grapes on beasts of burden. Floor of Synagogue. Image from Habas 2022.



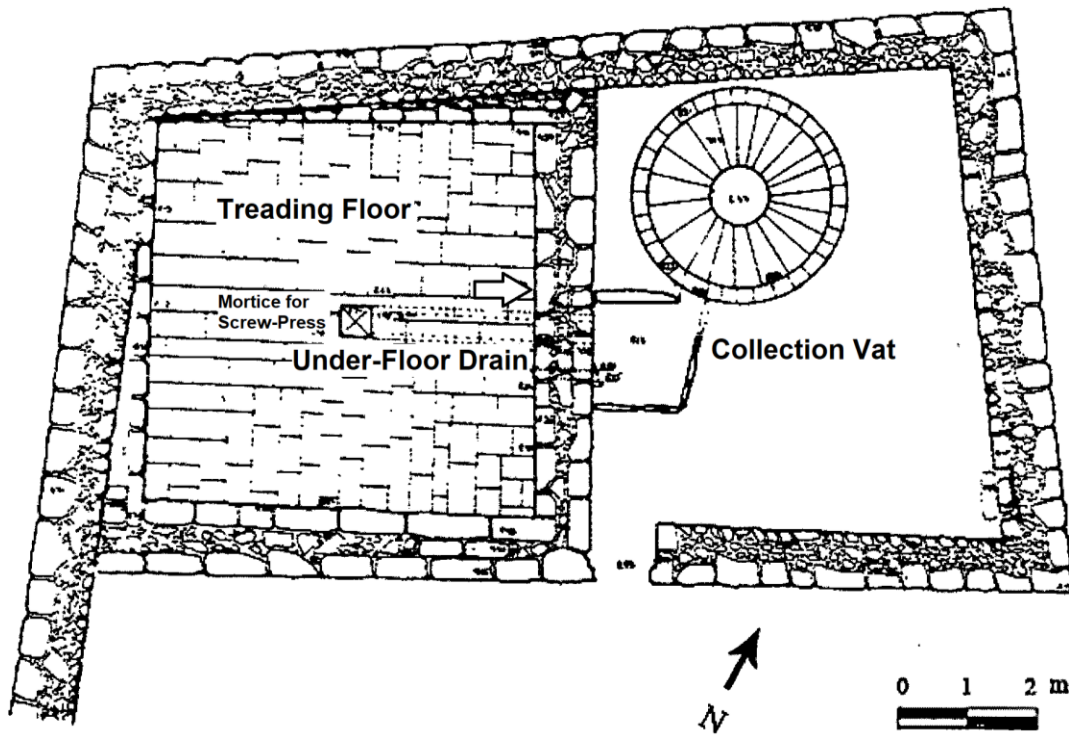
Figure 3: Mosaic of a camel laden with LRA4 Amphorae, the driver Orbikon, and a bunch of grapes. Found in the church in Kissufim, outside Gaza. Image from McCormick 2019.



*Figure 4: Grape harvest scene with donkey. From The Church of St. Stephan in Horvat Be'er-shema. Image from Habas 2022.*



*Figure 5: Pigeons using an LRA4 amphora as a birdhouse. From The Church of St. Stephan in Horvat Be'er-shema. Image from Habas 2022.*



*Fig. 70.4. Negev, wine press No. 4.*

Figure 6: A simple wine press found in Sobata. The arrow indicates the direction of juice flow. Image from Ayalon 2009, 405. Illustration by Gaby Mazor, labels by the author.

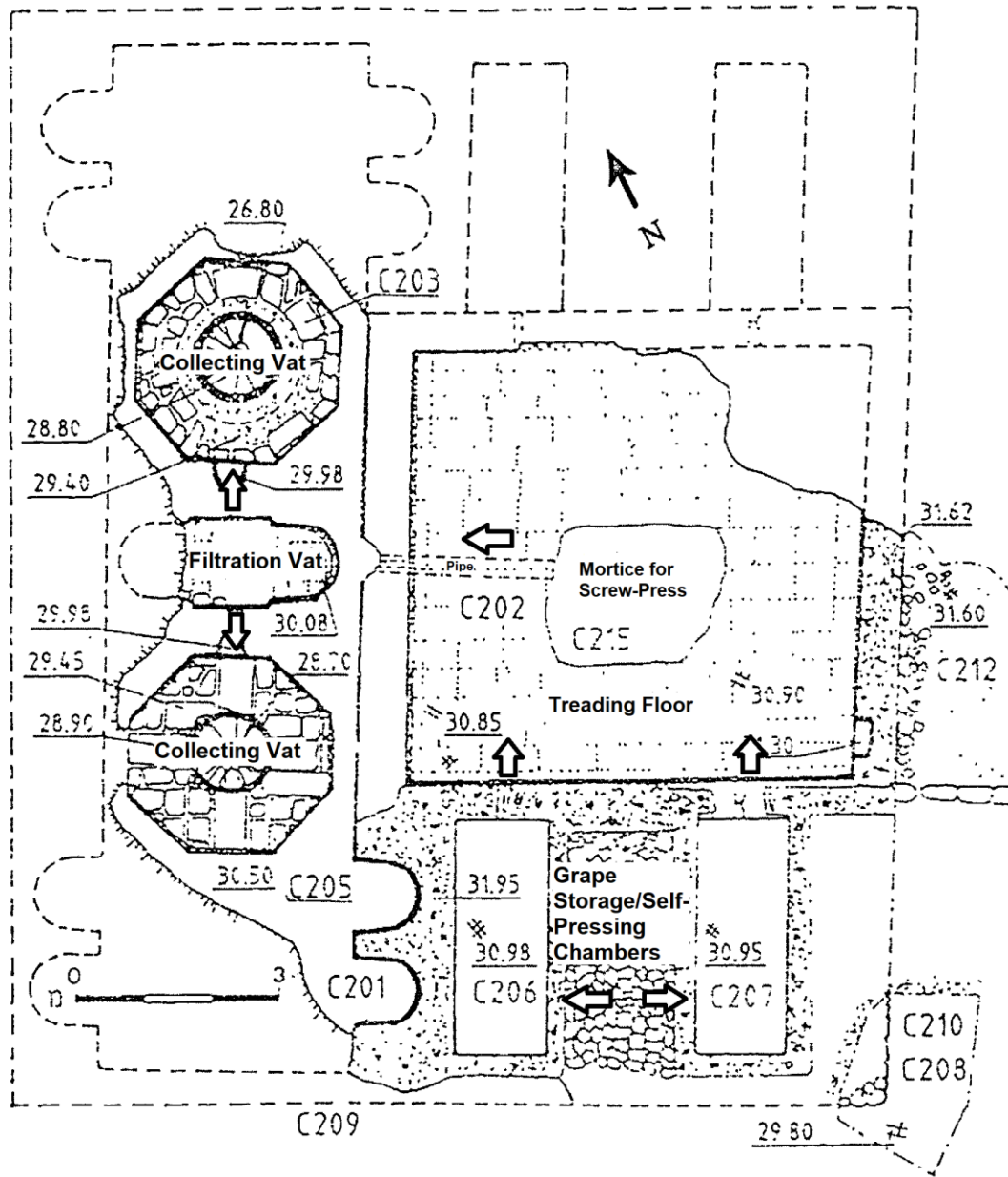


Fig. 59.2. Ashqelon, plan of the wine press in Area C.

Figure 7: A wine press from Ashqelon. The arrows indicate the direction of juice flow. Image from Ayalon 2009, 352. Illustration by Yigael Israel, labels by the author.

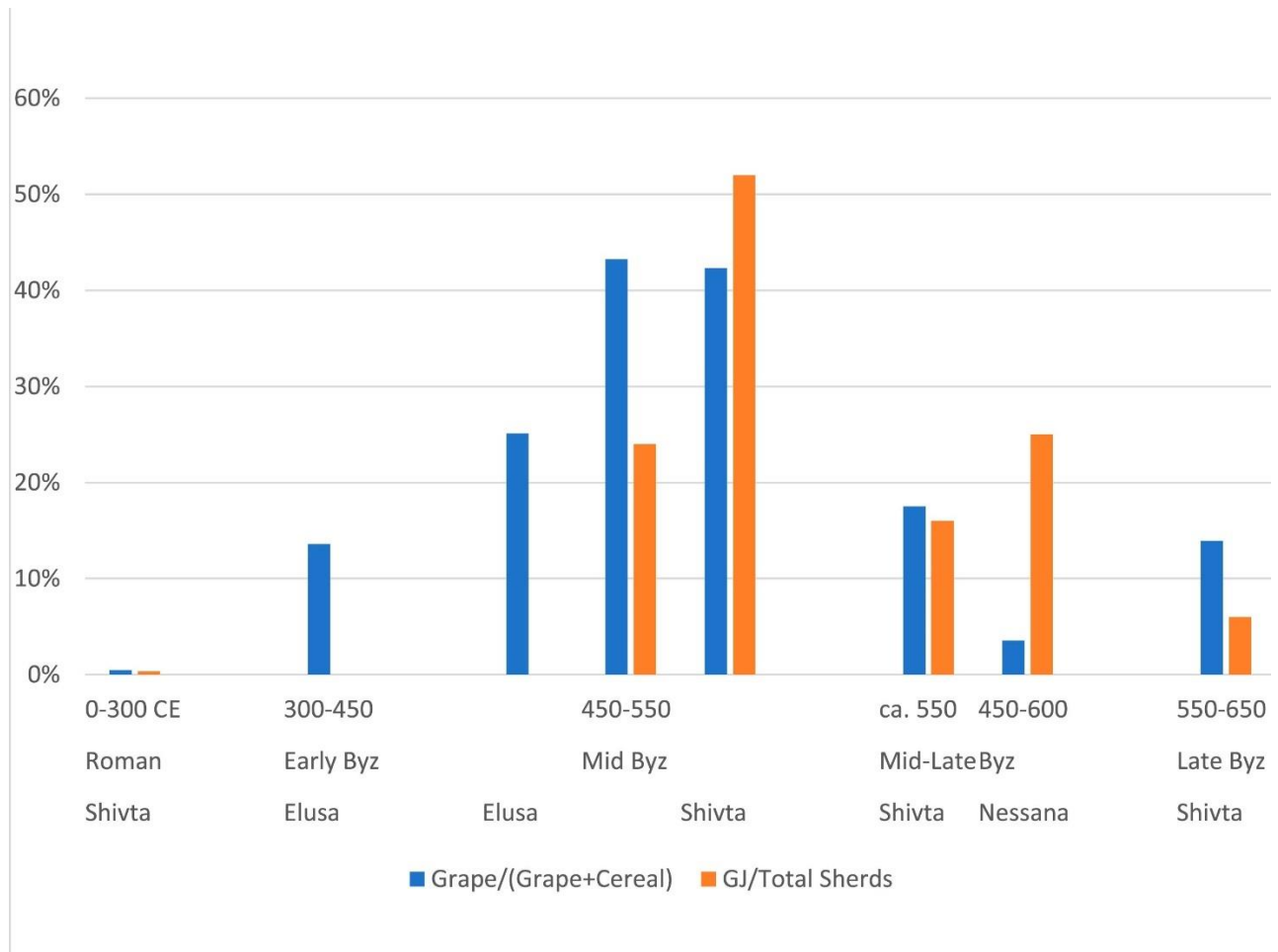


Figure 8: Proportions of grape pips relative to cereal remains and Gaza Jars as part of ceramics assemblages from sites across the Negev. From Fuks et al. 2020.

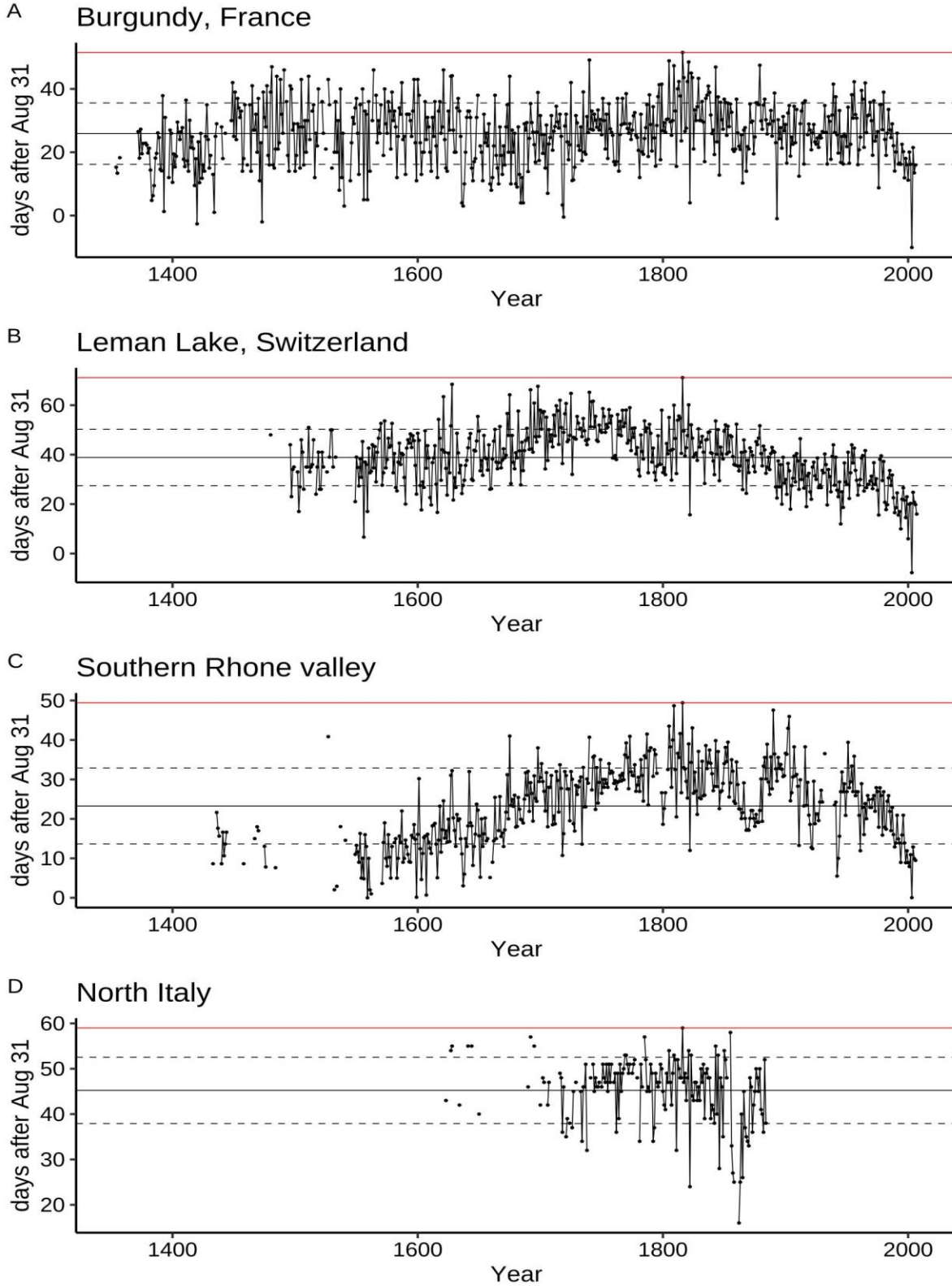


Figure 9: Comparative grape harvest dates (GHD) for four Western European locations. The solid black line indicates the mean GHD for that region. The dashed lines indicate one standard deviation above and below. The red line indicates the 1816 GHD. Data found in Daux 2012. Graphs by J. Watson.

A new type of late Roman storage jar from the Negev

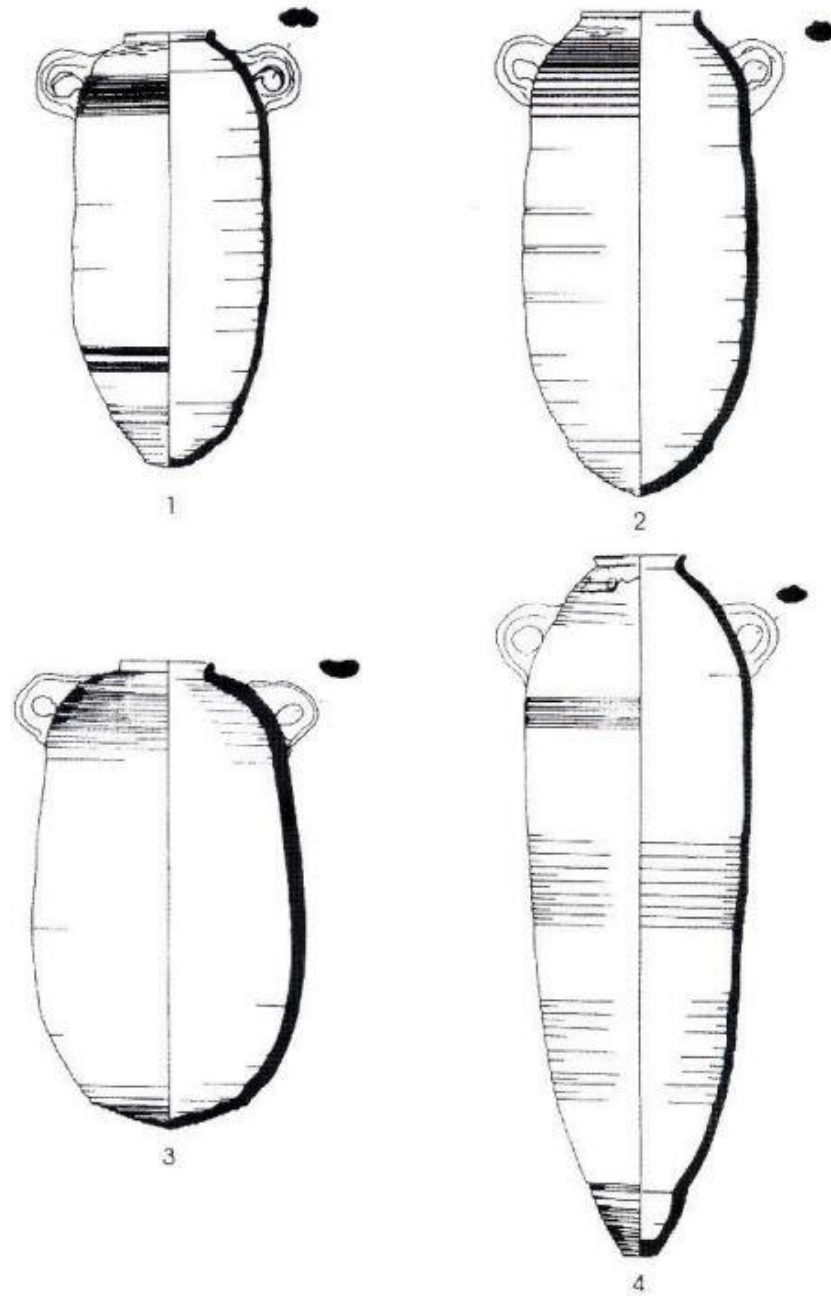


Fig. 2. 1. Jar type B1 from Avdat (Oboda). 2. Elusa jar (Type C) from Avdat. 3. Jar type B from Hurvat Raqiq. 4. Jar type A from Ard el Mahjar.

Figure 10: Profiles of variations 1-4 of LRA4 "Gaza Jars". The variations are ordered sequentially, 1 being the oldest form, 4 being the youngest. From Fabian and Goren 2002.



*Figure 11: Stacked Gaza jar bases in the storeroom at Er Rasm, facing northeast. From Erickson-Gini 2021. Photo by Shira Bloch.*

## Bibliography

- Abû'l-Faraj, Gregory, and Budge E A Wallis. 1932. *The Chronography of Gregory Abû'l-Faraj the Son of Aaron, the Hebrew Physician Commonly Known as Bar Hebraeus, Being the First Part of His Political History of the World*. Vol. 1. London: Oxford University Press.
- Almond, Douglas, Lena Edlund, Hongbin Li, and Junsen Zhang. 2007. "Long-Term Effects Of The 1959-1961 China Famine: Mainland China and Hong Kong." <https://doi.org/10.3386/w13384>.
- Amiran, David H.K. 1997. "The Madaba Mosaic Map as a Climate Indicator for the Sixth Century." *Israel Exploration Journal* 47 (1/2). Israel Exploration Society: 97–99. <http://www.jstor.org/stable/27926462>.
- Appleton, Thomas. Letter to Thomas Jefferson. 2013. *The Papers of Thomas Jefferson, Retirement Series*. May 1816 to 18 January 1817, September 27.
- Arjava, Antti. 2005. "The Mystery Cloud of 536 Ce in the Mediterranean Sources." *Dumbarton Oaks Papers* 59: 73. doi:10.2307/4128751.
- Asimov, Eric. 2018. "Great Bubbly From England, Believe It or Not." *The New York Times*, December 20, 2018. <https://www.nytimes.com/2018/12/20/dining/drinks/english-sparkling-wine.html>.
- Aston, W.G., trans. 1896. *Nihongi, Chronicles of Japan from the Earliest Times to A.D. 697*. London: K. Paul, Trench, Trübner.
- Ausonius = Ausonius. 1919. *Volume I: Books 1-17*. Translated by Hugh Evelyn-White. Harvard University Press. <https://www.loebclassics.com/view/LCL096/1919/volume.xml>.
- Avni, Gideon, Guy Bar-Oz, and Gil Gambash. 2023. "When 'the Sweet Gifts of Bacchus' Ended—New Archaeological Evidence for Settlement Changes and the Decline of Wine Production in Late Antique Southern Palestine." *Bulletin of the American Society of Overseas Research*, March, 000. <https://doi.org/10.1086/724060>.
- Ayalon, Etan, Rafi Frankel, and Amos Kloner. 2009. *Oil and Wine Presses in Israel from the Hellenistic, Roman and Byzantine Periods*. British Archaeological Reports Limited.
- Banerjee, Abhijit, Esther Duflo, Gilles Postel-Vinay, and Tim Watts. 2010. "Long-Run Health Impacts of Income Shocks: Wine and Phylloxera in Nineteenth-Century France." *Review of Economics and Statistics* 92 (4): 714–28. doi:10.1162/rest\_a\_00024.

- Bar-Oz, Guy, Lior Weissbrod, Tali Erickson-Gini, Yotam Tepper, Dan Malkinson, Mordechai Benzaquen, Dafna Langgut, et al. 2019. "Ancient Trash Mounds Unravel Urban Collapse a Century before the End of Byzantine Hegemony in the Southern Levant." *Proceedings of the National Academy of Sciences* 116 (17): 8239–48. <https://doi.org/10.1073/pnas.1900233116>.
- Behringer, Wolfgang. 2019. *Tambora and the Year without a Summer: How a Volcano Plunged the World into Crisis*. Polity.
- Bignon, Vincent, Eve Caroli, and Roberto Galbiati. 2017. "Stealing to Survive? Crime and Income Shocks in 19th Century France." *The Economic Journal* 127 (599): 19–49. doi:<http://www.jstor.org/stable/45023203>.
- Boaretto, Elisabetta, Marion Hernandez, Mae Goder-Goldberger, Vera Aldeias, Lior Regev, Valentina Caracuta, Shannon P. McPherron, Jean-Jacques Hublin, Steve Weiner, and Omry Barzilai. 2021. "The Absolute Chronology of Boker Tachtit (Israel) and Implications for the Middle to Upper Paleolithic Transition in the Levant." *Proceedings of the National Academy of Sciences of the United States of America* 118 (25). <https://doi.org/10.1073/pnas.2014657118>.
- Bohmrich, Roger. 1996. "Terroir: Competing Perspectives on the Roles of Soil, Climate and People." *Journal of Wine Research* 7 (1): 33–46. <https://doi.org/10.1080/09571269608718059>.
- . 2006. "The Next Chapter in the Terroir Debate." *Wine Business Monthly*, January 2006. <https://www.winebusiness.com/wbm/?go=getArticleSignIn&dataId=42095>.
- Boulay, Thibaut, and Sean Northrup. 2016. "Vineyard Ownership: A Habitus of Power? The Roots of Land Tenure and the Culture of Wine-Making among a New Political Class, from Constantine to Julian." *Journal of Late Antiquity* 9 (2): 415–35. <https://doi.org/10.1353/jla.2016.0018>.
- Briffa, K. R., P. D. Jones, F. H. Schweingruber, and T. J. Osborn. 1998. "Influence of Volcanic Eruptions on Northern Hemisphere Summer Temperature over the Past 600 Years." *Nature* 393 (6684): 450–55. doi:10.1038/30943.
- Büntgen, Ulf, Vladimir S. Myglan, Fredrik Charpentier Ljungqvist, Michael McCormick, Nicola Di Cosmo, Michael Sigl, Johann Jungclauss, et al. 2016. "Cooling and Societal Change during the Late Antique Little Ice Age from 536 to around 660 AD." *Nature Geoscience* 9 (3): 231–36. doi:10.1038/ngeo2652.
- Butler, Alban. Rev. 1866. *The Lives of the Saints*. Volume XI: November.

- Butler, Don W., Zachary C. Dunseth, Yotam Tepper, Tali Erickson-Gini, Guy Bar-Oz, and Ruth Shahack-Gross. 2020. "Byzantine—Early Islamic Resource Management Detected through Micro-Geoarchaeological Investigations of Trash Mounds (Negev, Israel)." *PLOS ONE* 15 (10): e0239227. <https://doi.org/10.1371/journal.pone.0239227>
- Canavati, Sergio, Matthew Bauman, and Damien Wilson. 2020. "The Wine Industry and the COVID-19 Pandemic." *Wine Business Journal*. doi:10.26813/001c.22307.
- Carlson, Thomas A. 2018. "When Did the Middle East Become Muslim? Trends in the Study of Islam's 'Age of Conversions.'" *History Compass* 16 (10): e12494. <https://doi.org/10.1111/hic3.12494>.
- "Carneros, Napa - Daily Totals for July." Weather - Napa County UCCE. University of California Cooperative Extension. <http://cenapa.ucanr.edu/about/weather/?weather=monthlyinfo&station=109&month=7> Accessed May 28, 2022.
- Cassiodorus = Cassiodorus. 2019. *The Variae*. Translated by Shane Bjornlie. Berkeley: University of California.
- Cheng, Wenli, and Hui Shi. 2019. "Surviving the Famine Unscathed? An Analysis of the Long-Term Health Effects of the Great Chinese Famine." *Southern Economic Journal* 86 (2): 746–72. <https://doi.org/10.1002/soej.12393>.
- Cohen, Prina, Roberto Bacilieri, Jazmín Ramos-Madrugal, Eyal Privman, Elisabetta Boaretto, Audrey Weber, Daniel Fuks, et al. 2023. "Ancient DNA from a Lost Negev Highlands Desert Grape Reveals a Late Antiquity Wine Lineage." *Proceedings of the National Academy of Sciences* 120 (17). doi:10.1073/pnas.2213563120.
- Collumella = Columella, Lucius Junius Moderatus, and Harrison Boyd Ash. 1941. *Lucius Junius Moderatus Columella on Agriculture: Res Rustica I-IV*. Vol. 1. Harvard University Press. or *Columella*. 1955. *On Agriculture, Volume III: Books 10-12. On Trees*. Translated by E.S. Forster and Edward Heffner. Vol. 3. Harvard University Press.
- CIAP = Sharon, Moshe. *Corpus Inscriptionum Arabicarum Palaestinae*. Leiden: Brill. 1992-2021
- Crivellaro, Alan, and Fritz H. Schweingruber. 2013. *Atlas of Wood, Bark and Pith Anatomy of Eastern Mediterranean Trees and Shrubs*. Springer EBooks. <https://doi.org/10.1007/978-3-642-37235-3>.
- Dahari, U, and O Sion. n.d. "Ruheiba—Rehovot in the Negev as a Model Desert Town." *Qadmoniot*, no. 154: 66–77.

- Daux, V., I. Garcia de Cortazar-Atauri, P. Yiou, I. Chuine, E. Garnier, E. Le Roy Ladurie, O. Mestre, and J. Tardaguila. 2012. "An Open-Access Database of Grape Harvest Dates for Climate Research: Data Description and Quality Assessment." *Climate of the Past* 8 (5): 1403–18. doi:10.5194/cp-8-1403-2012. Accessible at <https://www.ncei.noaa.gov/access/paleo-search/study/13194> .
- Decker, Michael D. 2009. *Tilling the Hateful Earth: Agricultural Production and Trade in the Late Antique East*. <http://ci.nii.ac.jp/ncid/BB00679698>.
- "The Decline of the Carthaginian Empire ...", Joseph Mallord William Turner, Exhibited 1817." 2023. *Tate*. Tate. Accessed March 10. <https://www.tate.org.uk/art/artworks/turner-the-decline-of-the-carthaginian-empire-n00499>.
- Dionysius = 1996. *Pseudo-Dionysius of Tel-Mahre, Chronicle (Known Also as the Chronicle of Zuqnin), Part III*. Translated by Witold Witakowski. Liverpool: Liverpool University Press.
- Dodd, Emlyn. 2020. "Population Decline and Wine Industry: Societal Transformation on Late Antique Delos (Greece)." In *The Resilience of the Roman Empire: Regional Case Studies on the Relationship Between Population and Food Resources*, edited by Dimitri Van Limbergen. BAR Publishing. 109-127
- Dolinka, Benjamin. 2007. *Be'er Shema - Birsama of the Notitia Dignitatum: A Prolegomenon to the 2006 Excavations. The Late Roman Army in the Near East from Diocletian to the Arab Conquest*. BAR International Series.
- Erickson-Gini, Tali. 2010. *Nabataean Settlement and Self-Organized Economy in the Central Negev Crisis and Renewal*. Oxford: Archaeopress.
- , V Lifshitz, and E Alajem. 2018. "Horvat Sa'adon – Excavations in the Roman Tomb and Byzantine Church." *Bulletin of the Anglo-Israel Archaeological Society* 36: 11–36.
- . 2021. "The Good Life: Evidence for the Production of Wine and Garum in an Early Roman Estate and Byzantine Monastery South of Ashkelon." *Archaeological Excavations and Research Studies in Southern Israel / חפירות ארכיאולוגיים בדרום הארץ*. doi:10.2307/j.ctv1rr6dc6.4.
- Fabian, Peter, and Yuval Goren. 2002. *A New Type of Late Roman Storage Jar from the Negev*. Edited by Humphrey. *The Roman and Byzantine Near East*. Vol. 3.
- Feder, Oded, and Tali Erickson-Gini. 2012. "Ashqelon, Shimshon Neighborhood." *Hadashot Arkheologiyot* 124 (August). <https://www.hadashot->

esi.org.il/Report\_Detail\_eng.aspx?print=nopic&id=2041&mag\_id=119+NB%2c+d  
ate+uncertain.

Fehl, Philipp. 1974. "The Account Book of Thomas Appleton of Livorno: A Document in the History of American Art, 1802-1825." *Winterthur Portfolio* 9: 123–51. doi:10.1086/495827.

Field, P.J.C. 2008 "Arthur's Battles." *Arthuriana*, vol. 18, no. 4, pp. 3–32. *JSTOR*, <http://www.jstor.org/stable/27870935>. Accessed 20 Apr. 2023.

Fong, Mary H. 1983. "The Iconography of the Popular Gods of Happiness, Emolument, and Longevity (Fu Lu Shou)." *Artibus Asiae* 44 (2/3): 159. doi:10.2307/3249596.

Fuchs, Hans-Jürgen. 2022. "The Ancestor of All Bicycle." *Deutsches Patent- Und Markenamt*. Deutsches Patent- und Markenamt. October 19. [https://www.dpma.de/english/our\\_office/publications/news/milestones/200jahrepotentfuerdasur-fahrrad/index.html](https://www.dpma.de/english/our_office/publications/news/milestones/200jahrepotentfuerdasur-fahrrad/index.html).

Fuks, Daniel, Gideon Avni, and Guy Bar-Oz. 2021. "The Debate on Negev Viticulture and Gaza Wine in Late Antiquity." *Tel Aviv* 48 (2): 143–70. doi:10.1080/03344355.2021.1968626.

———, Guy Bar-Oz, Yotam Tepper, Tali Erickson-Gini, Dafna Langgut, Lior Weissbrod, and Ehud Weiss. 2020. "The Rise and Fall of Viticulture in the Late Antique Negev Highlands Reconstructed from Archaeobotanical and Ceramic Data." *Proceedings of the National Academy of Sciences* 117 (33): 19780–91. doi:10.1073/pnas.1922200117.

Gale, George. 2011. *Dying on the Vine: How Phylloxera Transformed Wine*. Berkeley, California: University of California Press.

*Geoponika: Farm Work: A Modern Translation of the Roman and Byzantine Farming Handbook*. 2011. Bassus, Cassianus, ed Translated by Andrew Dalby. Prospect Books (UK).

Ghanoonparvar, M.R. 1995. "Dolma" *Encyclopaedia Iranica* Vol. VII, Fasc. 5, pp. 478-479

Grainger, Keith, and Hazel Tattersall. 2016. *Wine Production and Quality*. Oxford, UK: Wiley Blackwell.

Gibbons, Ann. 2018. "Why 536 Was 'the Worst Year to Be Alive'." *Science*, November 15. <https://www.science.org/content/article/why-536-was-worst-year-be-alive>.

Gregory of Tours = Gregory of Tours, and Ernest Brehaut. 1965. *History of the Franks*. New York, NY: Octagon Books.

- Gräslund, Bo, and Neil Price. 2012. "Twilight of the Gods? The 'Dust Veil Event' of AD 536 in Critical Perspective." *Antiquity* 86 (332): 428–43. doi:10.1017/s0003598x00062852.
- Habas, Lihi. 2022. "Trade and Transportation in the Light of the Mosaic Floors of the Holy Land." *SOMA 2016: Proceedings of the 20th Symposium on Mediterranean Archaeology*, 51–72. doi:10.2307/j.ctv2fcctvv.7.
- Hachlili, Rachel. 2009. "The 'Inhabited Scrolls' Mosaic Pavements - A Sixth-Century Trend." In *Ancient Mosaic Pavements: Themes, Issues, and Trends: Selected Studies*, 111–12. BRILL.
- Hahn, Hans–Werner. 2016. "Daniel Krämer, „Menschen Grasten Nun Mit Dem Vieh.' Die Letzte Grosse Hungerkrise Der Schweiz 1816/17. (Wirtschafts-, Sozial- Und Umweltgeschichte, Bd. 4.) Basel, Schwabe 2015." *Historische Zeitschrift* 303 (1): 237–39. doi:10.1515/hzhz-2016-0341.
- Haiman, Mordechai. 2009. "Ḥorbat Shelah (West): Final Report." *Hadashot Arkheologiyot: Excavations and Surveys in Israel* 121. <https://www.jstor.org/stable/26579195>.
- . 2011. "Khirbat Namus." *Hadashot Arkheologiyot* 123 (December). [http://www.hadashot-esi.org.il/report\\_detail\\_eng.aspx?id=1924&mag\\_id=118](http://www.hadashot-esi.org.il/report_detail_eng.aspx?id=1924&mag_id=118).
- Haldon, John F. 2016. *The Empire That Would Not Die: The Paradox of Eastern Roman Survival, 640-740*. London: Harvard University Press.
- Hannah, Lee, Patrick R. Roehrdanz, Makihiko Ikegami, Anderson V. Shepard, M. Rebecca Shaw, Gary Tabor, Lu Zhi, Pablo A. Marquet, and Robert J. Hijmans. 2013. "Climate Change, Wine, and Conservation." *Proceedings of the National Academy of Sciences* 110 (17): 6907–12. doi:10.1073/pnas.1210127110.
- Harding, Sierra, Omri Lernau, Wim Wouters, Nimrod Marom, and Deborah Cvikel. 2022. "First Evidence of Trade in Galilean Salted Fish on the Carmel Coast in the Early Islamic Period". *European Journal of Archaeology*, 1–21. <https://doi.org/10.1017/eea.2022.50>.
- Heinzelmann, Michael, Christian Schöne, Arne Schröder, Diana Wozniok, Florian Jordan, Tali Erickson-Gini, Marlu Kühn, Dafna Langgut, and Sina Lehnig. 2022. "Elusa – from Nabatean Trading Post to Late Antique Desert Metropolis. Results of the 2015–2020 Seasons." *Archäologischer Anzeiger*.
- Hickey, Todd. 2012. *Wine, Wealth, and the State in Late Antique Egypt: The House of Apion at Oxyrhynchus*. University of Michigan Press.

- Hirschfeld, Yizhar. 2006. "The Crisis of the Sixth Century: Climatic Change, Natural Disasters and the Plague." *Mediterranean Archaeology & Archaeometry* 6 (January): 19–32. <https://ui.adsabs.harvard.edu/abs/2006MAA.....6...19H/abstract>.
- Horace = Horace. 2004. *Odes and Epodes*. Translated by Naill Rudd. Harvard University Press.
- Horden, Peregrine, and Nicholas Purcell. 2000. *The Corrupting Sea: A Study of Mediterranean History*. Wiley-Blackwell.
- Israel, Yigal, and Tali Erickson-Gini. 2013. "Remains from the Hellenistic through the Byzantine Periods at the 'Third Mile Estate', Ashqelon." *'Atiqot*. <http://www.jstor.org/stable/23467644>.
- Jefferson, Thomas. Letter to Albert Gallatin. 2013. *The Papers of Thomas Jefferson, Retirement Series, Vol. 10, May 1816 to 18 January 1817*, September 8.
- Johnson, Hugh, and Jancis Robinson. 2013. *The World Atlas of Wine*. London: Mitchell Beazley.
- Katz, Ofer. 2012. "Horbat Lasan." *Hadashot Arkheologiyot* 124 (December). [http://www.hadashot-esi.org.il/report\\_detail\\_eng.aspx?id=2130](http://www.hadashot-esi.org.il/report_detail_eng.aspx?id=2130).
- Kedar, Y. 1956. "The Problem of Mounds or 'tuleilat El 'Anab' and Their Relation to Ancient Agriculture in the Central Negev." *Bull. Israel Exploration Soc.* 20.
- Keller, Markus. 2010. *The Science of Grapevines*. London : Elsevier Academic Press.
- Keys, David. 2000. *Catastrophe: An Investigation into the Origins of the Modern World*. New York: Ballantine Pub.
- Kingsley, Sean A. 2004. *Shipwreck Archaeology of the Holy Land: Processes and Parameters*. Bristol Classical Press.
- Krämer, Daniel. 2015. "*Menschen Grasten Nun Mit Dem Vieh*": Die Letzte Grosse Hungerkrise Der Schweiz 1816/17 : Mit Einer Theoretischen Und Methodischen Einführung in Die Historische Hungerforschung.
- Langgut, Dafna, Yotam Tepper, Mordechai Benzaquen, Tali Erickson-Gini, and Guy Bar-Oz. 2021. "Environment and Horticulture in the Byzantine Negev Desert, Israel: Sustainability, Prosperity and Enigmatic Decline." *Quaternary International* 593–594 (August): 160–77. <https://doi.org/10.1016/j.quaint.2020.08.056>.
- Lantos, Sára, Guy Bar-Oz, and Gil Gambash. 2020. "Wine from the Desert". *Near Eastern Archaeology* 83 (1): 56–64. <https://doi.org/10.1086/707483>.

- Liang, Zhenchang, Shengchang Duan, Jun Sheng, Shusheng Zhu, Xuemei Ni, Jianhui Shao, Chonghuai Liu, et al. 2019. "Whole-Genome Resequencing of 472 *Vitis* Accessions for Grapevine Diversity and Demographic History Analyses." *Nature Communications* 10 (1). doi:10.1038/s41467-019-09135-8.
- LSJ = Liddell, Henry George, and Robert Scott. 1959. *An Intermediate Greek-English Lexicon: Founded Upon the Seventh Edition of Liddell and Scott's Greek-English Lexicon*. Oxford University Press, USA.
- Lilly, Thomas G, and Paul A Ebb. 2000. "The A.D. 536 Event and The Middle to Late Woodland Transition in Northern Georgia." Essay. In *The Years without Summer: Tracing A.D. 536 and Its Aftermath*, edited by Joel D Gunn, 133–37. Oxford: British Archaeological Reports.
- Litt, Thomas, Christian Ohlwein, Frank H. Neumann, Andreas Hense, and Mordechai Stein. 2012. "Holocene Climate Variability in the Levant from the Dead Sea Pollen Record." *Quaternary Science Reviews* 49: 95–105. doi:10.1016/j.quascirev.2012.06.012.
- Long, Sophie, and Samantha Granville. 2023. "Californian Winemakers Are Learning Firefighting Techniques." *BBC News*, July 5, 2023. <https://www.bbc.com/news/business-66096061>.
- LP = Davis, Raymond. 2010. *The Book of Pontiffs (Liber Pontificalis): The Ancient Biographies of the First Ninety Roman Bishops to AD 715*. Translated Texts for Historians.
- Lucke, Bernhard, and Christoph M. Schmidt. 2017. "Debris Flows, Soil Creep and Heavy Rains in the Wadi Queilbeh, Northern Jordan." *Zeitschrift Für Geomorphologie Supplementary Issues* 61 (1): 159–201. [https://doi.org/10.1127/zfg\\_suppl/2016/0340](https://doi.org/10.1127/zfg_suppl/2016/0340).
- , Mohammed Shunnaq, Bethany J. Walker, Atef Shiyab, Zeidoun Al-Muheisen, Hussein Al-Sababha, Rupert Bäuml, and Michael Schmidt. 2012. "Questioning Transjordan's Historic Desertification: A Critical Review of the Paradigm of 'Empty Lands.'" *Levant* 44 (1): 101–26. <https://doi.org/10.1179/175638012x13285409187955>.
- Magness, Jodi. 1993. *Jerusalem Ceramic Chronology: Circa 200-800 CE*. A&C Black.
- Malalas, John. 1986. *The Chronicle of John Malalas: A Translation*. Translated by Elizabeth Jeffreys, Michael Jeffreys, and Roger Scott. Melbourne: Australian Association for Byzantine Studies.

- Mare, Harold. 1995. *The Technology of the Hydrological System at Abila of the Decapolis. Studies in the History and Archaeology of Jordan 05*. <http://publication.doa.gov.jo/Publications/ViewPublic/129>.
- Mayerson, Philip. 1993. "The Use of Ascalon Wine in the Medical Writers of the Fourth to the Seventh Centuries." *Israel Exploration Journal*, 43 (2/3): 169–73.
- . 1992. "The Gaza 'Wine' Jar (Gazition) and the 'Lost' Ashkelon Jar (Askalônion)." *Israel Exploration Journal* 42 (1/2): 78–80.
- . 1985. "The Wine and Vineyards of Gaza in the Byzantine Period." *Bulletin of the American Schools of Oriental Research* 257: 75–80. doi:10.2307/1356820
- . 1961. *The Ancient Agricultural Regime of Nessana and the Central Negeb*. London: British school of Archaeology in Jerusalem.
- . 1959. "Ancient Agricultural Remains in the Central Negeb: The Teleilat El-'anab." *Bulletin of the American Schools of Oriental Research* 153: 19–32. doi:10.2307/1355564.
- McCormick, Michael. 2021. "Gregory of Tours on Sixth-Century Plague and Other Epidemics." *Speculum* 96 (1): 38–96. doi:10.1086/711721.
- . 2019. "Radiocarbon Dating the End of Urban Services in a Late Roman Town." *Proceedings of the National Academy of Sciences of the United States of America* 116 (17): 8096–98. <https://doi.org/10.1073/pnas.1904037116>.
- Michael the Syrian* = Michael Rabo and Matti Moosa. 2014. *The Syriac Chronicle of Michael Rabo (the Great): A Universal History from the Creation*. Teaneck, NJ: Beth Antioch Press.
- Mikā'el, and Jean-Baptiste Chabot. 1963. "Volume 2." Essay. In *Chronique De Michel Le Syrien, Patriarche Jacobite D'Antioche (1166-1199)*, 220–21. Bruxelles: Culture & Civilisation.
- Moschus, John. 2008. *The Spiritual Meadow: Pratum Spirituale*. Translated by John Wortley. Trappist, KY: Cistercian Publications.
- Niklas, Britta, Jean-Marie Cardebat, Robin M. Back, Davide Gaeta, Vicente Pinilla, João Rebelo, Roberto Jara-Rojas, and Guenter Schamel. 2022. "Wine Industry Perceptions and Reactions to the Covid-19 Crisis in the Old and New Worlds: Do Business Models Make a Difference?" *Agribusiness* 38 (4): 810–31. doi:10.1002/agr.21748.

- T. Nissen, 1938, "Unbekannte Erzählungen aus dem Pratum Spirituale," *Byzantinische Zeitschrift* 38: 354-372. Retrieved from: <http://stephanus.tlg.uci.edu.us1.proxy.openathens.net/Iris/Cite?2856:004:27560>
- Noirot, Etienne. 1836. "Recherches Sur Les Époques de La Maturité Des Raisins." *Le Cultivateur*, August.
- Nordvig, Mathias, and Felix Riede. 2018. "Are There Echoes of the AD 536 Event in the Viking Ragnarok Myth? A Critical Appraisal." *Environment and History* 24 (3): 303–24. doi:10.3197/096734018x15137949591981.
- Newfield, Timothy. 2018. "The Climate Downturn of 536–50." In *The Palgrave Handbook of Climate History*, 447–93. Palgrave Macmillan UK eBooks. <https://doi.org/10.1057/978-1-137-43020-5>.
- "Oakville, Napa - Daily Totals for July." Weather - Napa County UCCE. University of California Cooperative Extension, 2022.
- Öniz, Hakan, and Lihi Habas, eds. 2022. *Trade and Transportation in the Light of the Mosaic Floors of the Holy Land. SOMA 2016: Proceedings of the 20th Symposium on Mediterranean Archaeology*. Oxford, United Kingdom of Great Britain and Northern Ireland: Archaeopress Publishing Ltd.
- Oppenheimer, Clive. 2003. "Climatic, Environmental and Human Consequences of the Largest Known Historic Eruption: Tambora Volcano (Indonesia) 1815." *Progress in Physical Geography: Earth and Environment* 27 (2): 230–59. doi:10.1191/0309133303pp379ra.
- OCD = Hornblower, Simon, Antony Spawforth, and Esther Eidinow. 2012. *The Oxford Classical Dictionary. The Oxford Classical Dictionary*. 4th ed. Oxford: Oxford University Press
- ODLA = Nicholson, Oliver. *The Oxford Dictionary of Late Antiquity*. Oxford University Press, USA, 2018.
- ODB = Kazhdan, Aleksandr Petrovich, Anthony Cutler, Alice-Mary Maffry Talbot, Timothy E. Gregory, and Nancy Patterson Ševčenko. *The Oxford Dictionary of Byzantium*, 1991.
- OED = OED Online. 2023. Oxford University Press. <http://www.oed.com/>
- Ovadia, A. 1969. "Excavations in the Area of the Ancient Synagogue at Gaza (Preliminary Report)." *Israel Exploration Journal* 19 (4): 193–98. <https://www.jstor.org/stable/27925198>.

- Palladius = Palladius Rutilius Taurus Aemilianus. 2013. *The Work of Farming (Opus Agriculturae): And, Poem on Grafting*. Translated by John Fitch. Prospect Books (UK).
- Park, Jinheum, QiuHong Jin, Jieun Choi, Junbeom Bahk, and Jungjae Park. 2021. "Late Holocene Climate Variability in Central Korea Indicated by Vegetation, Geochemistry, and Fire Records of the Yongneup Moor." *Palaeogeography, Palaeoclimatology, Palaeoecology* 584 (December): 110705. <https://doi.org/10.1016/j.palaeo.2021.110705>.
- Peacock, D. P. S., and D. F. Williams. 1986. *Amphorae and the Roman Economy: An Introductory Guide*. Longman Publishing Group.
- Peiser, Jaclyn. 2021. "A 1,500-Year-Old Wine Factory Was Found in Israel. Experts Say It's the Largest Known Winery from That Era." *The Washington Post*, October 11.
- Peregrine, Peter N. 2020. "Climate and Social Change at the Start of the Late Antique Little Ice Age." *The Holocene* 30 (11): 1643–48. doi:10.1177/0959683620941079.
- Peretz, Ilan. 2008. "Khirbat El-Hannuna." *Hadashot Arkheologiyot* 120 (July). [http://www.hadashot-esi.org.il/report\\_detail\\_eng.aspx?id=829&mag\\_id=114](http://www.hadashot-esi.org.il/report_detail_eng.aspx?id=829&mag_id=114).
- Persico, Meredith J., Donald E. Smith, and Michela Centinari. 2021. "Delaying Budbreak to Reduce Freeze Damage: Seasonal Vine Performance and Wine Composition in Two Vitis Vinifera Cultivars". *American Journal of Enology and Viticulture* 72 (4): 346–57. <https://doi.org/10.5344/ajev.2021.20076>.
- Pfister, Christian and Sam White. 2018. "A Year Without a Summer, 1816." Essay. In *The Palgrave Handbook of Climate History*, 447–93. London: Palgrave Macmillan.
- Phillimore, Egerton. 1888. Essay. In *The Annales Cambriae and Old-Welsh Genealogies from Harleian MS. 3859*, 141–83. Y Cymmrodor.
- Pliny the Elder = Pliny. 1938. *Natural History*. Translated by H Rackham. Harvard University Press. <https://www.loebclassics.com/view/LCL330/1938/volume.xml>.
- Postel-Vinay, G. 1989. "Debts and agricultural performance in the Languedocian Vineyard, 1870-1914", *Agrarian Organization in the Century of Industrialization: Europe, Russia, and North America*, pp. 161-86, JAI Press.
- Procopius = Procopius. 1971. *History of the Wars*. Translated by H.B. Dewing. Cambridge, MA: Harvard University Press.
- Pseudo-Zachariah the Rhetor = Geoffrey Greatrex, Phenix Robert R Jr, Cornelia B. Horn, Sebastian P. Brock, and Witold Witakowski. 2011. *The Chronicle of*

*Pseudo-Zachariah Rhetor Church and War in Late Antiquity*. Liverpool: Liverpool University Press.

- Purcell, Nicholas. 1985. "Wine and Wealth in Ancient Italy." *Journal of Roman Studies* 75 (November): 1–19. <https://doi.org/10.2307/300648>.
- Ramos, M. C., and G. V. Jones. 2018. "Relationships between Cabernet Sauvignon Phenology and Climate in Two Spanish Viticultural Regions: Observations and Predicted Future Changes." *The Journal of Agricultural Science* 156 (9). Cambridge University Press: 1079–89. doi:10.1017/S0021859618001119.
- Ramos-Madrigal, Jazmín, Anne Kathrine Runge, Laurent Bouby, Thierry Lacombe, José Alfredo Samaniego Castruita, Anne-Françoise Adam-Blondon, Isabel Figueiral, et al. 2019. "Palaeogenomic Insights into the Origins of French Grapevine Diversity." *Nature Plants* 5 (6): 595–603. doi:10.1038/s41477-019-0437-5.
- Ravelli, Angelo, Jan Van Der Meulen, Robert P J Michels, Clive Osmond, D. Barker, C. N. Hales, and Otto P. Bleker. 1998. "Glucose Tolerance in Adults after Prenatal Exposure to Famine." *The Lancet* 351 (9097): 173–77. [https://doi.org/10.1016/s0140-6736\(97\)07244-9](https://doi.org/10.1016/s0140-6736(97)07244-9).
- Reis Pereira, Mafalda, Helena Ribeiro, Ilda Abreu, José Eiras-Dias, Teresa Mota, and Mário Cunha. 2018. "Predicting the Flowering Date of Portuguese Grapevine Varieties Using Temperature-Based Phenological Models: A Multi-Site Approach." *The Journal of Agricultural Science* 156 (7). Cambridge University Press: 865–76. doi:10.1017/S0021859618000850.
- Reynolds, Paul, Tali Erikson-Gini, and John Riley. n.d. "Late Roman Amphora 4 (LRA 4)/"Gaza" Jars." The Levantine Ceramics Project. Accessed June 30, 2023. <https://www.levantineceramics.org/wares/857-late-roman-amphora-4-lra-4-gaza-jars>.
- Robinson, Jancis. 1994. *The Oxford Companion to Wine*. Oxford: Oxford Univ. Press.
- Rodgers, R. H. 1978. "Varro and Virgil in the "Geoponica"." *Greek, Roman and Byzantine Studies* 19 (3): 277. <https://www.proquest.com/scholarly-journals/varro-virgil-geoponica/docview/1301490738/se-2>.
- Roseboom, Tessa J., Jan Van Der Meulen, Clive Osmond, D. Barker, Angelo Ravelli, and Otto P. Bleker. 2001. "Adult Survival after Prenatal Exposure to the Dutch Famine 1944-45." *Paediatric and Perinatal Epidemiology* 15 (3): 220–25. <https://doi.org/10.1046/j.1365-3016.2001.00336.x>.
- Roskin, Joel, Itzhak Kutra, and Dan G. Blumberg. 2013. "Late Holocene Dune Mobilizations in the Northwestern Negev Dunefield, Israel: A Response to Combined Anthropogenic Activity and Short-Term Intensified Windiness."

*Quaternary International* 303 (July): 10–23. <https://doi.org/10.1016/j.quaint.2012.10.034>

Rowell, Alex, and Abū Nuwās. 2017. *Vintage Humour: The Islamic Wine Poetry of Abu Nuwas*. London: Hurst Publishers.

Ruffini, Giovanni R. 2011. "Village Life and Family Power in Late Antique Nessana." *Transactions of the American Philological Association* 141 (1): 201–25. <https://doi.org/10.1353/apa.2011.0002>.

Ruml, M., N. Korac, M. Vujadinovic, A. Vukovic, and D. Ivanisevic. 2016. "Response of Grapevine Phenology to Recent Temperature Change and Variability in the Wine-Producing Area of Sremski Karlovci, Serbia." *The Journal of Agricultural Science* 154 (2). Cambridge University Press: 186–206. doi:10.1017/S0021859615000453.

Seligman, Jon. 2020. "Were the Central Negev Settlements Suppliers or Importers of Gaza Wines?" *Journal of Roman Archaeology* 33: 249–70. doi:10.1017/s1047759420001002.

Sharon, Moshe. 1997. Essay. In *Corpus Inscriptionum Arabicarum Palaestinae, (CIAP)*, 2:200. Leiden: Brill.

Shelley, Mary W. 1831. "Introduction." Introduction. In *Frankenstein*. Vol. 1. London: Standard Novels. <http://romantic-circles.org/editions/frankenstein/1831v1/intro.html>.

Shultz, Edward J. Pu-sik Kim and Kang Hugh H W., trans. 2013. *The Silla Annals of the Samguk Sagi*. Gyeonggi-do Seongnam-si: Academy of Korean Studies Press.

———. 2012. *The Koguryo Annals of the Samguk Sagi*. and Edward J. Shultz. Seongnam-si, Korea: Academy of Korean Studies Press.

Sigl, M., M. Winstrup, J. R. McConnell, K. C. Welten, G. Plunkett, F. Ludlow, U. Büntgen, et al. 2015. "Timing and Climate Forcing of Volcanic Eruptions for the Past 2,500 Years." *Nature* 523 (7562): 543–49. doi:10.1038/nature14565.

Simon, Matt. 2022. "Wine Is Getting Pricier Thanks to a Logistical Nightmare." *WIRED*, December 23, 2022. <https://www.wired.com/story/wine-is-getting-pricier-thanks-to-a-logistical-nightmare/?redirectURL=https%3A%2F%2Fwww.wired.com%2Fstory%2Fwine-is-getting-pricier-thanks-to-a-logistical-nightmare%2F>.

Society for Historical Archeology. 2022. "Wine & Champagne Bottles." Bottle Typing/Diagnostic Shapes. May 5, 2022. <https://sha.org/bottle/wine.htm>.

- Smithsonian National Museum of Natural History. n.d. "Large Holocene Eruptions." Smithsonian Global Volcanism Program. Accessed January 17, 2012. <https://web.archive.org/web/20120117212357/http://volcano.si.edu/world/largeeruptions.cfm>.
- Stafne, Eric. 2019. "Vineyard Design." *Grapes*. The Cooperative Extension System. June 20. <https://grapes.extension.org/vineyard-design/>.
- Stothers, Richard B., and Michael R. Rampino. 1983. "Volcanic Eruptions in the Mediterranean before A.D. 630 from Written and Archaeological Sources." *Journal of Geophysical Research* 88 (B8): 6357. doi:10.1029/jb088ib08p06357.
- Taxel, Itamar. 2018. *Fragile Biography: The Life Cycle of Ceramics and Refuse Disposal Patterns in Late Antique and Early Medieval Palestine*.
- Telelis, Ioannis G. 2007. "Weather and Climate as Factors Affecting Land Transport and Communications in Byzantium." *Byzantion* 77. Peeters Publishers: 432–62. <http://www.jstor.org/stable/44173150>.
- Tepper, Yotam, Lior Weissbrod, Tal Fried, Nimrod Marom, Jennifer Ramsay, Mina Weinstein-Evron, Sophia Aharonovich, et al. 2018. "Pigeon-Raising and Sustainable Agriculture at the Fringe of the Desert: A View from the Byzantine Village of Sa'adon, Negev, Israel." *Levant* 50 (1): 91–113. doi:10.1080/00758914.2018.1528532.
- , Tali Erickson-Gini, Yoav Farhi, and Guy Bar-Oz. 2018. "Probing the Byzantine/Early Islamic Transition in the Negev: The Renewed Shivta Excavations, 2015–2016." *Tel Aviv* 45 (1): 120–52. doi:10.1080/03344355.2018.1412058.
- Thurmond, David L. 2006. *A Handbook of Food Processing in Classical Rome: For Her Bounty No Winter*. <http://ci.nii.ac.jp/ncid/BA78009197>.
- Tillotson, Simon. 2016. "1816, The Year Without a Summer." Episode. *In Our Time*. London: BBC Radio 4. <https://www.bbc.co.uk/programmes/b077j4yv>.
- Townsend, Chris. 2016. "Year Without a Summer." *The Paris Review*, October 25. <https://www.theparisreview.org/blog/2016/10/25/year-without-summer/>.
- UNESCO. n.d. "Delos." UNESCO World Heritage Centre. <https://whc.unesco.org/en/list/530/>.
- University College Cork. n.d. "Annals of Inisfallen: Annal AI5441 p.69." CELT: The Corpus of Electronic Texts. Accessed July 2, 2023a. <https://celt.ucc.ie/published/T100004/>.

- . n.d. “The Annals of Ulster U536.3.” CELT: The Corpus of Electronic Texts. Accessed July 2, 2023b. <https://celt.ucc.ie/published/T100001A/index.html>.
- University Corporation for Atmospheric Research. n.d. “Tree Rings and Climate.” UCAR Center for Science Education. <https://scied.ucar.edu/learning-zone/how-climate-works/tree-rings-and-climate>.
- University of Southampton. 2014a. “Almagro 54.” Roman Amphorae: A Digital Resource. 2014. Accessed June 30, 2023. <https://doi.org/10.5284/1028192>.
- . 2014b. “Late Roman Amphora 5.” Roman Amphorae: A Digital Resource. 2014. <https://doi.org/10.5284/1028192>.
- Varga, Daniel, and Svetlana Talis. 2021. “Byzantine Archaeological Remains in Beer Sheva, Israel.” *Athens Journal of History* 7 (3): 203–16. doi:10.30958/ajhis.7-3-2.
- Virgil = Virgil. 1916. *Eclogues. Georgics. Aeneid: Books 1-6*. Translated by H. Rushton Fairclough. Harvard University Press.
- Weiner, Steve, Alla Nagorsky, Itamar Taxel, Yotam Asscher, Rosa M. Albert, Lior Regev, Xin Yan, Filipe Natalio, and Elisabetta Boaretto. 2020. “High Temperature Pyrotechnology: A Macro- and Microarchaeology Study of a Late Byzantine-Beginning of Early Islamic Period (7th Century CE) Pottery Kiln from Tel Qatra/Gedera, Israel.” *Journal of Archaeological Science: Reports* 31 (June): 102263. <https://doi.org/10.1016/j.jasrep.2020.102263>.
- Weninger, Bernhard, Lee Clare, Eelco Rohling, Ofer Bar-Yosef, Utz Böhner, Mihael Budja, Manfred Bundschuh, et al. 2009. “The Impact of Rapid Climate Change on Prehistoric Societies during the Holocene in the Eastern Mediterranean.” *Documenta Praehistorica* 36: 7–59. doi:10.4312/dp.36.2.
- Weisburd, Stefi. “Excavating Words, a Geological Tool.” *Science News*, 1985, 91–94.
- White, Carolinne. 1998. “Life of Hilarion by Jerome.” In *Early Christian Lives*, 87–128. Penguin. <http://ci.nii.ac.jp/ncid/BA34746314>.
- Wickman, Chris. 2005. *Framing the Early Middle Ages: Europe and the Mediterranean, 400-800*. Oxford etc.: Oxford University Press.
- Winkler, A. J., James A. Cook, W. M. Kliwer, and Lloyd A. Lider. 1974. *General Viticulture: Second Revised Edition*. Univ of California Press.
- “Wine Labeling: Appellation of Origin.” 2023. *TTBGov*. Alcohol and Tobacco Tax and Trade Bureau. Accessed June 13. <https://www.ttb.gov/labeling-wine/wine-labeling-appellation-of-origin>.

Xoplaki, Elena. 2023. "Back to the Future : Learning from the Past." Zoom Presentation at University of St. Andrews for the conference *New Approaches to the History of Plague in Late Antiquity*, 3 February.

Zerefos, C. S., V. T. Gerogiannis, D. Balis, S. C. Zerefos, and A. Kazantzidis. 2007. "Atmospheric Effects of Volcanic Eruptions as Seen by Famous Artists and Depicted in Their Paintings." *Atmospheric Chemistry and Physics* 7 (15): 4027–42. doi:10.5194/acp-7-4027-2007.