7-20-2021

Quantifying Surplus and Sustainability in the Archaeological Record at the Carthaginian-Roman Urban Mound of Zita, Tripolitania

Brett Kaufman
University of Illinois Urbana, Champaign

Hans Barnard
University of California, Los Angeles

Ali Drine
Institut National du Patrimoine

Rayed Khedher
Wake Forest University

Alan Farahani
University of Nevada, Las Vegas, alan.farahani@unlv.edu

See next page for additional authors

Repository Citation

Kaufman, B., Barnard, H., Drine, A., Khedher, R., Farahani, A., Tahar, S., Jerray, E., Damiata, B. N., Daniels, M., Cerezo-Román, J., Fenn, T., Moses, V. (2021). Quantifying Surplus and Sustainability in the Archaeological Record at the Carthaginian-Roman Urban Mound of Zita, Tripolitania. *Current Anthropology* 1-14. University of Chicago Press.
http://dx.doi.org/10.1086/715275

Authors

Brett Kaufman, Hans Barnard, Ali Drine, Rayed Khedher, Alan Farahani, Sami Ben Tahar, Elyssa Jerray, Brian N. Damiata, Megan Daniels, Jessica Cerezo-Román, Thomas Fenn, and Victoria Moses

ANTHROPOLOGICAL CURRENTS: REPORT

Quantifying Surplus and Sustainability in the Archaeological Record at the Carthaginian-Roman Urban Mound of Zita, Tripolitania

Brett Kaufman, Hans Barnard, Ali Drine, Rayed Khedher, Alan Farahani, Sami Ben Tahar, Elyssa Jerray, Brian N. Damiata, Megan Daniels, Jessica Cerezo-Román, Thomas Fenn, and Victoria Moses

Cultural ecological theory is applied to a spatially and temporally bounded archaeological data set to document long-term paleoecological processes and associated sociopolitical behaviors. Volumetric excavations, treating the material culture of an archaeological matrix similar to an ecological core, can yield quantifiable frequencies of surplus goods that provide a multiproxy empirical lens into incremental changes in land use practices, natural resource consumption, and, in this case, likely overexploitation. Archaeological methods are employed to quantify cultural ecological processes of natural resource exploitation, industrial intensification, sustainability and scarcity, and settlement collapse during the colonial transition between Carthaginian and Roman North Africa. The data indicate that overexploitation of olive timber for metallurgical fuel taxed the ecological metabolism of the Zita resource base, likely contributing to a collapse of the entire local economic system.

Online enhancement: supplementary table.

Roman Occupation of Carthaginian North Africa

"Phoenician" is an exonym derived from the Greek *Φοινίκη* (pronounced *Phoinike*, possibly meaning "purple people/producers of purple dye" or maybe "palm tree") that is still used to describe the Iron Age Northwest Semitic peoples of the eastern Mediterranean Levantine coast based in the city-states of Tyre, Sidon, and Byblos, among others. Emic epigraphic evidence shows that Phoenicians rarely if ever referred to themselves as such (but see Krahmalkov 2000:10–13), preferring city of origin self-designations such as "Sidonian" (*Corpus Inscriptionum Semiticarum* [CIS] I 3 = *Kanaanäische und Aramäische Inschriften* [KAI] 14, 60, 269) or "Tyrian" (CIS I 102; Cooke 1903:90), descendant community self-affiliation such as "Nation of Tyre" (CIS I 7 = KAI 18), "Nation of Sidon" (KAI 60), "Nation of Carthage" (CIS I 269–271), "Nation of Gadir" (KAI 71), or "Citizen of Tyre" (Kaufman 2009), and metanational ethnolinguistic self-identity such as "Canaanite" (KAI 116), in addition to seeing themselves as communities of believers united around a certain deity such as Astarte (CIS I 263) or Melqart (CIS I 264, 3707; Harris 1936), or generally as bound by an ancestral connection as the "people of this land" (Byblos; CIS I 1 = KAI 10), where the memory of Lebanon would continue to play a central role even in their western colonies (CIS I 3914 = KAI 81).

Brett Kaufman is Assistant Professor in the Department of the Classics and Materials Research Laboratory of the Grainger College of Engineering of the University of Illinois at Urbana-Champaign (707 South Mathews Avenue, Urbana, Illinois 61801, USA [bsk@illinois.edu]). **Hans Barnard** is Associate Adjunct Professor in the Department of Near Eastern Languages and Cultures and Associate Researcher at the Cotsen Institute of Archaeology, University of California, Los Angeles (308 Charles E. Young Drive North, Los Angeles, California 90095, USA). **Ali Drine** is Directeur de Recherche and **Sami Ben Tahar** is Maître de Recherche at the Institut National du Patrimoine (04 Place du Château, Tunis 1008, Tunisia). **Rayed Khedher** is Visiting Assistant Professor in the Middle East and South Asia Studies Program at Wake Forest University (1834 Wake Forest Road, Winston-Salem, North Carolina 27109, USA). **Alan Farahani** is Assistant Professor in the Department of Anthropology, University of Nevada, Las Vegas (John S. Wright Hall, Building B, 4505 South Maryland Parkway, Las Vegas, Nevada 89154, USA). **Elyssa Jerray** is Associate Researcher at the Centre Camille Jullian, Aix-Marseille University (Aix-en-Provence, France). **Brian N. Damiata** is Assistant Researcher at the Cotsen Institute of Archaeology, University of California, Los Angeles (Box 951510, A210 Fowler Building, Los Angeles, California 90095, USA). **Megan Daniels** is Assistant Professor of Ancient Greek Material Culture in the Department of Classical, Near Eastern, and Religious Studies, University of British Columbia (Vancouver Campus, Buchanan C227, 1866 Main Mall, Vancouver, British Columbia C V6T 1Z1, Canada). **Jessica Cerezo-Román** is Assistant Professor and **Thomas Fenn** is Assistant Professor in the Department of Anthropology, University of Oklahoma (455 West Lindsey, Dale Hall Tower Room 521, Norman, Oklahoma 73019, USA). **Victoria Moses** is Instructor in the School of Anthropology, University of Arizona (PO Box 210030, Tucson, Arizona 85721-0030, USA). This paper was submitted 24 VI 19, accepted 13 I 21, and electronically published 20 VII 21.

Current Anthropology, volume 62, number 4, August 2021.
0011-3204/2021/6204-0005$10.00. DOI: 10.1086/715275

As the name suggests, the expansionist Tyrian state was associated in antiquity with trade in luxury goods and established a mercantile empire via the foundation of settlements, ports, and warehouses across the Mediterranean, including the first colonies on Sardinia, the Iberian Peninsula, and North Africa. One of these Tyrian colonies was Carthage, which after the Neo-Babylonian siege of Tyre (585–573 BC) became the central Phoenician city-state, developing its own empire via the establishment of colonies across North Africa, including Zita. Little is known about the earliest contact phase or the interactions between Phoenician settlers and the indigenous North Africans (i.e., Amazigh, Libyans, Numidians), and much more work remains to understand these dynamics (but see Brett and Fentress 1996; Kallala et al. 2010; Kallala and Sanmartí 2011; Kaufman et al. 2016; Sanmartí et al. 2012).

The early relationship between Carthage and its peer polity Rome can be characterized as mutualistic, with the two entities ratifying and reaffirming treaties in 509, 348, and 279 BC (De Lisle 2019:170). The Romans Latinized the Greek Φοινίκη as *Poenus*, or "Punic person" to describe the colonial descendants of the Tyrians. This relationship degenerated as the two empires clashed over trade routes and political supremacy in the Central and Western Mediterranean, with Rome ambivalently weaving historical animosity against Carthage in its own foundation legend in Virgil's *Aeneid*. In the course of the third century BC, the two polities became epic foes, and after 118 years of prolonged conflict (the three Punic Wars, 264–146 BC), Rome destroyed Carthage, which resulted in the political extinction of the Phoenician state. However, Punic peoples still remained a major demographic component of the Roman state, and the archaeological and historical era assigned to North Africa under Roman occupation is generally designated culturally as the Neo-Punic period.

Roman political economy employed diverse and adaptive mechanisms to incorporate defeated populations, even a defeated empire such as Carthage. Neo-Punic peoples, Carthaginian refugees, and Numidians alike were integrated into the Roman Republic, and eventually the Roman Principate, over the course of many centuries. Punic farmers, craftspeople, soldiers, senators, and smiths were based out of many urban centers, which continued to exist under the Romans, including what became the municipium of Zita (Mattingly 1994). The Romans granted the North African Neo-Punic population rights that no other conquered peoples enjoyed, including maintaining official Carthaginian titles within the Roman state apparatus (Goodchild 1950), the retention of the Punic cubit as a basic unit of architectural measurement (Raven 1993), and, in the case of the Iberian Peninsula, allowing for mints to issue bilingual Punic-Latin coinage series (Jiménez 2014:234–238). One anecdotal case for social mobility is that of Septimius Severus, the third century AD Roman African Emperor of Punic heritage (Birley 1988), while a likely native tongue of St. Augustine was the Neo-Punic language (Krahmalkov 2000). However, North Africa was ultimately a colonial territory divided into administrative regions (Africa Proconsularis, Tripolitania, Mauretania, etc.), where Roman veterans would be resettled and which was expected to

Figure 1. Zita forum. Typical of Roman fora and contemporary monumental structures across the empire, with Roman withdrawal, official spaces were repurposed from administrative to domestic and cottage industry use (cf. Rogers 2018 and the fourth to fifth centuries AD Roman basilica of Silchester). This included the stripping of plaster from the august walls for recycling, seen here in a pasty mass on the portico as labeled by the yellow circle. Stepping down through the colonnade and into the forum, the red circle identifies a late wall or pen built over the monumental forum interior floor.

Figure 2. Zita *tophet* deposit. Carved stelae were often erected over burial urns containing the remains of cremated neonates, infants, and children, associated with other vessels.

contribute raw materials and surplus goods to the state administration based out of Rome (Mattingly and Hitchner 1995).

The urban mound of Zita (Tunisian Tripolitania, also written as Zitha, Ziane, Zyan, Henchir Zian; occupied ca. 420–400 BC to AD 450; Ben Tahar et al., forthcoming) was chosen to study these colonial dynamics because of its extant infrastructure from both Roman and Carthaginian occupations, namely, a Julio-Claudian to Nerva-Antonine forum (AD 42 to ca. 180; fig. 1), a Neo-Punic ritual precinct or *tophet* (fig. 2), industrial remains including ceramic kilns and metallurgical workshops dated to the abandonment horizon, and many other unidentified features (Kaufman et al. 2015). The region of Tripolitania and North Africa in general served as a major breadbasket of Rome and provisioned massive amounts of cereals, wine, fish paste, and olive oil (fig. 3). Julius Caesar's annual fine against Lepcis Magna for 3 million pounds of olive oil (*Bell. Afr.* 97.3) gives a historical indication for the production capacity of this region, while archaeological work in Libya has allowed for reconstruction of Roman agricultural practices (Barker et al. 1982; Mattingly 1988). The North African Maghreb was, along with the Egyptian Nile Delta, a primary source for agricultural productivity throughout much of the Late Roman Republic and Principate (Rickman 1980:263–264). The region maintained its importance in the fourth century AD as the Eastern Emperors diverted Egyptian grain to Constantinople, and Rome in turn was forced to rely on the nonirrigated rain-fed agriculture of the Maghreb (Linn 2012:298–299; Raven 1993:184, 216; Teall 1959).

The archaeological record at Zita also indicates the vicissitudes of fortune that befell Punic and Roman urban centers over the centuries. The tell of Zita is ca. 34 ha with satellite sites radiating into the hinterland (fig. 4). According to our preliminary analysis of all diagnostic ceramic sherds recovered from survey and excavation, the earliest ceramic evidence from both systematic site-wide survey and excavation in Area III places the foundation of Zita at the end of the fifth century BC. This corresponds in general with the Carthaginian push into its "African hinterland" to secure its political economy beyond the confines of its own urban center (Fentress and Docter 2008). The Zita population began to abandon the site in AD 200, with final abandonment by AD 450.

Our excavations targeted two zones (Area III Square 1 [A3S1] and Area IV Square 1 [A4S1, the ecological core discussed below]) that had industrial debris on the surface in the form of

Figure 3. Modern olive groves looking southeast from the forum at Zita.

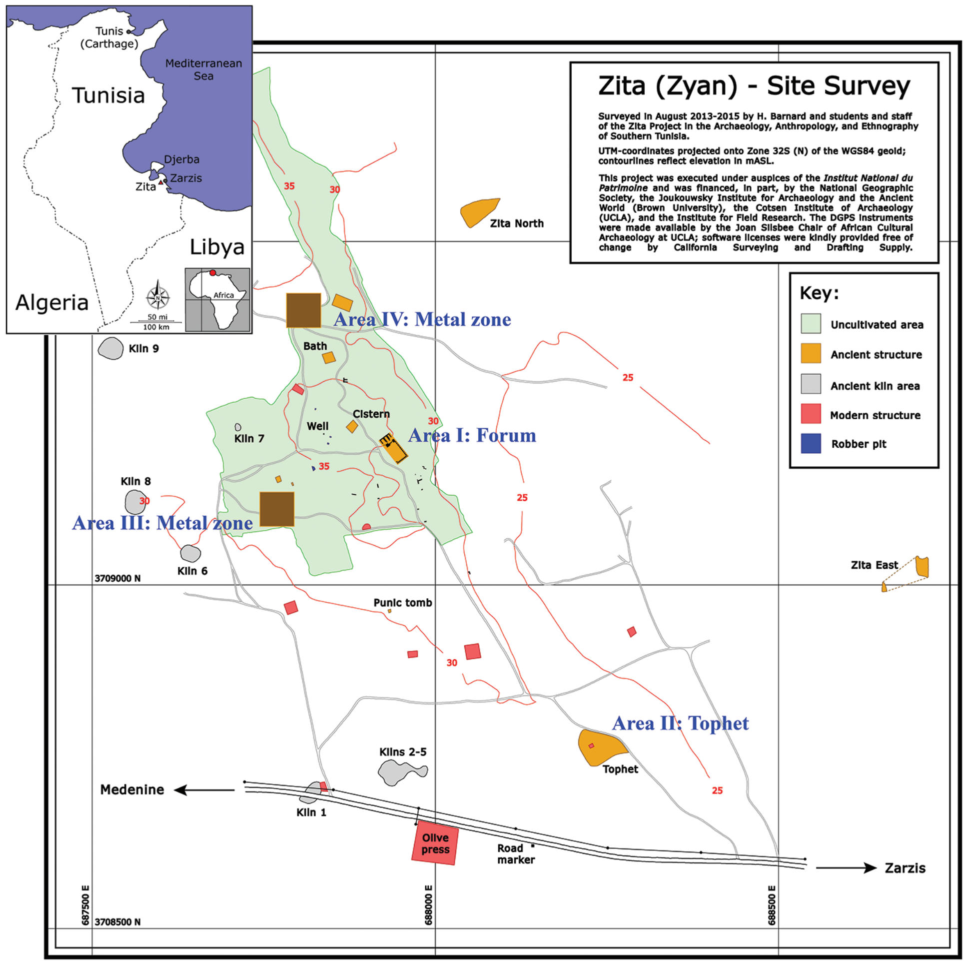

Figure 4. Map of the ancient remains at Zita, with areas of research indicated.

metallurgical slag, the by-product of metalliferous ore smelting. Following the construction of the Roman forum in AD 42, these two zones were reorganized into industrial output centers. In Area III, domestic material culture predominated continuously throughout the late Carthaginian and early Neo-Punic eras until a Roman industrial reorganization in the late first century AD (Moses et al. 2019; fig. 2). In Area IV, where any earlier Carthaginian remains are also as yet unexcavated, a zone was industrialized in the late first century AD. Area IV was abandoned around AD 200 (terminus ante quem based on ceramics), around 100 years later than the cessation of funerary deposits in the Neo-Punic ritual precinct, the tophet. Within a half century, by AD 250, the metallurgical facility in Area III as well as all the ceramic kilns were abandoned (figs. 4, 5).

The abandonment of Zita is perceived as a complete or near-complete reduction of human population. Only a residual occupation continued within what had been the political and administrative monumental forum structure until around AD 400–450, akin to other Roman fora at abandoned sites across the empire (Rogers 2018). While there may have been a temporary abandonment of the forum in the first half of the third century AD followed by reoccupation, the forum superstructure collapsed during the first half of the fifth century AD, sealing in the final occupation layer (fig. 6). There is no current evidence for Vandal occupation, although most of the urban mound remains unexcavated, including what appears to be a late structure of currently unestablished date built on the highest point of the tell above the forum. It is unclear whether the people of Zita moved to another location, whether disease or famine played a role in real reduction in human population, or whether the population became archaeologically less visible for other reasons (such as a switch from agriculture to pastoral nomadism). Archaeological and literary documents testify that the community moved to what became the nearby modern city of Zarzis (ancient Gergis; De La Blanchère 1887:449; *Stadiasmus Maris Magni*). Several other Tripolitanian sites of the Lesser Syrtis were abandoned in the third century AD (Ben Tahar 2010, 2018; Fentress, Drine, and Holod 2009; Ritter and Ben Tahar 2020), some temporarily with later reoccupation, while other abandonments were permanent such as that of Zita.

For as problematic as the term is (Bénabou 1976; Cerezo-Román et al. 2017; Ghisleni 2018 and responses; Versluys 2014 and responses; Woolf 1998), "Romanization" at Zita is characterized by industrialization and economic intensification. The

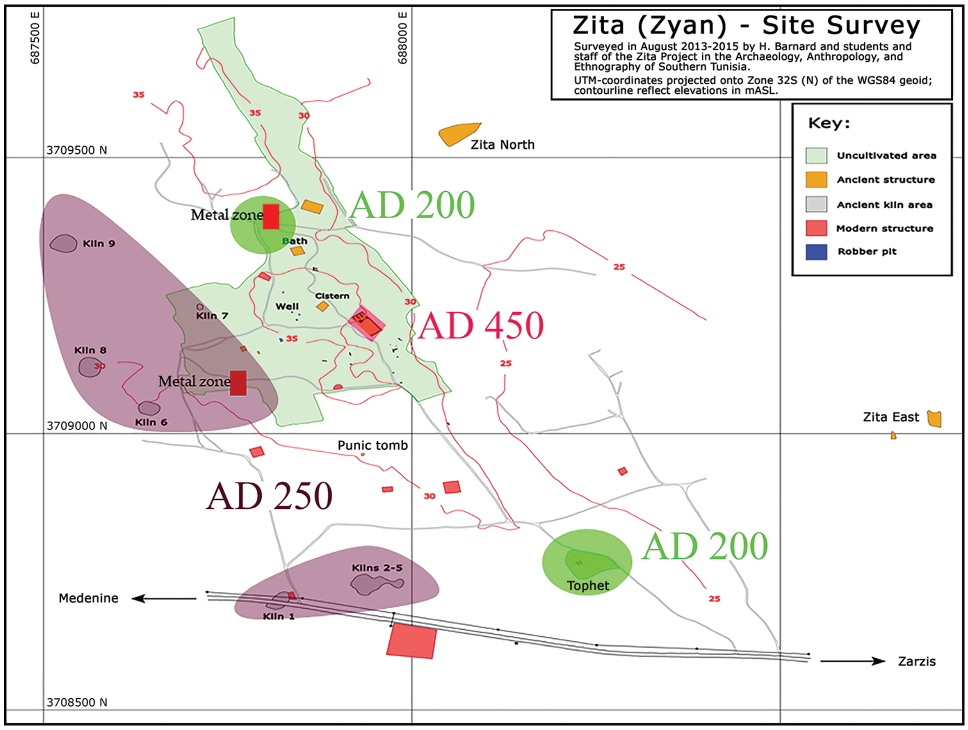

Figure 5. Abandonment horizon at Zita based on preliminary results of survey and excavation. The *tophet* (Area II) and Area IV metallurgical zone were abandoned by AD 200 (green) and the kilns and outer rung of the urban center were deserted by AD 250 (purple), leaving only a small population that sought refuge within the forum architecture until the collapse of this structure by AD 450 (pink).

extraction of material surplus was a major goal for the Romans in North Africa, with local administration facilitating the shipment of surplus goods (olive oil, wine, metal hardware) into the Roman imperial apparatus. However, unsustainable production of materials can exceed the productive ecology of a region, and the collapse and abandonment of Zita starting in ca. AD 200 may be partially attributable to the switch from Punic rural economy to industrialized Roman surplus economy.

Archaeological Methods and Cultural Ecology

Natural resources and raw material exploitation were dynamic processes in antiquity, with material production of any given resource dependent on a variety of others. For example, processes requiring pyrotechnology, such as the production of metal, ceramics, lime, and glass, were only possible with abundance of fuel in the form of timber, dung, peat, or charcoal products thereof. Because the abandonment horizon of Zita is characterized by the collapse of such industries (at least nine kilns and two metallurgical workshops), fieldwork was geared toward analyzing the long-term effects of surplus production. It is our contention that intensified unsustainable industrialization at Zita led in part to local economic collapse followed by settlement abandonment observable at a multicentury temporal depth.

State-level colonial dynamics are usually resource driven, as colonial administrations exploit mineral, fuel, and human resources and amass surplus (Dietler 2010; Kaufman 2018:4–13; Lightfoot et al. 2013; Morehart 2014; Morehart and De Lucia 2015; Stanish 2017:9; Townsend 2009; see Hayden 2020 and responses for transegalitarian storage surplus). Environmental degradation wrought by industrial economies is witnessed at both global and local scales, and archaeological modeling correlating related materials has the potential to qualify and quantify cultural responses to environmental pressures (Dalfes 1997; Grattan, Gilbertson, and Hunt 2007; Schmidt 1997; Schneider and Sagan 2005; Stephens et al. 2019; Steward 1968; Vitousek et al. 1997). Colonial production and consumption dynamics at the scale of empire or state are in fact the sum of numerous local production facilities. This is where archaeology can contribute to discussions of global economic interactions—high-resolution investigation of local sites that together are the parts equaling the imperial or planetary sum over long periods of time.

The industrial or colonial ecology of a site or region is defined here as being the natural resource energy expenditure combined with the health and resilience of the population, drawing on Butzer's (1982:7) understanding of human ecology as a process of systemic energy flows, as well as calculation of an ecosystem's material flow account. Exploitation of mineral and human capital affects the societal and industrial metabolism of a site and its population, where these metabolisms are defined as "systems that exchange materials and energy with the natural environment" in order to maximize surplus generation (Eisenmenger

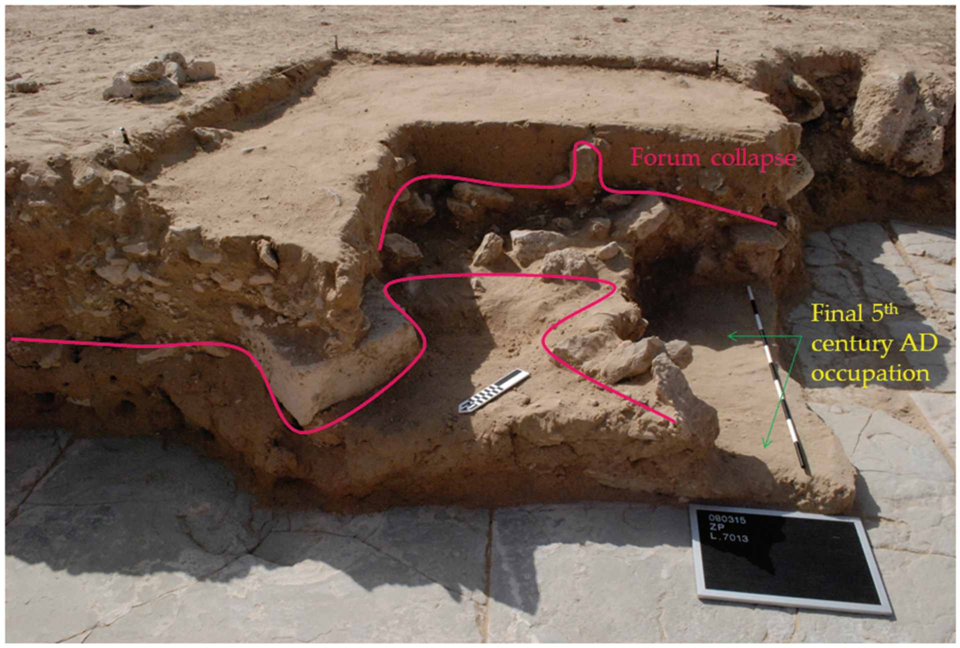

Figure 6. Excavation of Roman forum collapse. The final fifth century AD stratum was sealed by the collapse of the superstructure (between pink lines), which marked an end to the archaeologically visible occupation of the tell (green arrows and yellow text) until modern agricultural activity.

and Giljum 2007:288). Archaeology is an ideal tool to investigate these correlated material relationships, as a spatially and temporally bounded data set recovered from volumetric excavation serves as an empirical proxy for the production and consumption behaviors of the population—in this case a Punic population undergoing polity transition under the Roman Empire.

In the case of Zita—a Punic toponym that can be translated as "Olive City"—the diachronic ecological metabolism of the site is quantified via processes of deforestation or orchard felling, defined as available olive timber measured via the proxy of MNI carbonized olive pits (A4S1 core $n = 105$, all excavated sediment collected by hand and sieved with 1 cm mesh; fig. 7) used to fuel the metallurgical furnaces measured via the proxy of kilograms of slag (A4S1 core = 9.8 kg). Olive pits were deemed to be a valid proxy as they were common enough to be randomly discarded, therefore representing available olive timber to be used for wood charcoal fuel.

Stratigraphic excavations in a metallurgical zone identified through surface slag were carried out in a 2 × 1 × 1.76-m trench (A4S1, loci 5100–5121). As seen in figure 8, the lower layers of the core are distinct due to a densely packed rock matrix, likely the remains of a structure, while the upper layers are an ashy black and orange sedimentary deposit, likely a metallurgical waste dumping site in close proximity to a furnace. Both artifact types (olive pits and slag) were density weighted and extrapolated based on excavation volume and standardized per cubic meter, temporally bracketed by radiocarbon chronologies (figs. 9, 10; table S1, available online) and pottery typologies. Slag can be reverse engineered to determine the kinds of metal used to generate the slag by-product. In the case of Zita, with several pieces of slag so far qualitatively analyzed for presence/absence of metal components using x-ray fluorescence spectroscopy, all seem to be remnant from the production of iron or steel.

The entire ecological metabolism of Zita was of course more complex and multifaceted, with many other systems of material exchange (Eisenmenger and Giljum 2007) and with satellite sites surrounding the urban center discovered through survey (such as "Zita East" and "Zita North" in fig. 4). There would have been multiple olive presses, orchards, and other agricultural and horticultural fields as evidenced through archaeological survey (Drine 1999; Jerray 2015) and identifications of macrobotanical remains from Area III of not only olives but also colocynth,

Figure 7. Illustrative carbonized olive pit excavated from A3S1.

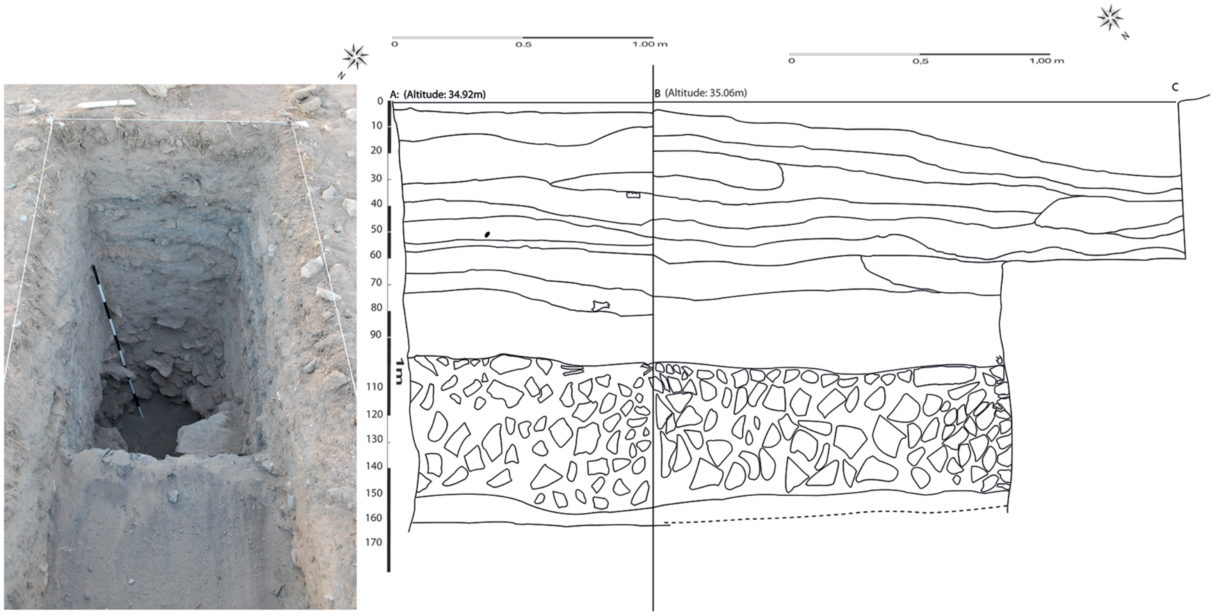

Figure 8. Photograph on last day of excavations and corresponding drawing of stratigraphic profile of ecological core A4S1 (technical drawing by Moèz Achour).

grapes, wheat, barley, and perhaps, based on the charcoal evidence, Mt. Atlas mastic tree (*Pistacia atlantica*). However, while delineating an exact boundary for the Zita urban ecology is complicated by the fact that the city was part of regional and international political systems, A4S1 is considered representative of certain aspects of the economy, specifically extractive metallurgy using metallurgical fuel, and as such represents one distinct temporally and spatially bounded material flow intersection between the horticultural and industrial activities of Zita urban society.

Results and Discussion: Surplus and Sustainability

The ceramic range for ecological core A4S1 dates from ca. AD 50 to 200, confirmed with radiocarbon dates of olive pits ranging from cal AD 74 from 221 (fig. 9). When confronted with the

Sample ID	UCIAMS#	^{14}C Age (^{14}C yrs BP)	Unconstrained calibrated date (calAD)	Constrained modeled date (calAD)[1]
5103 ZP51003.4	166637	1875 ± 15	124 – 217 (95.4%)	133 – 221 (95.4%) A: 98.6%
5109 ZP51008.4	166638	1860 ± 15	129 – 230 (95.4%)	132 – 215 (95.4%) A: 103.2%
5110 ZP51009.2	166639	1845 ± 15	130 – 145 (6.8%) 153 – 237 (88.6%)	131 – 213 (95.4%) A: 47.2%
5111 ZP5101.2	166640	1885 ± 15	120 – 215 (95.4%)	128 – 205 (95.4%) A: 106.7%
5112 ZP51011.1	166641	1850 ± 15	130 – 145 (9.4%) 153 – 237 (86.0%)	126 – 190 (94.3%) 202 – 206 (1.2%) A: 57.9%
5113 ZP51012.2	166642	1875 ± 20	121 – 229 (95.4%)	122 – 182 (95.4%) A: 107.2%
5116 ZP51017.5	166643	1900 ± 15	81 – 98 (8.8%) 112 – 210 (86.6%)	117 – 174 (94.6%) 198 – 202 (0.8%) A: 119.2%
5119 ZP51018.5	166644	1905 ± 15	80 – 100 (14.1%) 108 – 209 (81.3%)	110 – 170 (93.6%) 193 – 202 (1.8%) A: 128.6%
5120 ZP51020.1	166645	1910 ± 15	77 – 206 (95.4%)	85 – 163 (95.4%) A: 132.8%
5121 ZP51021.1	166646	1925 ± 15	29 – 42 (2.3%) 59 – 168 (89.6%) 186 – 203 (3.6%)	74 – 161 (94.4%) 192 – 126 (1.1%) A: 109.5%

[1] A represents sample agreement index. A value >60% indicates an acceptable fit.

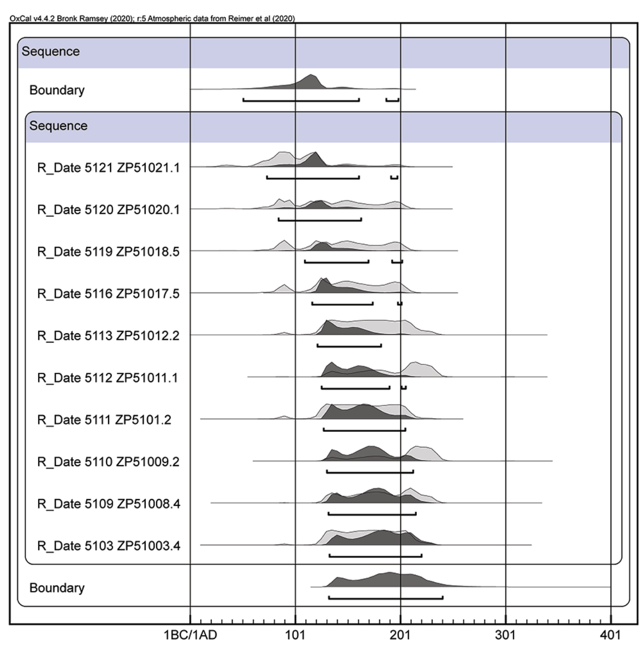

Figure 9. Modeled radiocarbon dates based on relative sequence as a constraint for the A4S1 ecological core/volumetric excavation (OxCal 4.4.2).

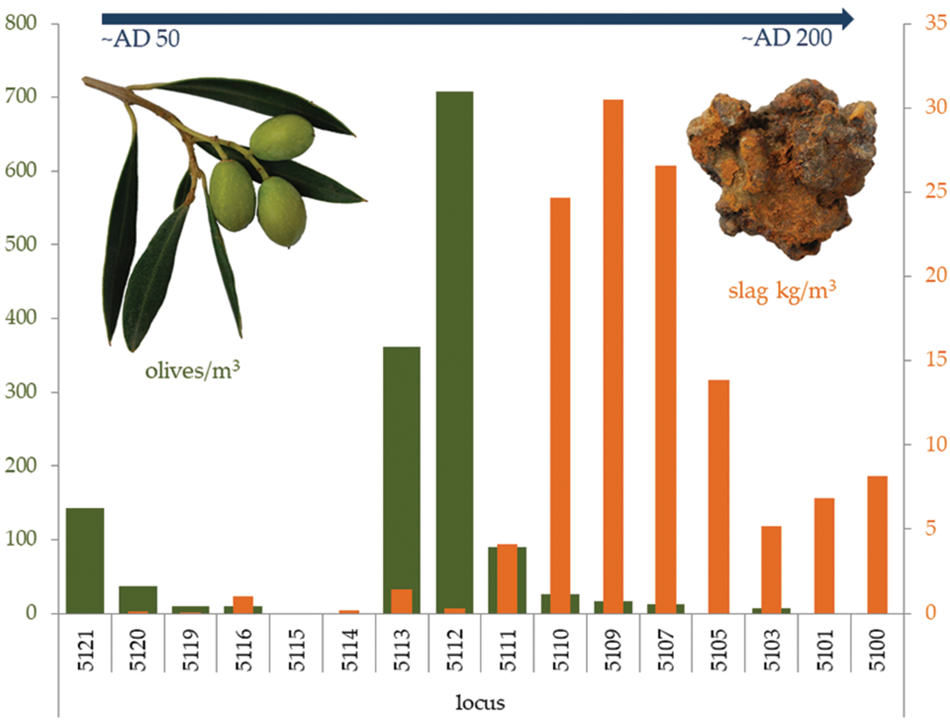

Figure 10. Correlation and frequencies of metallurgical production (slag proxy) and olive timber fuel (olive pit proxy) availability over time inferred from A4S1; the raw data are available in online supplement A.

olive and slag correlation data (fig. 10; table S1), these dates clearly show that following construction of the Julio-Claudian forum in AD 42, there was a minor crash in olive oil production, perhaps due to a reorganization of the economy (loci 5121–5115). Intensification (boom; Hobson 2015; Mattingly 1988) in olive oil production represented in loci 5113–5112 is followed by a collapse (bust) culminating in locus 5111. Locus 5111 marks a recommissioning of the zone from olive oil to metallurgical production, an industrialization process attested across the site. These resources are inversely correlated as the olive timber fuel needed to charge the metal furnaces (that sharply increase output after locus 5111) likely contributed to the observed collapse in olive oil capabilities (evidenced through decreasing numbers of the olive pit proxy). The metal boom lasts through locus 5109 but then somewhat sharply declines and bottoms out ca. AD 200, contemporary with the beginning of the abandonment of Zita (locus 5100, surface layer).

These data indicate that overexploitation of olive timber for fuel taxed the ecological metabolism of the Zita resource base, likely contributing to a collapse of the entire urban economic system. Nearby pollen cores support this contention at the regional level, as olive tree numbers are recorded as declining throughout the Roman period (Jaouadi and Lebreton 2018).

This interpretation is furthermore supported by preliminary anthracological analysis of charcoal (fig. 11) recovered from A4S1 as well as another excavated metallurgical zone, A3S1 (3 × 3 × 2.81 m). Olive (*Olea europaea*) was the only wood charcoal fuel identified in pre- and early metallurgical contexts ($n = 4$) and comprised 73% of the identified metallurgical charcoal by weight (table 1). Although sample size is small ($n = 17$, total weight = 25.4 g) and further analysis is necessary, the totality of wood charcoal evidence from these contexts suggests that olive timber was one of the main sources of metallurgical fuel at Zita but that in the final years of the settlement, alternative fuel sources were sought. Timber fuel resources would not have been acquired from cutting down olive trees, which can take a decade to fruit and last for several generations when properly tended. Instead, it is likely that selected branches were cut down as a consequence of extensive pruning (selective cutting of branches to remove those dead or unproductive ones and encourage fruit bearing by increasing access to light and/or air on others), a necessary practice for olive tree orchard management that has a long recorded history in the Mediterranean (Foxhall 2007:124–126). In addition, sick or dead trees also may have been used. However, as fuel requirements increased throughout the Roman industrial period, we cannot rule out that whole trees were felled.

Practices such as these continue in the region today by traditional charcoal makers, or *maradmi*, who reduce olive wood to charcoal in a *mardouma* (مردومة) furnace. Although the techniques themselves may have differed, and no direct cultural analogy is proposed here between the ethnographic present and archaeological past, wood to charcoal ratios can be reasonably established by ethnoarchaeometric interviews and observations that were conducted in Zarzis by team members under the auspices of the Institut National du Patrimoine and that are slated to be published separately (for expanded discussion on theory

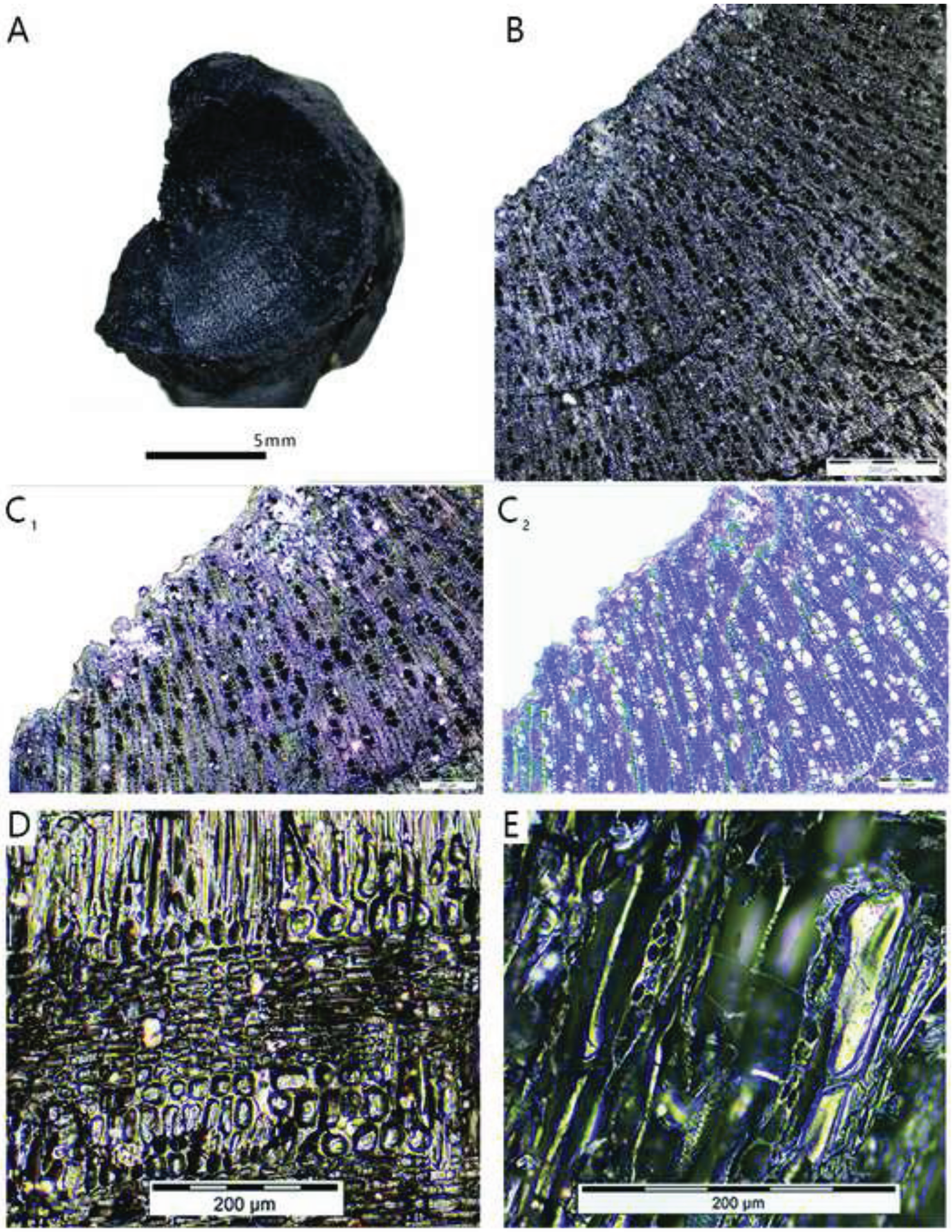

Figure 11. Microanatomical features of olive wood charcoal from Zita, where *A* is an entire olive wood charcoal specimen (locus 5024), *B* and C_1 are the 5 × and 10 × cross section of a wood charcoal specimen (locus 5031) illustrating distinct growth rings, uni- to bi-seriate rays, diffuse-porous vessel structure, and vessel chains up to four/five in length, with image enhancement (C_2) to highlight these features. In addition, other microanatomical features include one to three rows of upright cells followed by majority procumbent cells in radial section (*D*) and spiral thickenings visible in the tangential sections (*E*).

Table 1. Charcoal identifications from metallurgical contexts A3S1 and A4S1

Locus	Pottery bucket	Trench	Specimen no.	Identification	Weight (g)	Context
5005	50005.3	A3S1	1	cf. *Pistacia atlantica*	.8205	Metallurgical
5005	50005.3	A3S1	2	cf. *P. atlantica*	1.405	Metallurgical
5009	50010.7	A3S1	1	Desert shrub cf. *Artemisia*	2.435	Metallurgical
5009	50010.7	A3S1	2	Desert shrub cf. *Artemisia*	.787	Metallurgical
5019	50027.1	A3S1	1	*Olea europaea*	.145	Metallurgical
5019	50027.1	A3S1	2	*O. europaea*	.618	Metallurgical
5024	50032.2	A3S1	1	*O. europaea*	3.1	Metallurgical
5026	50033.2	A3S1	1	*O. europaea*	3.19	Metallurgical
5026	50033.2	A3S1	2	*O. europaea*	5.51	Metallurgical
5031	50038.1	A3S1	1	*O. europaea*	.917	Metallurgical
5035	50042.8	A3S1	1	*O. europaea*	3.17	Transition from domestic to metallurgical
5111	51010.1	A4S1	1	*O. europaea*	.882	Early metallurgical
5116	51017.3	A4S1	1	*O. europaea*	.518	Premetallurgical
5116	51017.3	A4S1	2	*O. europaea*	.269	Premetallurgical
5116	51017.3	A4S1	3	*O. europaea*	.254	Premetallurgical
5117	51016.2	A4S1	1	*O. europaea*	.594	Metallurgical
5117	51016.2	A4S1	2	*O. europaea*	.828	Metallurgical

and methods, see Costin 2000; Lane 2005; Whiteley 2004; Wylie 1985). Some of the salient results are reported preliminarily here. For example, the maradmi rule of thumb is that there is a one-third yield of charcoal from wood. This means that as the wood is left to smolder in order to reduce the noncarbon components, ca. 1,000 kg of olive wood would yield ca. 333 kg of charcoal.

Estimations of slag to fuel yield are minimal in the archaeometallurgical, experimental archaeological, and ethnographic literature. However, when considering one widely accepted estimate (Craddock 1995:193–194; Merkel 1990) that 1 kg of slag requires 2 kg of fuel (albeit for copper production, not wrought iron; but based on the Ellingham diagram, the reduction of iron oxides typically requires more energy than copper oxides, making this 1 : 2 kg of slag : fuel conservative for our purposes—in other words, the same amount of fuel would reduce more copper oxide than iron oxide given similar conditions), we can begin to approximate the amounts of fuel that would have been required to produce the slag mounds at Zita. For example, at the low end of production (locus 5111), 4 kg/m^3 of slag would require 8 kg/m^3 of charcoal fuel, requiring 24 kg/m^3 of olive wood, while at the upper end (L. 5109), 30 kg/m^3 of slag would require 60 kg/m^3 of charcoal fuel, requiring 180 kg/m^3 of olive wood. Because both Roman and Punic ferrous metallurgy relied on bloomery smelting (primary reduction of iron ore to intermediate bloom product), further refinement of the metal into ingots or billets would be necessary. Crew's (1991) experiment showed that 100 kg of charcoal fuel would be required to yield 1 kg of fully smithed iron from a bloom, reminding us that yet more fuel would be needed to finalize the metallurgical production process.

Additionally, slag is known to inhibit the growth of vegetation, further compounding the effects of ecological degradation (Friedman 2013:316–318; Pyatt et al. 2000). To account for potential effects driven by heavy metal pollution, sediment samples were also retrieved from the ecological core and are currently being analyzed to gauge whether the sediment is indeed contaminated by trace pollutants. The slag heap is much bigger than our narrow sounding, and the next steps in this research will be to combine the mardouma wood to charcoal yield with volumetric analysis of the slag heaps themselves on the basis of ground-penetrating radar data that we acquired in order to ascertain absolute fuel consumption patterns.

Although we employed high-resolution recovery methods in the excavation wherever possible, it should be kept in mind that archaeological data are necessarily partial and that the same data set can be subject to a variety of equally valid interpretations. Therefore, we should also entertain the possibility that the drop in olive frequency is due to a nonscarcity-driven recommissioning of the zone, mentioned above, and not solely due to a general shortage in the availability of olive fuel. Furthermore, some layers, particularly the uppermost ones such as 5100, will have been disturbed by formation processes that can affect artifact or ecofact frequencies, a perennial challenge in any archaeological interpretation (Schiffer 1983). In addition to a much more intensive blanket sampling strategy for archaeobotanical remains, additional cores should be excavated to further quantify availability, specifically in the ceramic kiln complexes where amphorae were being produced in order to store and transport surplus olive oil and likely wine. Understanding the use-life histories of these kiln complexes and the charcoal used for firing clay would greatly enhance our picture of other material flow account inputs to the ecological metabolism of the site. That being said, as the data currently stand, with dramatic shifts in production that relied solely on rapidly dwindling olive trees for both oil and fuel followed by population abandonment, the ecological explanation for abandonment is still tenable and in our opinion most plausible.

Questions surrounding human ecology as it relates to potential heavy metal contamination or other pathological detriments induced by Roman industrialization also require bioarchaeological evidence. Romanization at Zita, much as it likely was at other Neo-Punic sites across North Africa, illustrates that colonial relationships can take many forms. Roman managers used a dual strategy of enfranchisement into the new order, with tolerance of the old, in order to leverage Punic labor and craft expertise and exploit local natural resources. This cultural tolerance is witnessed via the persistence of Punic language for centuries, including being allowed on Roman monumental inscriptions with Neo-Punic peoples retaining notorious Carthaginian personal names (i.e., Hannibal, Himilco), while official Carthaginian titles (such as *špṭ* or "judge") were syncretized with Roman offices (*Suffete*), an anomaly of Roman history (Birley 1988:16; Goodchild 1950; Harris 1936:153; Levi Della Vida 1935; Mattingly 1987:73). Cultural continuity at Zita is also evidenced zooarchaeologically via dietary stability from Punic to Roman eras (Moses et al. 2019).

Perhaps the most striking line of evidence for Punic cultural continuity at Zita is that cremation practices and their association with the gods and goddesses of the old Phoenician pantheon continued well throughout the Roman period, albeit with Latinized names (McCarty 2019). These were carried out in demarcated precincts (tophets), where during the Punic era infants and children were allegedly sacrificed to deities such as the god Ba'al Hammon, who was Latinized to Saturn, and the goddess Tanit, who was Latinized to Juno Caelestis (at Zita, Tanit as Caelestis: *Inscriptions Latines D'Afrique* [ILAfr] 12; also possibly Dagon: *Répertoire d'Épigraphie Sémitique* [RES] 558; Berger 1905).

A tophet is described archaeologically as a Phoenician-Punic urnfield containing the remains of cremated subadults. Tophet sites are most typically found in the Central Mediterranean associated with ancient communities influenced or controlled by the Carthaginian state. We know of tophets continuing into the Roman period at places like Henchir el-Hami (Ferjaoui and Alexandropoulos 2007), Dougga (McCarty 2013), and N'gaous (D'Andrea and Giardino 2009), as well as at Zita. The Neo-Punic sanctuary compound dedicated to Caelestis/Tanit and Saturn/Baal at Roman Carthage, although no longer a tophet, provides evidence for continuing worship of Phoenician deities stratigraphically located over the old Punic tophet (Hurst 1999).

At Zita, our survey and excavations have dated the tophet to the Neo-Punic era (ca. 50–30 BC to AD 100). By AD 100, mortuary deposits cease, but ceramic evidence recovered from survey indicates that people continued visiting and perhaps leaving votive ceramic vessels until AD 200. The history of scholarship of tophets has tended to focus on proving presence or absence of human sacrifice (Schwartz et al. 2017; Smith et al. 2013; Xella et al. 2013). Although this question is of great interest, often ignored is an approach that views these burials as an ideal opportunity to gauge infant and childhood health as a proxy of overall population health. A separate study is being prepared to report on these findings in full, but preliminary paleopathological results obtained by Cerezo-Román indicate that the health of most Zita infants and children was compromised at the time of death. Whether an increase in the pace of industrialization and corollary negative impact on human health caused by smoke or other gaseous fumes, heavy metal toxicity in soil or water, or other factors contributed to these negative health outcomes is still being investigated. Comprehensive paleopathological conclusions at Zita across age groups are complicated by the fact that we have not yet identified the location of the adult necropolis, but results may become clearer as we reconstruct the stratigraphic relationships between mortuary deposits within the tophet itself.

Regarding Neo-Punic tophet depositional history in general, a preliminary view argues that the mechanics of imperial control were most profitably employed by leaving local organizational structures intact, specifically religious ones. Eventually, however, Roman tolerance was either rescinded, or people drifted from the Phoenician ways. The ceramic record at Zita shows that mortuary deposits in the tophet cease within a generation or two of the construction of the Roman forum.

Conclusions and Next Steps

The archaeological proxies of metallurgical fuel and metallurgical slag provide an empirical material flow account of long-term ecological-industrial processes at the urban mound of Zita in the Saharan-Mediterranean region of Tripolitania. The population of Zita began to desert the city ca. AD 200, with the Area IV metallurgical zone being one of the first areas to be abandoned. Over the next half century, the archaeological visibility for occupation of Zita gradually disappeared, except within the forum alone where a small group of people repurposed administrative structures for domestic use until architectural collapse ca. AD 400–450. To what extent did the abandonment of Zita have to do with overexploitation of the economic base in this semiarid region? The boom and bust nature of resource use from the A4S1 ecological core data indicates that ecological stress at least played a part in the abandonment of the city, likely in tandem with other sociopolitical and socioeconomic processes.

Olive trees were exploited for both their oil and their fuel, and the intense and singular investment placed in this arboreal resource introduced instability into the local socioeconomic system of Zita. Preliminary evidence suggests that olive wood charcoal was used extensively to fuel the metallurgical furnaces for centuries at Zita. These timber fuel resources were heavily taxed in the final years of the city and so greatly reduced in number as to represent an economic crash from which the city seems never to have recovered. The fact that some of the latest metallurgical loci in A3S1 relied on charcoal from a wild shrubby brush, and perhaps pistachio trees, clearly indicates a need to locate alternative fuel sources. It may be posited preliminarily that this switch in wood fuel represents a final desperate measure to keep the furnaces stoked once olive orchards were spent, but a greater anthracological research regime will be needed to state this conclusively. Furthermore, although the Romans appeared to have tolerated the presence of sacred Punic ritual at the Zita tophet in what Roman administrators likely saw as a management strategy to induce the population to cooperate with the new colonial-industrial ecology, we have determined that the great majority of infants and children buried there all died with a variety of health problems.

In tandem with a certain degree of tolerance for Punic culture and religion, a century or two of Roman industrial activities at Zita exceeded the local ecological metabolism of the area, contributing to the abandonment of the ancient city. Contraction of the local economy at Zita may have been exacerbated by other global, pan-empire epidemiological, political, pollutive, and climatic phenomena. These would include the compounded stresses of the Antonine Plague (outbreak in the AD 160s) and the Plague of Cyprian (ca. AD 249–270), the latter concurrent with the "Crisis of the Third century AD," during which frequent and highly unstable political and military turnover may have resulted in a series of shortsighted resource squeezes—all during a period of drought, cooling, and intensification of volcanic eruptions (AD 235–293; Harper 2015; Manning 2013; McCormick et al. 2012:186–190). Peak atmospheric emissions of lead from metallurgical activities—a global proxy for a likely decline in local human health due to this pollution—are recorded until the second century AD, followed by a collapse in production that extended well into the third century AD and beyond (Hong et al. 1994; McConnell et al. 2018). The intensification and spread of agriculture (primarily oliviculture), in addition to the appetite for exotic beast hunts in gladiatorial combat (*venationes*, often exploiting lions and elephants) until the late second century AD accelerated habitat loss and extirpation of North African wild fauna (for both pest control and entertainment), further degrading natural ecosystems (Bomgardner 1992; Mackinnon 2006). The increase of diseases during this period may even be linked to the intensification of livestock production, with potential zoonotic diseases compounding the other environmental effects on human health.

More research is required using high-resolution methods at Zita and elsewhere to refine our understanding of these socio-environmental processes. Next steps should include additional investigation into potential heavy metal pollution and potentially correlated health detriments and paleopathologies, estimations of total slag mass and corollary fuel requirements to link our experimental and ethnoarchaeological fuel yield estimates with absolute fuel losses, and an expanded archaeobotanical strategy.

Acknowledgments

We thank the National Geographic Society Committee for Research and Exploration (grant 9696-15), National Natural Science Foundation of China (grant 51850410507), Rust Family Foundation (award RFF-2018-53), Institut National du Patrimoine, Cotsen Institute of Archaeology (UCLA), Joukowsky Institute for Archaeology and the Ancient World (Brown University), Institute for Cultural Heritage and the History of Science and Technology (University of Science and Technology Beijing), and Institute for Field Research. We also thank John Marston for assistance with preliminary identifications of the wood charcoal material.

References Cited

Barker, Graeme W. W., Gerraint Dyfed Barri Jones, D. Dilbertson, and D. Jones. 1982. The UNESCO Libyan Valleys Survey 1979–1981: palaeoeconomy and environmental archaeology in the pre-desert. *Libyan Studies* 13:1–34.

Bénabou, Marcel. 1976. *La Résistance Africaine á La Romanisation*. Paris: Maspero.

Ben Tahar, Sami. 2010. Le site de Soûq el Guébli à l'époque punique: nouvelles recherches, nouvelles données. In *Histoire et patrimoine du littoral tunisien. Actes du Ier séminaire, Nabeul, 28–29 Novembre 2008*. Pp. 65–102. Tunis.

———. 2018. Henchir Bourgou (Jerba) à la lumière des dernières découvertes archéologiques. *Mitteilungen des Deutschen Archäologischen Instituts Römische Abteilung* 124.

Ben Tahar, Sami, Ali Drine, Brett Kaufman, and Hans Barnard. Forthcoming. Zita from the fifth century BCE to the second century CE: the ceramic evidence. *Carthage Studies* 12.

Berger, Philippe. 1905. Une inscription Néopunique de Ziane et des Marques d'Ouvriers peintes sur des Citernes de Roogga (Tunisie). *Comptes Rendus des Séances de l'Académie des Inscriptions et Belles-Lettres* 49(4):388–389.

Birley, Anthony R. 1988. *Septimius Severus: the African emperor*. New Haven, CT: Yale University Press.

Bomgardner, D. L. 1992. The trade in wild beasts for Roman spectacles: a green perspective. *Anthropozoologica* 16:161–166.

Brett, Michael , and Elizabeth Fentress. 1996. *The Berbers*. Oxford: Blackwell.

Butzer, Karl W. 1982. *Archaeology as human ecology: method and theory for a contextual approach*. New York: Cambridge University Press.

Cagnat, René, Alfred Merlin, and Louis Chatelain. 1923. *Inscriptions Latines D'Afrique (Tripolitaine, Tunisie, Maroc)*. Paris: Ernest Leroux.

Cerezo-Román, Jessica, Koen Deforce, Denis Henrotay, and Wim Van Neer. 2017. From life to death: dynamics of personhood in Gallo-Roman funerary customs, Luxembourg province, Belgium. In *Cremation and the archaeology of death*. J. Cerezo-Román, A. Wessman, and H. Williams, eds. Pp. 148–176. Oxford: Oxford University Press.

Chabot, J.-B. 1907. *Répertoire d'épigraphie Sémitique*. Vol. 2, *Corpus Inscriptionum Semiticarum*. Paris: Imprimerie Nationale.

Cooke, G. A. 1903. *A text-book of North-Semitic inscriptions*. Oxford: Oxford University Press.

Costin, Cathy L. 2000. The use of ethnoarchaeology for the archaeological study of ceramic production. *Journal of Archaeological Method and Theory* 7(4):377–403.

Craddock, Paul T. 1995. *Early metal mining and production*. Washington, DC: Smithsonian Institution Press.

Crew, Peter. 1991. The experimental production of prehistoric bar iron. *Journal of the Historical Metallurgy Society* 25(1):21–36.

Dalfes, H. N. 1997. Environmental vulnerability of early societies: some reflections on modeling issues. In *Third millennium BC climate change and Old World collapse*. H. N. Dalfes, G. Kukla, and H. Weiss, eds. Pp. 691–697. Berlin: Springer.

D'Andrea, Bruno, and Sara Giardino. 2009. Le Tophet: où et pourquoi. L'Identité Phénicenne, Le Cercle de Carthage et La Phase Tardo-Punique. In *VIIème Congrès International des Études Phéniciennes et Puniques, Hammamet, Tunisie*, 1519–1551. https://hal.archives-ouvertes.fr/hal-02280710/file/le_tophet_ou_et_pourquoi.lidentite_phen.le_tophet_ou_et_pourquoi_lidentite_phen.pdf.

De La Blanchère, M. 1887. Lettre du 13 Octobre 1887. In *Bulletin Archéologique du Comité Travaux Historiques*. Paris.

De Lisle, Christopher. 2019. The Punic Wars (264–146 BCE). In *The Oxford handbook of the Phoenician and Punic Mediterranean*. B. Doak and C. López-Ruiz, eds. Oxford: Oxford University Press, doi: 10.1093/oxfordhb/9780190499341.013.13.

Dietler, Michael. 2010. *Archaeologies of colonialism: consumption, entanglement, and violence in ancient Mediterranean France*. Berkeley: University of California Press.

Donner, H., and W. Röllig, eds. 1968. *Kanaanäische und Aramäische Inschriften*. 3 vols. Wiesbaden: Harrassowitz.

Drine Ali. 1999. Restes de pressoirs à huile et à vin à Gigthi et à Zarzis. *Africa* XVII:47–68.

Eisenmenger, Nina, and Stefan Giljum. 2007. Evidence from societal metabolism studies for ecological unequal trade. In *The world system and the earth system: global socioenvironmental change and sustainability since the Neolithic*. A. Hornborg and C. Crumley, eds. Pp. 288–302. Walnut Creek, CA: Left Coast.

Fentress, Elizabeth, and Roald F. Docter. 2008. North Africa: rural settlement and agricultural production. In *Rural landscapes of the Punic world*. P. van Dommelen and C. Gómez Bellard, eds. Pp. 101–128. London: Equinox.

Fentress, Elizabeth, Ali Drine, and Renata Holod, eds. 2009. *An island through time: Jerba studies, volume 1: the Punic and Roman periods*. Portsmouth, RI: Ministère de la Culture et de la Sauvegarde du Patrimoine, American Academy in Rome, University of Pennsylvania.

Ferjaoui, A., and J. Alexandropoulos. 2007. *Le sanctuaire de Henchir el-Hami: de Ba'al Hammon au Saturne Africain*. Paris: Institut National du Patrimoine.

Foxhall, L. 2007. *Olive cultivation in ancient Greece: seeking the ancient economy*. Cambridge: Cambridge University Press.

Friedman, Hannah. 2013. Agriculture in the Faynan: food supply for the mining industry. In *The Roman agricultural economy: organization, investment, and production*. A. Bowman and A. Wilson, eds. Pp. 307–322. Oxford: Oxford University Press.

Ghisleni, Lara. 2018. Contingent persistence: continuity, change, and identity in the Romanization debate. *Current Anthropology* 59(2):138–166.

Goodchild, R. G. 1950. Two monumental inscriptions of Lepcis Magna. *Papers of the British School at Rome* 18:72–82.

Grattan, J. P., D. D. Gilbertson, and C. O. Hunt. 2007. The local and global dimensions of metalliferous pollution derived from a reconstruction of an eight thousand year record of copper smelting and mining at a desert-mountain frontier in Southern Jordan. *Journal of Archaeological Science* 34:83–110.

Harper, Kyle. 2015. Pandemics and passages to Late Antiquity: rethinking the plague of c.249–270 described by Cyprian. *Journal of Roman Archaeology* 28:224–260.

Harris, Zellig Sabbettai. 1936. *A grammar of the Phoenician language*. New Haven, CT: American Oriental Society.

Hayden, Brian. Archaeological pitfalls of storage. *Current Anthropology* 61(6): 763–793.

Hobson, Matthew S. *The North African boom: evaluating economic growth in the Roman province of Africa Proconsularis (146 B.C. – A.D. 439). Supplmentary Series 100*. Portsmouth, RI: Journal of Roman Archaeology.

Hong, S., J. P. Candelone, C. C. Patterson, and C. F. Boutron. 1994. Greenland ice evidence of hemispheric lead pollution two millennia ago by Greek and Roman civilizations. *Science* 265:1841–1843.

Hurst, Henry. 1999. *The sanctuary of Tanit at Carthage in the Roman Period, Journal of Roman Archaeology, Supplementary Series Number 30*. Portsmouth, RI: Journal of Roman Archaeology.

Jaouadi, Sahbi, and Vincent Lebreton. 2018. Pollen-based landscape reconstruction and land-use history since 6000 BC along the margins of the southern Tunisian desert. In *Plants and people in the African past*. A. M. Mercuri, A. C. D'Andrea, R. Fornaciari, and A. Höhn, eds. Pp. 548–572. Basel: Springer.

Jerray E. 2015. La production d'amphores romaines en Tripolitaine occidentale: les ateliers de Zitha et de sa région en Tunisie méridionale. Phd thesis, Université d'aix-Marseille.

Jiménez, Alicia. 2014. Punic after Punic times? the case of the so-called "Libyophoenician" coins of Southern Iberia. In *The Punic Mediterranean: identities and identification from Phoenician settlement to Roman Rule*. J. C. Quinn and N. C. Vella, eds. Pp. 219–242. Cambridge: Cambridge University Press.

Kallala, Nabil, and Joan Sanmartí, eds. 2011. *Althiburos I: la fouille dans l'aire du capitole et dans la nécropole méridionale, Documenta 18*. Barcelona: Université de Barcelona, Institut Català d'Arqueologia Clàssica, Institut National du Patrimoine (Tunisie), Tarragone.

Kallala, Nabil, Joan R. Torres, Joan S. Grego, M. C. Belarte, Bouthéina M. Telmini, Thaïs Fadrique, Rafael Jornet i Niella, Daniel L. Reyes, Núria M. Cortés, and Sílvia V. Lamas. 2010. Sobre los orígenes de la civilización Númida y su relación con la colonización Fenicia. *Mainake* XXXII(I):279–299.

Kaufman, Brett. 2018. Anthropology of metallurgical design: a survey of metallurgical traditions from hominin evolution to the industrial revolution. In *Metallurgical design and industry: prehistory to the space age*. B. Kaufman and C. L. Briant, eds. Pp. 1–70. Cham: Springer.

———. 2009. A citizen of Tyre in Sabratha: colonial identity in Punic North Africa. *Maarav: a Journal for the Study of the Northwest Semitic Languages and Literatures* 16(1):39–48.

Kaufman, Brett, Ali Drine, Hans Barnard, and Rayed Khedher. 2015. Research at the ancient Neo-Punic city of Zita, Tunisia. *Backdirt Annual Review of the Cotsen Institute of Archaeology* 2015:76–79.

Kaufman, Brett, Christian Fischer, Roald F. Docter, Boutheina M. Telmini, and Fethi Chelbi. 2016. Ferrous metallurgy from the Bir Massouda metallurgical precinct at Phoenician and Punic Carthage and the beginning of the North African Iron Age. *Journal of Archaeological Science* 71:33–50.

Krahmalkov, Charles R. 2000. *Phoenician-Punic dictionary, Orientalia Lovaniensia Analecta 90*. Leuven: Peeters.

Levi Della Vida, Giorgio. 1935. Due iscrizioni neopuniche du Leptis Magna. *Africa Italiana* VI:3–15.

Lightfoot, Kent G., Lee M. Panich, Tsim D. Schneider, and Sara L. Gonzalez. 2013. European colonialism and the Anthropocene: a view from the Pacific Coast of North America. *Anthropocene* 4:101–115.

Linn, Jason. 2012. The Roman grain supply, 442–455. *Journal of Late Antiquity* 5(2):298–321.

Mackinnon, M. 2006. Supplying exotic animals for the Roman amphitheatre games: new reconstructions combining archaeological, ancient textual, historical and ethnographic Eata. *Mouseion: Journal of the Classical Association of Canada* 6(2):137–161.

Manning, Sturt W. 2013. The Roman World and climate: context, relevance of climate change, and some issues. In *The ancient Mediterranean environment between science and history*. W. V. Harris, ed. Pp. 103–170. Leiden: Brill.

Mattingly, D. J. 1987. Libyans and the "Limes": culture and society in Roman Tripolitania. *Antiquités Africaines* 23:71–94.

———. 1988. The olive boom: oil surpluses, wealth and power in Roman Tripolitania. *Libyan Studies* 19:21–41.

———. 1994. *Tripolitania*. Ann Arbor: University of Michigan Press.

Mattingly, David J., and R. Bruce Hitchner. 1995. Roman Africa: an archaeological review. *Journal of Roman Studies* 85:165–213.

McCarty, Matthew M. 2013. The Tophet and infant sacrifice. In *The Oxford handbook of the Phoenician and Punic Mediterranean*. B. Doak and C. López-Ruiz, eds. Oxford: Oxford University Press.

———. 2019. Continuities and contexts: the tophets of Roman Imperial-Period Africa. In *The Tophet in the Phoenician Mediterranean*. P. Xella, ed. Verona: Essedue Edizioni, doi: 10.1093/oxfordhb/9780190499341.013.21.

McConnell, Joseph R., Andrew I. Wilson, Andreas Stohl, Monica Arienzo, Nathan J. Chellman, Sabine Eckhardt, Elisabeth M. Thompson, A. Mark Pollard, and Jørgen Peder Steffensen. 2018. Lead pollution recorded in Greenland ice indicates European emissions tracked plagues, wars, and imperial expansion during antiquity. *Proceedings of the National Academy of Sciences of the USA* 115(22):5726–5731.

McCormick, Michael, Ulf Büntgen, Mark A. Cane, Edward R. Cook, Kyle Harper, Peter Huybers, Thomas Litt, et al. 2012. Climate change during and after the Roman Empire: reconstructing the past from scientific and historical evidence. *Journal of Interdisciplinary History* XLIII(2):169–220.

Merkel, John F. 1990. Experimental reconstruction of Bronze Age copper smelting based on archaeological evidence from Timna. In *The ancient metallurgy of copper: archaeology, experiment, theory*. B. Rothenberg, ed. Pp. 78–122. London: Institute for Archaeo-Metallurgical Studies, Institute of Archaeology, University College London.

Morehart, Christopher T. 2014. The potentiality and the consequences of surplus: agricultural production and institutional transformation in the Northern Basin of Mexico. *Economic Anthropology* 1(1):154–166.

Morehart, Christopher T., and Kristin De Lucia. 2015. Surplus: the politics of production and the strategies of everyday life. In *Surplus: the politics of production and the strategies of everday life*. C. T. Morehart and K. De Lucia, eds. Pp. 3–44. Boulder, CO: University Press of Colorado.

Moses, Victoria, Brett Kaufman, Ali Drine, Hans Barnard, Sami Ben Tahar, Elyssa Jerray, and Megan Daniels. 2019. Zooarchaeological evidence for meat consumption at Zita, Tunisia, during the Punic to Roman occupations (2nd century BCE to 3rd century CE). *International Journal of Osteoarchaeology* 29:549–559.

Pyatt, F. B., G. Gilmore, J. P. Grattan, C. O. Hunt, and S. McLaren. 2000. An imperial legacy? an exploration of the environmental impact of ancient metal mining and smelting in Southern Jordan. *Journal of Archaeological Science* 27:771–778.

Raven, Susan. 1993. *Rome in Africa*. Third ed. London and New York: Routledge.

Renan, Ernest, ed. 1881. *Corpus Inscriptionum Semiticarum I: Inscriptiones Phoenicias Continens*. Paris: E Reipublicae.

Rickman, G. E. 1980. The grain trade under the Roman Empire. *Memoirs of the American Academy in Rome* 36:261–275.

Ritter, Stefan, and Sami Ben Tahar. 2020. New insights into the urban history of Meninx (Jerba). *Antiquités Africaines* 56:101–128.

Rogers, Adam. 2018. *The archaeology of Roman Britain: biography and identity*. London: Routledge.

Sanmartí, Joan, Nabil Kallala, M. Carme Belarte, Joan R. Torres, Bouthéina M. Telmini, Rafael Jornet, Souad Miniaoui, et al. 2012. Filling gaps in the protohistory of the Eastern Maghreb: the Althiburos Archaeological Project (El Kef, Tunisia). *Journal of African Archaeology* 10(1):21–44.

Schiffer, Michael B. 1983. Toward the identification of formation processes. *American Antiquity* 48(4):675–706.

Schmidt, Peter. R. 1997. Archaeological views on a history of landscape change in East Africa. *Journal of African History* 38(3):393–421.

Schneider, Eric D., and Dorion Sagan, eds. 2005. *Into the cool: energy flow, thermodynamics, and life*. Chicago: University of Chicago Press.

Schwartz, J. H., F. D. Houghton, L. Bondiolo, and R. Macchiarelli. 2017. Two tales of one city: data, inference and Carthaginian infant sacrifice. *Antiquity* 91(356):442–454.

Smith, P., L. E. Stager, J. A. Greene, and G. Avishai. 2013. Age estimations attest to infant sacrifice at the Carthage Tophet. *Antiquity* 87:1191–1199.

Stadiasmus Maris Magni. 1855. Stadiasme de la Grande Mer, 102. In *Geography Graeci Minores*. K. Müller, ed. Paris: Editore Ambrosio Firmin Didot.

Stanish, Charles. 2017. *The evolution of human co-operation: ritual and social complexity in stateless societies*. Cambridge: Cambridge University Press.

Stephens, Lucas, Dorian Fuller, Nicole Boivin, Torben Rick, Nicolas Gauthier, Andrea Kay, Ben Marwick, et al. 2019. Archaeological assessment reveals Earth's early transformation through land use. *Science* 365:897–902.

Steward, Julian H. 1968. Causal factors and processes in the evolution of prefarming societies. In *Man the hunter*. Richard B. Lee and Irven DeVore, eds. Pp. 1–14. New York: Aldine.

Teall, John L. 1959. The grain supply of the Byzantine Empire, 330–1025. *Dumbarton Oaks Papers* 13:87–139.

Townsend, Patricia K. 2009. *Environmental anthropology: from pigs to policies, Second Edition*. Long Grove, IL: Waveland.

Versluys, Miguel John. 2014. Understanding objects in motion: an *archaeological* dialogue on Romanization (and responses). *Archaeological Dialogues* 21:1–20.

Vitousek, P. M., H. A. Mooney, J. Lubchenco, and J. M. Melillo. 1997. Human domination of Earth's ecosystems. *Science* 277:494–499.

Whiteley, Peter. 2004. Ethnography. In *A companion to the anthropology of American Indians*. T. Biolsi, ed. Pp. 435–471. Malden, MA: Blackwell.

Woolf, Greg. 1998. *Becoming Roman: the origins of provincial civilization in Gaul*. Cambridge: Cambridge University Press.

Wylie, Alison. 1985. The reaction against analogy. *Advances in Archaeological Method and Theory* 8:63–111.

Xella, P., J. Quinn, V. Melchiorri, and P. Van Dommelen. 2013. Phoenician bones of contention. *Antiquity* 87(338):1199–1207.